HKDSE Chemistry Pastpaper Collection

Paper I

By Topic

Section 6 - 12

HKAL/HKASL Paper 1996-2013

HKCEE Paper 1990-2011

HKDSE Sample Paper 2011

HKDSE Practices Paper 2012

HKDSE Paper 2012-2022

Content

Remarks:

Directions: Decide whether each of the two statements is true or false: if both are true, then decide whether or not the second statement is a correct explanation of the first statement. Then select one option from A to D according to the following table:

A. Both statements are true and the 2nd statement is correct explanation of the Misstatement.

B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.

C. The 1st statement is false but the 2nd statement is true.

D. Both statements are false.

SECTION 6 Microscopic World II

Multiple-Choice Questions

CE11_05

Hydrogen chloride has a low boiling point because

A. weak covalent bonds exist between hydrogen chloride molecules.

B. weak covalent bonds exist between hydrogen atoms and chlorine atoms.

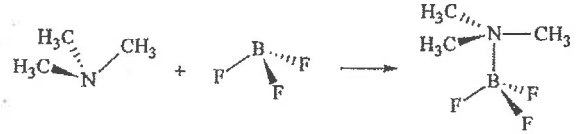
C. weak van der Waals' forces exist between hydrogen chloride molecules.

D. weak van der Waals' forces exist between hydrogen ions and chloride ions.

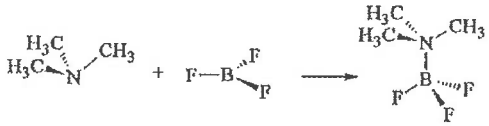
AL06(I)_03

Which of the following best represents the reaction of $(CH_3)_3N$ with BF_3 to form $(CH_3)_3NBF_3$?

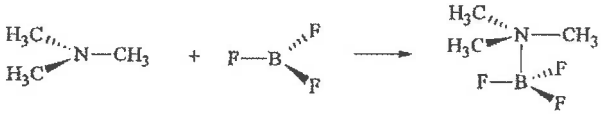
A.



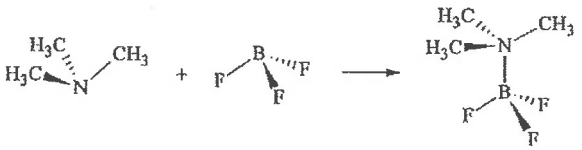
B.



C.



D.



ASL08(I)_05

Which one of the following molecules has a zero dipole moment?

A. BF_3 B. PH_3

C. SO_2 D. HCl

ASL12(I)_03

Which of the following species is NOT planar?

A. Boron trifluoride B. Nitrate(V) ion

C. Phosphorus trichloride D. Phenylethene

DSE12PP_02

Which of the species shown below does NOT follow the 'octet rule'?

A. Na_2O B. MgO
C. PCl_3 D. SCl_4

DSE12PP_16

Which of the following molecules is non-polar?

A. $BeCl_2$ B. NH_3
C. H_2O D. HCl

DSE12PP_17

Ammonia is very soluble in water. Which of the following statements best accounts for this phenomenon?

A. Both ammonia molecule and water molecule are polar.
B. Ammonia molecule and water molecule are of comparable sizes.
C. Ammonia undergoes ionization in water.
D. Ammonia forms hydrogen bond with water.

DSE12_05

Which of the following molecules is polar?

A. BF_3 B. C_{60}
C. NH_3 D. SF_6

DSE12_12

Which of the following molecules is planar?

A. BF_3 B. NH_3
C. CH_4 D. PCl_5

DSE13_23

To which of the following molecules is/are the 'octet rule' NOT applicable?

(1) OF_2
(2) NO_2
(3) CS_2

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE13_24

1st statement	2nd statement
The boiling point of hydrogen chloride is higher than that of hydrogen fluoride.	The molecular size of hydrogen chloride is greater than that of hydrogen fluoride.

DSE14_22

Which of the following molecules have non-octet structures?

(1) NO_2
(2) PBr_3
(3) BCl_3

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE14_23

When a negatively charged rod is placed near a jet of liquid running out from a burette, the jet of liquid deflects towards the rod. Which of the following may the liquid be?

(1) Water
(2) Hexane
(3) Trichloromethane

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE14_24

1st statement	2nd statement
All acidic gases can react with CaO(s) to form salt and water only.	All acidic gases contain hydrogen as one of their constituent atoms.

DSE15_11

In the species below, the underlined atom is the central atom, and all non-central atoms have octet electronic arrangement. In which of them does the central atom NOT have octet electronic arrangement?

A. $\underline{S}F_2$ B. $\underline{C}F_2$
C. $\underline{C}S_2$ D. $\underline{N}Cl_3$

DSE15_24

1st statement	2nd statement
The boiling point of H_2O is lower than that of HF.	The electronegativity of oxygen is lower than that of fluorine.

DSE16_16

Which of the following compounds has the highest boiling point?

A. HF B. HCl
C. PH_3 D. H_2Se

DSE16_21

Which of the following molecules have a similar shape?

(1) BCl_3
(2) NH_3
(3) PF_3

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE17_12

Which of the following molecules is polar?

A. CO_2
B. PCl_3
C. SiF_4
D. SF_6

DSE17_24 [OUT]

1st statement	2nd statement
Both buckminsterfullerence (C_{60}) and graphite are good conductors of electricity.	Buckminsterfullerence (C_{60}) and graphite are different forms of carbon.

DSE18_16

Which of the following molecules is/are nonpolar?

(1) BCl_3
(2) PCl_3
(3) $CHCl_3$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

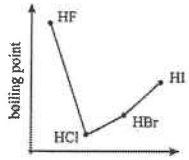
DSE19_13

Which of the following combinations is correct?

	Molecule	Molecular shape
A.	OF_2	Linear
B.	CS_2	V-shapd
C.	NCl_3	Trigonal planar
D.	PF_3	Trigonal pyramidal

DSE20_20

20. Refer to the sketch below :



Which of the following can explain the variation of the boiling points of the hydrogen halides ?

(1) The boiling point of HF is higher than that of HCl because the hydrogen bonds between HF molecules are stronger than the van der Waals' forces between HCl molecules.
(2) The boiling point of HI is higher than that of HBr because HI molecules are more polar than HBr molecules.
(3) HCl has the lowest boiling point because it has the smallest molecular size.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE20_22

22. Which of the following statements concerning ice and water at 0 °C are correct ?

(1) The density of ice is lower than that of water because ice has an open structure but water does not.
(2) In ice, the hydrogen bonds between the molecules are weaker than the covalent bonds in the molecules.
(3) In ice, each molecule links up with only two neighbouring molecules by hydrogen bonds.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE21_10

10. Which of the following processes involves the breaking of hydrogen bonds ?

A. $H_2(l) \rightarrow H_2(g)$
B. $HBr(l) \rightarrow HBr(g)$
C. $CH_3OH(l) \rightarrow CH_3OH(g)$
D. $CH_3CHO(l) \rightarrow CH_3CHO(g)$

Structural Questions

AL00(I)_01 (modified)

Explain why nitrogen forms only one chloride, NCl_3, whereas phosphorus forms two chlorides, PCl_3 and PCl_5.

(2 marks)

AL00(I)_01

Account for the order of boiling point for the two series of compounds below:

$H_2O > C_2H_5OH > C_2H_5OC_2H_5$

$H_2S < C_2H_5SH < C_2H_5SC_2H_5$

(3 marks)

AL00(I)_01

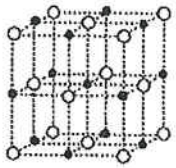
The diagrams below show the arrangement of atoms, ions or molecules in four crystalline substances: graphite, ice, iodine and sodium chloride.

(a) Write the name of the substance of each structure in the space provided.

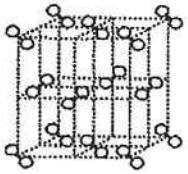
(b) Label, on the diagrams, the types of interactions that are present in these substances.

(i)

(ii)



(iii)



(iv)

(6 marks)

ASL00(II)_09

Silicon forms a hydride with formula SiH_4.

(a) Draw the three-dimensional structure of SiH_4.

(1 mark)

(b) The electronegativity values (Pauling's scale) of H and Si are 2.1 and 1.8 respectively. State, with explanation, whether or not SiH_4 is a polar molecule.

(2 marks)

(c) The boiling points of Si and SiH_4 are 2628 K and 161 K respectively. Explain why the boiling point of SiH_4 is much lower than that of Si.

(2 marks)

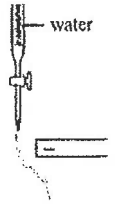
AL01(I)_01 [Same as DSE13_01]

Explain, in terms of structure and intermolecular force, why water is denser than ice.

(2 marks)

ASL01(I)_01

A negatively charged rod was brought near a jet of water running out from a burette. The jet of water was deflected as shown:



(a) With reference to the structure of water, explain why the jet of water was deflected.

(2 marks)

(b) State the effect on the jet of water if the negatively charged rod is replaced by a positively charged rod. Explain your answer.

(2 marks)

(c) If cyclohexane is used instead of water and a negatively charged rod is brought near the liquid jet, would the liquid jet be deflected? Explain your answer.

(2 marks)

AL02(I)_03

CO_2 and SiO_2 are oxides of Group IV elements. Account for the fact that CO_2 is a gas while SiO_2 is a high melting solid under room temperature and atmospheric pressure.

(2 marks)

ASL02(I)_04

For the substances below, sketch the variations of their boiling points and account for the variations.

Hydrides of Group VI elements, H_2O, H_2S, H_2Se and H_2Te

(4 marks)

AL02(II)_01

Ammonia (NH_3) and phosphine (PH_3) are hydrides of nitrogen and phosphorus respectively. Account for each of the following phenomena:

(a) The bond angle between two N–H bonds in NH_3 (about 107°) is greater than that between P–H bonds in PH_3 (about 94°).

(2 marks)

(b) NH_3 is very soluble in water but PH_3 is sparingly soluble.

(1 mark)

AL03(I)_01

Elemental oxygen exists in the atmosphere in two forms, O_2 and O_3.

(a) Draw the electronic structure of O_3.

(1 mark)

(b) Suggest why O_3 is more soluble in water than O_2.

(2 marks)

ASL03(I)_02

Arrange the following compounds in order of increasing boiling point. Explain your answer.

$CH_3(CH_2)_2CH_3$, $CH_3(CH_2)_3Cl$, $CH_3(CH_2)_3OH$, $CH_3(CH_2)_3CH_3$

(5 marks)

AL03(II)_03

The 'octet rule' is commonly used in elementary chemistry course to account for the formation of chemical bonds.

(a) What is the octet rule?

(1 mark)

(b) With appropriate examples, state two limitations of the octet rule.

(2 marks)

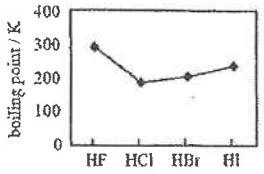
AL04(I)_02

Consider the noble gases, He, Ne, Ar Kr and Xe. Sketch a graph to show the variation of boiling point of these noble gases and account for the variation.

(2 marks)

ASL04(I)_03

The graph below shows the variation of boiling point of four hydrogen halides.



(a) Account for the variation of boiling point of HCl, HBr and HI.

(2 marks)

(b) Suggest why HF has the highest boiling point among the four hydrogen halides.
[Similar to DSE12_02]

(2 marks)

(c) Do you agree with the following statement? Explain your answer.
'H–F bond is more polar than H–I bond, therefore HF(aq) is a stronger acid than HI(aq).'

(2 marks)

AL04(II)_01 (modified)

A gaseous compound A has the following composition by mass:

N 21.6%, O 49.2% and F 29.2%

(a) Deduce the empirical formula of A.

(2 marks)

(b) If the molecular mass of A is in the range of 60 to 70 and hence deduce its molecular formula.

(2 marks)

(c) Draw all possible three-dimensional structures of A.

(3 marks)

AL05(I)_02

Nitrogen monoxide reacts with fluorine to form nitrosyl fluoride, FNO, according to the following equation:

$$2NO(g) + F_2(g) \longrightarrow 2FNO(g)$$

Draw the electronic structure of nitrosyl fluoride.

(1 mark)

ASL05(I)_02

(a) (i) Draw a three-dimensional structure for each of the following species:

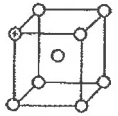
PH_3 and NH_4^+

(2 marks)

(ii) Which species in (i) has a larger bond angle? Explain.

(1 mark)

(b) The diagram below shows part of the lattice of caesium chloride with one caesium ion labelled with a positive (+) sign.



(i) In this diagram, mark all caesium ions with a positive (+) sign and all chloride ions with a negative (–) sign.

(1 mark)

(ii) What is the number of nearest chloride surrounding each caesium ion in caesium chloride crystal?

(1 mark)

(iii) Explain why caesium chloride is an insulator of electricity in the solid state, but it conducts electricity in the molten state.

(2 marks)

ASL05(I)_05

In a highly pressurized steam boiler, the oxygen dissolved in water can cause corrosion to the metallic parts of the boiler. The dissolved oxygen can be removed by adding hydrazine (N_2H_4) into the boiler.

(a) Draw the electronic diagram of a hydrazine molecule, showing electrons in the outermost shells only.

(1 mark)

(b) The reaction of hydrazine with oxygen gives nitrogen and water. Write the chemical equation for this reaction. Hence, suggest one advantage of using hydrazine as an anticorrosive agent in steam boilers.

(2 marks)

(c) A steam boiler contains 3.2×10^4 dm^3 of water. The dissolved oxygen in the water is 6.4 mg dm^{-3}. Calculate the mass of hydrazine required to remove all the oxygen present in the water.

(2 marks)

AL05(II)_02 (modified) [Similar to DSE13_02, DSE19_06]

Account for the following: "Sulphur dioxide possesses a overall molecular polarity while carbon dioxide does not."

(3 marks)

AL05(II)_03 [OUT]

Fullerences refer to the class of near spherical allotropes of carbon including C_{60}, C_{70} and C_{84}. They are made by electric arc discharge of graphite rods in an inert atmosphere. A sample is known to contain the above-mentioned fullerenes. Suggest an instrumental method to show the presence of these fullerenes in the sample and state the expected results.

(2 marks)

ASL05(II)_09

Arrange the following compounds **B**, **C** and **D** in order of increasing boiling point, and explain your answer.

$CH_3(CH_2)_3CH_3$	$CH_3(CH_2)_3OH$	$CH_3CH_2COCH_3$
B	**C**	**D**

AL06(I)_02a

Both diamond and graphite are allotropes of carbon.

(i) Give the meaning of the term 'allotrope'.

(1 mark)

(ii) Draw a diagram to show the three-dimensional arrangement of carbon atoms in graphite, and indicate the interactions between the carbon atoms.

(2 marks)

(iii) Given:

$$C(\text{diamond}) \longrightarrow C(\text{graphite}) \qquad \Delta H^\circ = -2\ kJ\ mol^{-1}$$

Explain why the conversion of diamond into graphite will not occur spontaneously under normal conditions.

(1 mark)

(iv) Name two allotropes of another element in Period 2, and draw the structures of these allotropes.

(2 marks)

AL06(II)_02

(a) Explain why ice is less dense than water. [Same as DSE13_02]

(3 marks)

(b) Explain why it is possible to skate smoothly on ice at temperature below 0 °C.

(2 marks)

AL06(II)_02

Ammonia and hydrogen azide (HN_3) are hydrides of nitrogen. Draw a possible electronic structure of hydrogen azide.

(1 mark)

AL07_Sample Paper [OUT]

A sample of soot obtained from an experiment was known to contain fullerenes. When the sample was treated with benzene, a red solution and a black residue were obtained. This solution, upon evaporation, left behind red crystals – a mixture containing mainly C_{60} and C_{70}.

(a) Suggest why C_{60} and C_{70} are soluble in benzene, while the residue is not.

(2 marks)

(b) Suggest a method to isolate C_{60} and C_{70} from the red crystals.

(2 marks)

(c) Both C_{60} and graphite are allotropes of carbon. With reference to their structures, compare the electrical conducting properties of C_{60} and graphite in solid state.

(2 marks)

ASL07(I)_01

Tetraethyl lead, $Pb(C_2H_5)_4$, was once widely used as an anti-knock agent in petrol. This anti-knocking function of $Pb(C_2H_5)_4$ is now commonly performed by methyl *t*-butyl ether (MTBE) instead.

(a) Draw the three-dimensional structure of $Pb(C_2H_5)_4$. (You are required to show only the stereochemistry of the central atom.)

(1 mark)

(b) Write the chemical equation for the complete combustion of $Pb(C_2H_5)_4$.

(1 mark)

(c) Based on environmental consideration, suggest *two* reasons why MTBE instead of $Pb(C_2H_5)_4$ is now used in petrol.

(2 marks)

AL07(I)_02

Write the Lewis structure of SO_4^{2-} and $S_2O_3^{2-}$ ions, and give the oxidation state of all sulphur atoms in each of these ions.

(4 marks)

AL08(I)_01

(a) Draw a 'dot-and-cross' diagram to show the arrangement of the outermost electrons in the species $NH_2^-(g)$, and predict the shape of this species

(2 marks)

(b) Arrange the H–N–H for the three species: $NH_2^-(g)$, $NH_3(g)$ and $NH_4^+(g)$. Explain your ordering.

(2 marks)

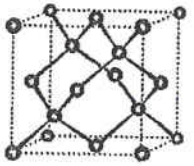
AL08(II)_01

Both sodium and chlorine are elements in Period 3 of the Periodic Table. At room temperature and atmospheric pressure, Na_2O is a solid with a very high melting point whereas Cl_2O is a gas. Account for this difference in property between Na_2O and Cl_2O.

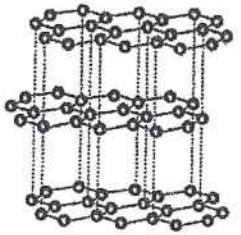
(2 marks)

AL08(II)_04

Both diamond and graphite are allotropes of carbon. A unit cell of diamond and a part of the structure of graphite are shown below:



a unit cell of diamond

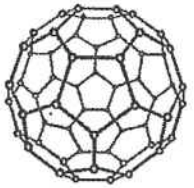


a part of the structure of graphite

(a) Diamond and graphite show a marked difference in electrical conductivity. Account for their difference in electrical conductivity in terms of bonding and structure. [Similar to DSE14_01]

(3 marks)

(b) Buckminsterfullerence (C_{60}) is another allotrope of carbon. [OUT]



structure of buckminsterfullerene

Suggest and explain how you would differentiate two samples of black powder, one of buckminsterfullerene and the other of graphite by

(i) a physical method, and

(2 marks)

(ii) a spectroscopic method.

(2 marks)

ASL09(I)_01 [Same as DSE13_02]

(a) Draw the respective electronic structure of BF_3 and NH_3. Hence, deduce the shape of each species.

(3 marks)

(b) Draw the three-dimensional structure of the product formed from the reaction of BF_3 with NH_3.

(1 mark)

AL09(I)_02

The compound $(CN)_2$ resembles the halogen in many ways and is often described as a "pseudohalogen"

(a) Draw the Lewis structure of $(CN)_2$.

(1 mark)

(b) Deduce the physical state of $(CN)_2$ at room temperature.

(1 mark)

ASL09(II)_04

The table below lists the melting points and boiling point of *cis*-1,2-dichloroethene and *trans*-1,2-dichloroethene.

Compound	Melting point / °C	Boiling point / °C
cis-1,2-dichloroethene	−80	60
trans-1,2-dichloroethene	−50	48

Explain why

(a) *cis*-1,2-dichloroethene has a higher boiling point, and

(2 marks)

(b) *trans*-1,2-dichloroethene has a higher melting point.

(2 marks)

ASL10(I)_04 (Modifieid)

Both nitrogen and phosphorus are Group V elements. Phosphorus forms two chlorides, PCl_3 and PCl_5, but nitrogen forms only one chloride, NCl_3.

(a) Suggest why NCl_5 does not exist.

(2 marks)

(b) Draw the three-dimensional structure of each of the following molecules: PCl_3 and PCl_5.

(2 marks)

(c) Suggest why phosphorus forms PI_3 but not PI_5.

(2 marks)

AL11(I)_01

(b) (i) For each of the following molecules, draw its three-dimensional structure:

OF_2 and SF_6

(2 marks)

(ii) Suggest why SF_6 exists while OF_6 does not.

(2 marks)

AL11(I)_03 [Similar to DSE14_02]

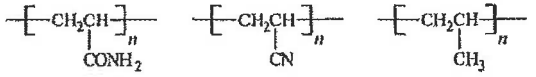
(b) Account for each of the following:

Ethanol is miscible with water, but ethoxyethane is not.

(2 marks)

ASL11(II)_08

Polyacrylamide, polyacrylonitrile and polypropene are three polymeric materials used as textile fabrics.



polyacrylamide polyacrylonitrile polypropene

Arrange these polymers in order of increasing tensile strength. Explain your arrangement.

(4 marks)

ASL12(I)_01

(a) Draw a Lewis structure for thiocyanate ion, SCN^-.

(1 mark)

ASL13(I)_01

Complete the table below for the three types of binary covalent compounds by giving ONE example and stating its molecular shape for each type.

Type	Example	Molecular shape
XY_2 (one lone pair on X)		
XY_2 (no lone pair on X)		
XY_3 (one lone pair on X)		

(3 marks)

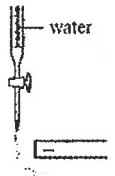
AL13(I)_01

(b) Arrange the hydrogen halide HF, HCl and HBr in increasing order of boiling point. Explain your arrangement.

(3 marks)

DSE11SP_06

A negatively charged rod was brought near a jet of water running out from a burette. The jet of water was deflected as shown:



(a) With reference to the structure of water, explain why the jet of water was deflected.

(2 marks)

(b) State the effect on the jet of water if the negatively charged rod is replaced by a positively charged rod. Explain your answer.

(2 marks)

(c) If hexane is used instead of water and a negatively charged rod is brought near the liquid jet, would the liquid jet be deflected? Explain your answer.

(2 marks)

DSE12PP_03

(b) Consider the nitrogen compound NCl_3.

(i) Draw the electron diagram of NCl_3, showing electrons in the outermost shells only.

(1 mark)

(ii) The shape of NCl_3 is similar to that of NH_3. Explain why this is so.

(2 marks)

DSE12PP_06

The table below lists some information about six hydroxy compounds, A, B, C, D, E and F.

Compound	Structural formula	Boiling point at 1 atm / °C	Density at 20 °C / g cm^{-3}
A	CH_3OH	65	0.7914
B	CH_3CH_2OH	78	0.7893
C	$CH_3CH_2CH_2OH$	97	0.8035
D	$CH_3CH(OH)CH_3$	82	0.7855
E	$HOCH_2CH_2CH_2OH$	213	1.0597
F	$HOCH_2CH(OH)CH_2OH$	290	1.2613

(a) Give the systematic name of **E**.

(1 mark)

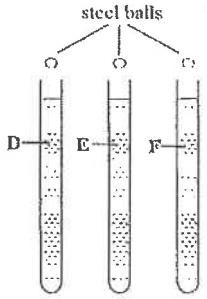
(b) Account for the variation in boiling points of **A**, **B** and **C**.

(2 marks)

(c) Explain why the density of **C** is greater than that of **D**.

(2 marks)

(d) Three identical steel balls are added separately to three identical vertical glass tubes each containing the same volume of **D**, **E** and **F** as shown in the diagram on the right.



In which tube will the steel ball take the longest time to reach the bottom? Explain your answer. (You are required to consider the intermolecular attraction forces involved.)

(3 marks + 1 mark)

DSE12_04 [Similar to ASL04(I)_03b]

With the aid of a diagram, explain the formation of hydrogen bonding in hydrogen fluoride.

(3 marks)

DSE13_01 [Same as AL06(II)_02]

Water is the most abundant compound on the Earth's surface. It is very important to life on Earth.

(c) Explain, for molecular level, why the density of ice is lower than that of water.

(3 marks)

DSE13_02 [Similar to AL05(II)_02, ASL09(I)_01, DSE19_06]

Both BF_3 and NH_3 exist as simple molecules.

(a) For each of these molecules, draw its three-dimensional structure.

(2 marks)

(b) For each of these molecules, explain whether or not it is polar.

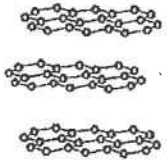
(2 marks)

(c) BF_3 reacts with NH_3 to give F_3BNH_3. Describe the bond formation between BF_3 and NH_3.

(2 marks)

DSE14_01 [Similar to AL08(II)_04(a)]

Graphite is a form of carbon and has a layer structure. Graphene is an individual single layer of graphite. Their structures are shown below:



graphite

graphene

(a) Thin sheets of graphene can be easily peeled off from graphite using adhesive tape.

(i) Explain why graphene can be easily peeled off.

(1 mark)

(ii) Explain whether graphene can conduct electricity.

(1 mark)

(iii) Draw the electron diagram for a molecule of the compound formed by complete combustion of graphene, showing *electrons in the outermost shells* only.

(1 mark)

(b) Based on the fact that graphene can be easily peeled off from graphite, a student concluded that graphite should have a low melting point due to its layer structure. Explain whether you agree with this conclusion.

(2 marks)

(c) Fullerene (such as C_{60}) is another form of carbon. Briefly describe the structure of C_{60}, and suggest why it is soluble in some organic solvents. [OUT]

(3 marks)

DSE14_02 [Similar to ASL11(I)_03b]

Draw the structure of ethane-1,2-diol, and suggest whether it is soluble in water.

(3 marks)

DSE16_04

Consider the molecules CO_2, CS_2 and CH_2Br_2.

(a) For each of the following molecules, draw its three-dimensional structure.

(i) CS_2

(1 mark)

(ii) CH_2Br_2

(1 mark)

(b) Identify, with explanation, the polar bond(s) in CH_2Br_2.

(2 marks)

(c) Suggest why, under room temperature and pressure, CO_2 is a gas but CS_2 is a liquid.

(2 marks)

DSE17_05

Explain the following increasing order of the boiling point of these substances:

$$H_2 < F_2 < HF$$

(3 marks)

DSE18_03 [Similar to AL13(I)_01]

(a) Explain whether $BaCl_2$ or OCl_2 would have a higher melting point.

(2 marks)

(b) Explain the following decreasing order of the boiling points of three substances:

$$NH_3 > PH_3 > CH_4$$

(3 marks)

(c) Draw a three-dimensional diagram to represent the molecular shape of SF_6.

(1 mark)

DSE19_06 [Similar to AL05(II)_02, DSE13_02]

Consider CH_2Cl_2 and CCl_4 molecules :

(a) Draw the three-dimensional structure of a CH_2Cl_2 molecule.

(1 mark)

(b) (i) Explain why CH_2Cl_2 is a polar molecule but CCl_4 is not.

(1 mark)

(ii) Explain why CCl_4 has a higher boiling point than CH_2Cl_2.

(2 marks)

3. (a) Draw a three-dimensional diagram to represent the shape of each of the following molecules :

(i) NH_3

(ii) BH_3

3. (b) (ii) Explain why H_3NBH_3 is a solid but ethane is a gas at room conditions.

2022

9. Consider the following three compounds :

X : $CH_3CH_2CH_2CH_2OH$ **Y** : $HOCH_2CH_2OH$ **Z** : CH_3COOCH_3

Which of the following shows the decreasing order of their solubilities in water ?

A. **X > Y > Z**
B. **Z > Y > X**
C. **Y > Z > X**
D. **Y > X > Z**

4 (c) (i) Draw the three-dimensional structure of a SF_6 molecule.

(c) (ii) Explain whether SF_6 is a polar molecule.

(2 marks)

(d) Explain the following increasing order of the boiling points of the three compounds :

$BF_3 < SF_6 < H_2O$

2022

Section A Industrial Chemistry

Answer **ALL** parts of the question.

1. (a) Answer the following short questions :

(i) Under certain conditions, ethanoic acid can be manufactured by the following reaction :

$$CH_3OH(l) + CO(g) \xrightarrow{Rh,\ HI} CH_3COOH(l)$$

(1) Suggest one reason why this reaction is considered to be green.

(2) Suggest one reason why this reaction is NOT considered to be green.

(2 marks)

Marking Scheme

MCQ

CE11_05	C (75%)	AL06(I)_03	B	ASL08(I)_05	A	ASL12(I)_03	C
DSE12PP_02	D	DSE12PP_16	A	DSE12PP_17	D	DSE12_05	C (82%)
DSE12_12	A (84%)	DSE13_23	B (61%)	DSE13_24	C (54%)	DSE14_22	B (62%)
DSE14_23	B (74%)	DSE14_24	D (51%)	DSE15_11	B (77%)	DSE15_24	C (59%)
DSE16_16	A (68%)	DSE16_21	C (72%)	DSE17_12	B (69%)	DSE17_24	C (77%)
DSE18_16	A (65%)	DSE19_13	D				

DSE20_20 A
DSE20_22 A

Structural Questions

AL00(I)_01 (modified)

Electronic arrangement of P is 2, 8, 5, and its outermost electron can hold maximum 18 electrons. Therefore, P can extend the octet structure and form 5 covalent bonds. [1]

In N, its outermost electron shell can only accept 3 electrons to complete its octet. ∴ It can form only 3 covalent bonds [1]

AL00(I)_01

$H_2O > C_2H_5OH > C_2H_5OC_2H_5$

Intermolecular attraction in water and in alkanols is mainly Hydrogen bond. **In H_2O, there are two hydrogen bond per molecule.** [½]

In C_2H_5OH, there is only one hydrogen bond per molecule. [½]

$C_2H_5OC_2H_5$ does not form hydrogen bond. The intermolecular attraction is mainly van der Waals' forces (much weaker than hydrogen bond). [½]

∴ b.p. : $H_2O > C_2H_5OH > C_2H_5OC_2H_5$

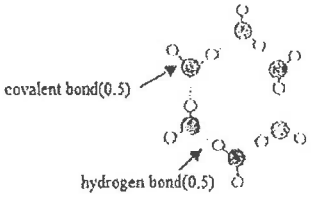
$H_2S < C_2H_5SH < C_2H_5SC_2H_5$

Intermolecular attraction **is van der Waals' forces.** [½]

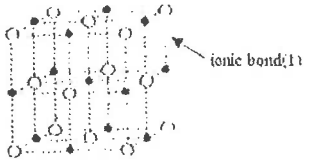
Strength of van der Waals' forces increases with no. of electron in a molecule / relative molecular size. [1]

∴ b.p. : $H_2S < C_2H_5SH < C_2H_5SC_2H_5$

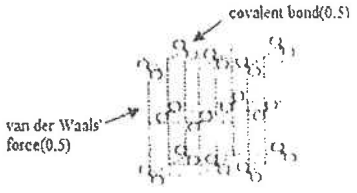
AL00(I)_01



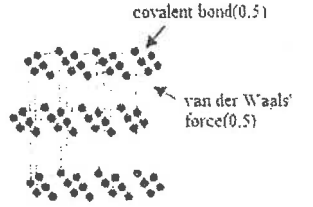
Ice



Sodium chloride [2] [1]

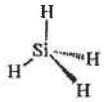


Iodine



Graphite [2] [1]

ASL00(II)_09

(a)  [1]

(b) The difference in electronegativties between Si and H = 2.1 – 1.8 = 0.3 [½]
Although each Si–H bond is polar, **four Si–H bonds are arranged tetrahedrally,** [1]
and all bond dipole moments of Si–H bond are cancelled out. Hence, SiH_4 is non-polar. [½]

(c) SiH_4 has a simple molecular structure and they are held by weak van der Waals' force, [1]
while Si has a giant covalent structure, and all Si atoms are bonded by strong covalent [1]
bond. Large amount of energy is needed to break Si–Si bond.

(d) (i) An atom of the same element with same number of proton, but different [1]
number of neutron.

(ii) **They have similar boiling point and chemical properties as SiH_4 and SiD_4** [1]
have the same type and strength of intermolecular force, and same bonding [½]
environment. [½]

AL01(I)_01

In ice and liquid water, the intermolecular attraction is **hydrogen bond.** [½]
Each H_2O molecule can form **a maximum of four hydrogen bonds with its neighbour / bond tetrahedrally with four H_2O molecules.** In ice, the molecules do not have translational motion. ∴ Ice as an **open structure.** [½]
In liquid water, translational motion of H_2O molecules brings the molecules close together. ∴ $H_2O(l)$ has a higher density. [½]

ASL01(I)_01

(a) The structure of water is non-liner. [1]
The dipole moments on the two O–H bonds cannot cancel each other / water has a net dipole moment. Hence water is a polar molecule and it would be attracted by the electric field. [1]

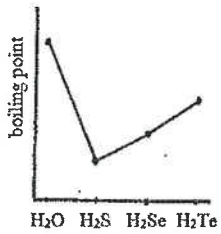
(b) The water jet will be attracted towards the rod. [1]
Water molecules will orientate themselves in alignment with the electric field so that they will be attracted. [1]

(c) The jet is not attracted. Only a weak dipole moment is induced in hexane molecules. [2]
The attraction between the induced diploe and the electric field is not strong enough to cause a deflection of the liquid jet.
OR, The liquid jet is attracted by the electric field. In the presence of an electric field, a diploe moment will be induced in the hexane molecule.

AL02(I)_03

CO_2 exists as simple molecules and the intermolecular attraction is van der Waals' forces. [1]
SiO_2 has a giant covalent network structure. Attraction between CO_2 molecules is weak, but attraction between Si and O atoms in $SiO_2(s)$ is strong. [1]

ASL02(I)_04



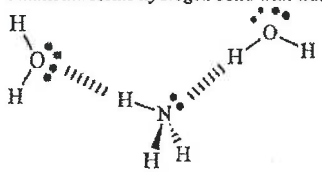
[1]

H_2O is a simple molecule and they are held by **strong hydrogen bond,** while other are only held by weak van der Waals' force. More energy is needed to break down strong hydrogen bond. Hence, the boiling point of H_2O are much higher than that of the rest. [1]
Other Group VI hydrides are simple molecule and they are held by **weak van der Waals'** forces. While the **strength of van der Waals' force increases with the molecular size.** Since the size of GroupVI hydrides increases down the group, hence the boiling point of hydrides also increases down the group. [1]

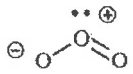
AL02(II)_01

(a) Both NH_3 and PH_3 have a pyramidal shape [1]

Electronegativity difference between N and H is greater than that between P and H. [½]
N–H bonds in NH_3 are more polar than P–H (almost non-polar) in PH_3.
Stronger repulsion between bond pairs in NH_3 than in PH_3 cause the bond angles in NH_3 to have a large value. [½]

(b) Ammonia forms hydrogen bond with water. [1]

P–H bonds in PH_3 are non-polar and lone pair on P is not readily donated. ∴ PH_3 is only sparingly soluble. [1]

AL03(I)_01

(a)  [1]

(b) O_2 is non-polar; O_3 has a v-shaped. [1]
The vector sum of the dipole moments of the O–O bonds in O_3 is non-zero.
∴ O_3 molecules has a net dipole moment / polar. H_2O molecule has a net dipole moment / polar. [½]
The electrostatic attraction between O_3 and H_2O is stronger than that between O_2 and H_2O (like dissolves like). [½]

ASL03(I)_02

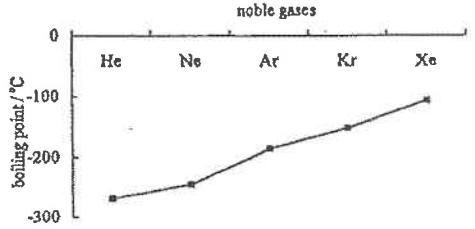
Boiling point increases in the order:
$CH_3(CH_2)_2CH_3$ < $CH_3(CH_2)_3CH_3$ < $CH_3(CH_2)_3Cl$ < $CH_3(CH_2)_3OH$ [1]
Both $CH_3(CH_2)_2CH_3$ and $CH_3(CH_2)_3CH_3$ are non-polar. Their intermolecular attraction is weak van der Waals' force. [1]
The strength of van der Waals' foces increases with their molecular size. [1]
∴ The boiling point of $CH_3(CH_2)_3CH_3$ is higher than the boiling point of $CH_3(CH_2)_2CH_3$.
$CH_3(CH_2)_3Cl$ has a net dipole moment. Its intermolecular attraction is stronger than that in alkanes but weaker than the intermolecular between the alcohol molecules. [1]
Stronger hydrogen-bond exist between the alcohol molecules. ∴ $CH_3(CH_2)_3OH$ has the highest boiling point. [1]

AL03(II)_03

(a) Octet rule – all atoms tend to attain the stable electronic configuration of a noble gas (in most case an "octet") by sharing or transfer of electrons. [1]

(b) Limitations of octet rule (any TWO of the following): [2]
1. some compound exists as radical (species with odd no. of electron) e.g. NO_2
2. some molecules contain atoms with electron no. greater than 8, e.g. PCl_5, SF_6
3. some molecules contain atoms with electron no. less than 8. e.g. BCl_3
4. elements for from the ends of a period fail to form ions with an octet structure, e.g. Fe forms Fe^{2+} and Fe^{3+}, Cu forms Cu^{2+}
5. not applicable for atoms which form a doublet structure e.g. H, Li, etc.

AL04(I)_02



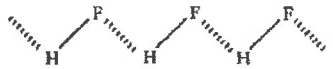
[1]

The intermolecular attraction between noble gas molecules is dispersion force / van der Waals' forces. [½] The strength of van der Waals' forces increases with the number of electrons / atomic size of the noble gas. [½] ∴ The boiling point of noble gas increases as the group is descended.

ASL04(I)_03

(a) The intermolecular attraction in HCl, HBr and HI is predominantly van der Waals' forces. [1] The strength of van der Waals' forces increases with increase in number of electrons (or molecular size). [1] ∴ boiling poing: HCl < HBr < HI

(b) F is highly electronegative and has a very small size. The H–F bond is strongly polarized. Hydrogen bonds are formed between H–F molecules. [1]



Extra energy is required to overcome the hydrogen bonds when HF(l) boils. [1]
∴ The boiling point of HF is exceptionally high as compared with the other hydrogen halides.

(c) No.
The strength of an acid H–X depends on the extent of the equilibrium [1]
$H–X(aq) \rightleftharpoons H^+(aq) + X^-(aq)$
rather thant he polarity of H–X bond.
In HF(aq), $H^+(aq)$ and $F^-(aq)$ form tight ion-pairs. Thus the concentration of $H^+(aq)$ [1] is lower than expected.

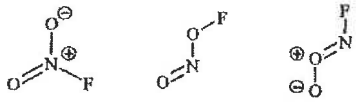
AL04(II)_01 (modifield)

(a) Mole ratio of N : O : F = $\frac{21.6}{14} : \frac{49.2}{16} : \frac{29.2}{19}$ [½]
= 1.543 : 3.075 : 1.537 = 1 : 2 : 1 [½]
∴ empirical formula: NO_2F [1]

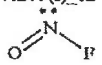
(b) Molecular formula of A : $(NO_2F)_n$
$60 < (14.0 + 16.0 \times 2 + 19.0)n < 70$ [1]
$0.923 < n < 1.077$, $n = 1$ (n must be an integer)

Molecular formula: NO_2F [1]

(c) [3]



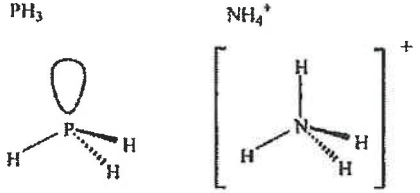
AL05(I)_02



[1]

ASL05(I)_02

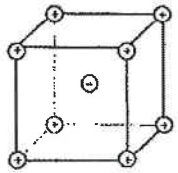
(a) (i) [2]



(ii) NH_4^+

In NH_4^+ all four electron pairs are bond pairs, but in PH_3 there are one lone pair and three bond pairs. The repulsion between lone pair and bond pair is stronger than that between bond pair and bond pair. ∴ The bond angles in PH_3 are squeezed to a value less than 109°28'. [1]

(b) (i)



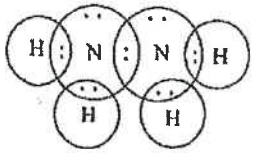
[1]

(ii) 8 [1]

(iii) In solid state, the ions have no translational motion. ∴ CsCl(s) is an electrical insulator. In molten state, the cations and anions can move under the influence of an electric field. [1]

ASL05(I)_05

(a)



[1]

(b) $N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$ [1]

The products H_2O and N_2 are non-corrosive. [1]

OR, $N_2(g)$ formed will be released ∴ No other materials will be introduced into the water.

(c)

$$\text{Moles of } N_2H_4 = \text{moles of } O_2 \text{ present} = \frac{3.2 \times 10^4 \times 6.4 \times 10^{-3}}{16 \times 2} \quad [1]$$

$$\text{Mass of hydrazine required} = \frac{3.2 \times 10^4 \times 6.4 \times 10^{-3}}{16 \times 2} \times 32 = 204.8\ \text{g} \quad [1]$$

AL05(II)_02 (modified)

SO_2 is of V-shape  [1]

CO_2 is liner, O=C=O [1]

In SO_2, the vector sum of two S=O bond polarity is non-zero. In CO_2, the vector sum of the two C=O bond bond polarity is zero. [1]

AL05(II)_03

Mass spectrometry [1]

Peaks of m/z ratios 720, 840 and 1008 can be found in the mass spectrum [1]

ASL05(II)_09

Boiling point: B < D < C [1]

The boiling point of a compound depends on its intermolecular attraction.

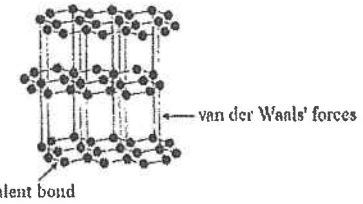
The intermolecular attraction of B is van der Waals' forces. This attraction force is weakest among the three. [1]

The attraction between molecules of C is hydrogen bond which is the strongest among the three. ∴C has the highest boiling point. [1]

AL06(I)_02a

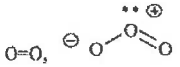
(i) Allotrope: one of the several possible forms of an element, which are significantly different in physical or chemical properties / which have different structures. [1]

(ii) Diagram + labels of interatomic attractions: 2 marks [2]



(iii) The conversion of diamond to graphite has very high activation energy. The reaction is very slow under normal conditions. [1]

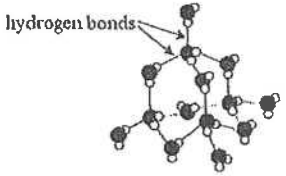
(iv) Oxygen and ozone [1]



[1]

AL06(II)_02

(a) The intermolecular attraction in both ice and liquid water is hydrogen-bond [1]
The directional character of hydrogen bond makes the water molecules in ice to arrange tetrahedrally to form an open structure. [½] [½]

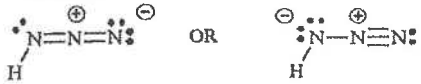


When ice melts, the open structure collapses. Molecules can be packed more closely together in liquid water than in ice. ∴ Ice has a smaller density than water. [1]

(b) $H_2O(s)$ ⟷ $H_2O(l)$
Lower density Higher density

The blade of the skate exerts a high pressure on ice. The position of the above equilibrium shifts to the right, ice melts. [1]
The water formed can help reduce the friction between blade of the skate and ice. [1]

AL06(II)_02



[1]

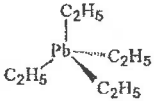
AL07_Sample Paper [OUT]

(a) **The residue consists of inorganic components like graphite that is insoluble in benzene, whereas C_{60} and C_{70} are nonpolar molecules held by dispersion forces (van der Waals' force) and thus are soluble in nonpolar benzene.** [1] [1]

(b) **Heat the red crystals in vacuum or in an atmosphere of noble gas.** [1]
C_{60} and C_{70} will sublime out at a temperature of 400 –500 °C, depositing to form a brown or grayish layer of powdery molecular crystals. [½] [½]

(c) Like graphite, fullerenes can conduct electricity. [1]
due to the presence of delocalized electrons. [1]

ASL07(I)_01

(a)

[1]

(b) Any ONE of the following: [1]
$2Pb(C_2H_5)_4 + 27O_2 \longrightarrow 2PbO + 16CO_2 + 20H_2O$
$3Pb(C_2H_5)_4 + 41O_2 \longrightarrow Pb_3O_4 + 24CO_2 + 30H_2O$
$Pb(C_2H_5)_4 + 14O_2 \longrightarrow PbO_2 + 8CO_2 + 10H_2O$

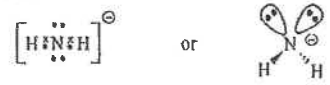
(c) Any TWO of the following: [2]
Combustion of tetraethyl lead(TEL) gives lead compounds which are highly toxic.
Leaded petrol cannot be used in cars equipped with catalytic converter.
MTBE is an oxygen-containing compound. It can enhance the complete combustion of petrol.

AL07(I)_02


[2]

SO_4^{2-}: O.S. of S = +6 [1]
$S_2O_3^{2-}$: O.S. of central S atom = +4; [½]
O.S. of the other S atom = 0 [¼]

AL08(I)_01

(a)


[1]

v-shaped [1]

(b) Bond angle: $NH_4^+(g) > NH_3(g) > NH_2^-(g)$ [1]
In the outermost electron shell of the N atom in the three species, the numbers of lone-pairs and bond-pairs are as follow:

Species	No. of bond-pairs	No. of lone-pairs

$NH_4^+(g)$	4	0
$NH_3(g)$	3	1
$NH_2^-(g)$	2	2

[½]

In each of the three species, the electron pairs in the outermost shell of N are arranged tetrahedrally.

The repulsion between the electron pairs is in the order:

Lone pair-lone pair repulsion > Lone pair-bond pair repulsion > bond pair - bond pair repulsion [½]

Bond angles in the species are: NH_4^+ 109.5 °, NH_3 107.5°, NH_2^- 104.5°

AL08(II)_01

Na_2O is an ionic solid in giant ionic structure. The strong attraction between the cations and anions makes it a high melting point solid. [1]

Cl_2O exists as simple molecules. The intermolecular attraction is weak van der Waals' force. It is much weaker than ionic bond in Na_2O. [1]

AL08(II)_04

(a) Diamond is covalent crystal. Each carbon form four (single) bonds and the electrons are localized / no delocalized electrons. [½] [½]

∴ Diamond is a poor conductor / insulator of electricity.

In graphite, each carbon atom is covalently bonded to only three other carbon atoms in its layer, one outer electron of each carbon is free / delocalized. These [½] [½]

"free" electrons are delocalized and moved in the direction of an electric field / within the layers. ∴ Graphite is an electrical conductor. [1]

(b) (i) Adding an organic solvent (e.g. benzene), C_{60} is soluble but graphite powder is not. [1]

Explanation: C_{60} exists as simple molecules and is non-polar. It is soluble in non-polar solvents. Graphite is a covalent crystal. It is not soluble in most solvents. [1]

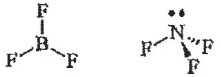
OR Packing of powder to form a solid mass. Graphite conducts electricity but the other does not.

OR Check m.p. / b.p. C_{60} sublimes but the other does not.

(ii) Mass spectrometry: C_{60} gives a peak of m/z = 720 for the molecular ion. [1]

Explanation: C_{60} exists as simple molecules and its relative molecular mass is 720. [1]

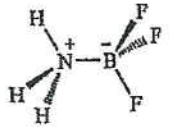
ASL09(I)_01

(a)  [½]

 [½]

For BF_3, there are 3 bond-pair (no lone-pair) in the outermost shell of B. To minimize electronic repulsion, the 3 bond-pairs in BF_3 will be arranged in a trigonal planar shape. [1]

For NF_3, there are 3 bond-pairs and 1 lone-pair in the outermost shell in N. The electron pairs in NF_3 will also be arranged tetrahedrally. The molecule is trigonal pyramidal in shape. The bond angle < 109° as repulsion between lone-pair and bond-pair is stronger than that between bond-pair and bond-pair. [1]

(b)  [1]

AL09 (I)_02

(a) ⋮N≡C—C≡N⋮ [1]

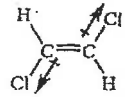
(b) $(CN)_2$ exists as simple molecules. Its relative molecular mass is smaller than that of Cl_2. [½]

$(CN)_2$ is a gas. [½]

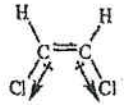
ASL09(II)_04

(a) The boiling point of a compound depends on its intermolecular attraction. [1]

For *trans*-isomer, the dipole moments of the C–Cl bonds cancel each other, thus resulting in weak intermolecular attraction. [½]



For *cis*-isomer, the vector sum of the two dipole moments gives rise to a net dipole moment. The intermolecular attraction is stronger.

 [½]

(b) In addition to intermolecular attraction, the melting point of a compound depends also on the degree of compactness of molecules in the solid state. [1]

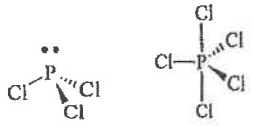
The *cis*-isomer has a lower symmetry. It fits into a crystalline lattice relatively poorly and therefore has a lower melting point. [1]

ASL10(I)_04 (Modified)

(a) Electronic configuration of N: 2, 5 [1]

In N, its outermost electron shell can only accept 3 electrons to complete its octet. ∴ It can form only 3 covalent bonds. [1]

(b)



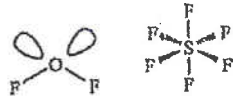
[2]

(c) The size of I is much smaller than that of Cl. [1]

The repulsion between P–I bonds is greater than that of P–Cl bonds, and destabilize the PI_3 structure. [1]

ASL11(I)_01

(b) (i)



[2]

(ii) S is a Period 3 element. It can expand its octet structure by using the 3rd electron shell. [1]

O is a Period 2 element. Its 2nd electron shell cannot expand its octet structure. [1]

ASL11(I)_03

(b) For water, the intermolecular attraction is hydrogen bond. [½]

Ethoxyethane molecules are weakly polar, and the intermolecular attraction is van der Waals' force. [½]

Ethanol has an –OH group which enables its molecules to form hydrogen bond with water. [1]

Ethanol molecule interact strongly with water molecules, but ethoxyethane molecules do not.

OR, The interaction between propane and water molecules is so weak that it cannot overcome the hydrogen bond between water molecules.

ASL11(II)_08

Tensile strength: polypropene < polyacrylonitrile < polyacrylamide

Explanation:

Polyacrylamide contains both C=O group and NH_2 group. The attraction between polymer chains in predominately hydrogen bond. [1]

Polyacrylonitrile contains polar C≡N group. The attraction between polymer chains is van der Waals' force which is weaker than hydrogen bond. [1]

Polypropene is non-polar and the attraction between polymer chains in PP is van der Waals' force which is the weakest. [1]

ASL12(I)_01

(a)

[1]

ASL13(I)_01

Type	Example	Molecular shape	
XY_2 (one lone par on X)	SO_2 / $SnCl_2$	V-shape / bent	[1]
XY_2 (no lone par on X)	CO_2 / $BeCl_2$	Linear	[1]
XY_3 (one lone par on X)	BF_3 / SO_3	Trigonal planar	[1]

AL13(I)_01

(a) Boiling point: HCl < HBr < HF [1]

All three hydrogen halides are polar molecules.

In HBr and HCl, the intermolecular attraction force is van der Waals' force, while van der Waals' force is stronger for molecules with more electrons / larger molecular size. [1]

∴ b.p. of HBr > b.p. of HCl

F has a very small size and is highly electronegative.

Hydrogen bonds are formed between HF molecules, and hydrogen bond is stronger than van der Waals' force. [1]

∴ HF as the highest b.p.

DSE11SP_06

(a) The structure of water is non-liner. [1]

The dipole moments on the two O–H bonds cannot cancel each other / water has a net dipole moment. Hence water is a polar molecule and it would be attracted by the electric field. [1]

(b) The water jet will be attracted towards the rod. [1]

Water molecules will orientate themselves in alignment with the electric field so that they will be attracted. [1]

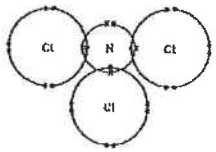
(c) The jet is not attracted. Only a weak dipole moment is induced in hexane molecules. [2]

The attraction between the induced diploe and the electric field is not strong enough to cause a deflection of the liquid jet.

OR, The liquid jet is attracted by the electric field. In the presence of an electric field, a diploe moment will be induced in the hexane molecule.

DSE12PP_03

(b) (i)



[1]

(ii) The nitrogen in NCl_3 and that in NH_3 both have the same number of electron bond-pairs and lone electron pairs / have three electron-pairs and one lone electron pair in their outermost shells. [1]

The repulsion between these electron pairs causes both NCl_3 and NH_3 to adopt a trigonal pyramidal shape. [1]

DSE12PP_06

(a) Propane-1,3-diol / 1,3-propanediol [1]

(b) All three compounds have a hydroxyl group / are monohydric alcohols. The boiling point of these compounds depends on the strength of van der Waals' forces between molecules. [1]

The strength of van der Waals' forces in alcohol increases with the carbon chain length / molecular size. Boiling point increases in the order: **A < B < C** [1]

(c) For isomeric compounds with the same functional group, the strength of intermolecular force is affected by the shape of the molecules. [1]

The structure of $CH_3CH_2CH_2OH$ allows the molecules to have a greater area of contact than those of $CH_3CH(OH)CH_3$. ∴ $CH_3CH_2CH_2OH$ has a greater density. [1]

OR, The structure of $CH_3CH(OH)CH_3$ makes the formation of Hydrogen bonds less effective. ∴ $CH_3CH(OH)CH_3$ has a smaller density.

(d) F [1]

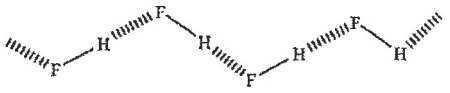
The rate at which the steel balls drop depends on the viscosity of the liquid / the resistance (frictional force) experienced by the ball. This is related to the intermolecular attraction of the liquids. [1]

In the three compounds, the intermolecular attraction is predominately hydrogen bonds. The no. of hydrogen bonds former per molecule is 1 in D 2 in E and 3 in F. F forms the greatest number of hydrogen bonds per molecule. ∴ F is the most viscos and the ball will drop most slowly. [1]

OR, F has the highest boiling point among the three compounds. Its intermolecular attraction is strongest. ∴ The ball will drop most slowly in F.

Effective communication (Award 1 mark if candidates can express their ideas clearly.) [1]

DSE12_04



✓ The drawing should show at least TWO HF molecules. [1]
✓ Should show complete HF molecules.
✓ Should indicate the hydrogen bonds by dashed lines.
✓ Each H atom can only form one hydrogen bond.
✓ F–H–F angle not necessary be drawn as 180° in the drawing.

Fluorine / F is a highly electronegative element. [1]

The H–F covalent bond is very /highly polar / The H–F molecule is highly polarized. [1]

DSE13_01

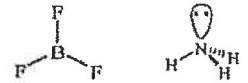
(c) The attraction between water molecules is predominately hydrogen bond. [1]

Hydrogen bond is directional. In ice, the H_2O molecules have a tetrahedral arrangement / are packed in an open structure. [1]

In liquid water, the H_2O molecules have relative motion and this leads to the collapse of the open structure. The molecules become more closely packed. ∴ liquid water has higher density than ice. [1]

DSE13_02

(a) BF_3 NH_3



[2]

(b) BF_3 is a non-polar molecule. The three polar B–F bonds are symmetrically arranged on the same plane / dipole moments cancel out / net dipole moment is 0. [1]

NH_3 is a polar molecule. The molecule has a lone pair in its outermost shell and thus the three polar N–H bonds are not on the same plane / diploe moments cannot cancel out / net dipole moment is not 0. [1]

(c) In BF_3, there are three (bond) electron pairs / there is a vacant site / 6 electrons only / electron deficient in the outermost shell of the B atom. [1]

By accepting the lone pair of electrons from the nitrogen atom of NH_3 / forming dative bond with N, boron attains the stable electronic configuration of neon (a noble gas). [1]

DSE14_01

(a) (i) Layers of graphite are held together by van der Waals' forces / weak intermolecular forces only. [1]

(ii) Yes, graphene has delocalized electrons / electrons in graphene are not localized / mobile electrons / electrons will flow. [1]

(iii)  (Accept any symbols of electrons, ignore shape) [1]

Not accepted: Showing electrons in the inner shells.

(b) No. Graphene layers are made up of a giant covalent structure. [1]

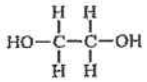
A large amount of energy is needed during melting to destroy the large amount of strong covalent bonds between atoms. [1]

(c) C_{60} has a spherical shape (ball) / and with strong covalent bonds between atoms. [1]

C_{60} has a simple molecular structure. [1]

The van der Waals' forces / attractive forces between C_{60} molecules are of comparable / similar strength as those in organic solvent. [1]

DSE14_02

  $HOCH_2CH_2OH$ [1]

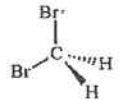
(Accept condensed or skeletal structural formula)

It has a smaller molecular size. / It is a small molecule. / It has a short carbon chain. [1]

The hydroxyl groups in it can form hydrogen bonds with water. [1]

DSE16_04

(a) (i)  [1]

(ii)  [1]

(b) C—H and C—Br bonds are polar. [1]

(Accept if only either one of C-H or C-Br bond is mentioned)

C and H / C and Br have different electronegativities. [1]

C is more electron-withdrawing than H / Br is more electron-withdrawing than C.

(Accept if only either C / H or C / Br is mentioned)

(c) The intermolecular forces between CS_2, CO_2 molecules are van der Waals' forces. [1]

As CS_2 has greater molecular size than CO_2, the van der Waals' forces between CS_2 molecules are stronger than those between CO_2 molecules. [1]

DSE17_05

Both molecules of H_2 and F_2 are held by weak van der Waals' forces. [1]

The van der Waals' forces between F_2 are stronger that those between H_2 because larger

size of F_2 than H_2. (Accept: F_2 molecule has more electrons than H_2 molecule; Not Accept: F_2 has a higher molecular mass than H_2) [1]

Hydrogen bond exists among HF molecules and hydrogen bond is stronger than van der Waals' forces.

DSE18_03

(a) The electrostatic attraction between Ba^{2+} and Cl^- in $BaCl_2$ is ionic bond, while intermolecular attraction between OCl_2 molecules are van der Waals' forces. [1]

OR, $BaCl_2$ is an ionic compound, while OCl_2 has a simple molecular structure. [1]

As ionic bond is much stronger than van der Waals' forces / intermolecular forces between OCl_2 molecules, $BaCl_2$ would have a higher melting point than OCl_2.

(b) Both molecules of PH_3 and CH_4 are held by van der Waals' forces / intermolecular forces. [1]

The van der Waals' forces between PH_3 are stronger than those between CH_4 because of the larger molecular size of PH_3 than CH_4. [1]

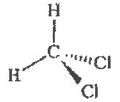
(Accept: PH_3 molecule has more electrons than CH_4)

OR, Intermolecular forces between PH_3 molecules are stronger than that between CH_4 molecules as PH_3 is polar while CH_4 is non-polar.

Hydrogen bond exists among NH_3 molecules that is stronger than van der Waals' forces. [1]

(c)  [1]

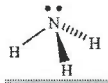
DSE19_06

(a)  [1]

(b) (i) The polarities of bonds in CCl_4 cancel out each other while those in CH_2Cl_2 do not. [1]

(Accept drawings with suitable annotations.)

(ii) CCl_4 has a larger molecular size than CH_2Cl_2, therefore it has larger van der Waals' forces between molecules / intermolecular forces, and hence it has a higher boiling point. [1] [1]

3. (a) (i)  1

(Accept answer without showing the lone-pair electrons)

(ii)  1

(b) (i) • B–N is the dative covalent bond. 1

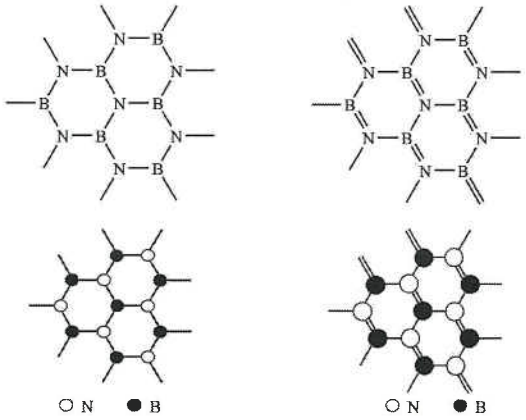
• The lone electron pair on nitrogen atom of NH_3 is donated to form a dative covalent bond with the boron atom of BH_3. 1

(ii) • Both are van der Waals' forces between their respective molecules. 1

• As H_3NBH_3 is polar but ethane is not, the van der Waals' forces between H_3NBH_3 molecules are stronger than those between ethane molecules. 1

(Only the 2nd mark will be given if the candidate answered in terms of "intermolecular forces" instead of van der Waals' forces)
(2nd mark not accept comparison of molecular size)

(iii) 2



(1 mark for showing the fused hexagonal structure, need to show at least 2 fused rings)
(1 mark for showing alternating N and B atoms)
(Ignore the double bonds in the structure)

SECTION 7 Redox Reactions, Chemical Cells and Electrolysis

Multiple-Choice Questions

CE90_01

Which of the following elements in the third period of the Periodic Table is the strongest reducing agent?

A. sodium
B. sulphur
C. chlorine
D. aluminium

CE90_05

In going down the group VI elements of the Periodic Table, there is an increase in

(1) the size of the atoms.
(2) the melting point of the elements.
(3) the oxidizing power of the elements.

Which of the following combinations is correct?

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE90_13

A pupil, working with dilute acids in the laboratory, carelessly poured the unused acids into the sink. Later it was found that the copper pipe in the sink had begun to leak. Which of the following acids is/are most likely to have caused the damage?

(1) dilute nitric acid
(2) dilute sulphuric acid
(3) dilute hydrochloric acid

A. (1) only
B. (2) only
C. (1) and (2) only
D. (2) and (3) only

CE90_16

Sulphuric acid is NOT used to prepare carbon dioxide from limestone because

A. the reaction between sulphuric acid and limestone is reversible.
B. the reaction between sulphuric acid and limestone is too vigorous.
C. sulphuric acid is a strong oxidizing agent.
D. an insoluble product is formed which stops further reaction.

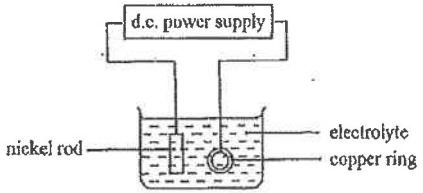
CE90_19

In which of the following pairs of substances is the oxidation number of the sulphur atom and the nitrogen atom the same?

A. H_2SO_4 and HNO_3
B. SO_2 and HNO_2
C. SCl_2 and NO
D. NaHS and NH_3

CE90_23

A student tries to plate a copper ring with nickel using the set-up below:



Which of the following combination is correct?

	Anode	Cathode	Electrolyte
A.	copper ring	nickel rod	$Ni^{2+}(aq)$
B.	nickel rod	copper ring	$Ni^{2+}(aq)$
C.	copper ring	nickel rod	$Cu^{2+}(aq)$
D.	nickel rod	copper ring	$Cu^{2+}(aq)$

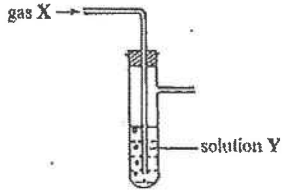
CE90_24

Which of the following pairs of metals would be expected to give the largest voltage when they are used as electrodes in a simple chemical cell using potassium nitrate solution as the electrolyte?

A. Zn and Pb
B. Mg and Ag
C. Pb and Cu
D. Fe and Mg

CE90_27

Gas X is bubbled steadily into solution Y as shown in the set-up below:

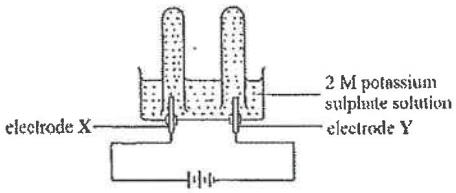


In which of the following cases will NO observable change occur in solution Y?

	gas X	solution Y
A.	sulphur dioxide	bromine water
B.	sulphur dioxide	calcium hydroxide
C.	carbon dioxide	bromine water
D.	carbon dioxide	calcium hydroxide

CE91_06

Direction: Questions 6 and 7 refer to the following electrolysis experiment.



The gases collected at electrodes X and Y respectively are in the volume ratio of

A. 1 : 1
B. 1 : 2
C. 1 : 4
D. 2 : 1

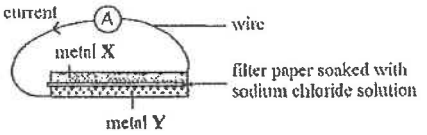
CE91_07

Which of the following statements concerning the experiment is/are correct?

(1) The pH value of the potassium sulphate solution remains unchanged at the end of the experiment.
(2) The concentration of the potassium sulphate solution remains unchanged at the end of the experiment.
(3) The products of electrolysis at electrodes X and Y would remain unchanged if 2M sulphuric acid were used instead of 2M potassium sulphate solution.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE91_09

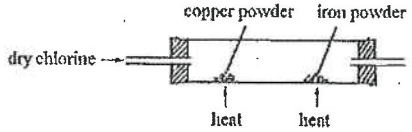


Which of the following combinations would produce the largest current flow from metal X to metal Y in the external circuit?

	metal X	metal Y
A.	Fe	Cu
B.	Mg	Ag
C.	Ag	Zn
D.	Cu	Pb

CE91_10

Dry chlorine is passed in excess over heated copper powder and iron powder as shown in the diagram below:



What is/are the product(s) at the end of the experiment?

A. copper(II) chloride only
B. iron(II) chloride only
C. copper(II) chloride and iron(II) chloride
D. copper(II) chloride and iron(III) chloride

CE91_12

Which of the following tests should be used to detect the presence of sulphite ions in a given solution **X**?

A. On adding barium chloride solution to **X**, a white precipitate is formed.
B. On adding lead(II) nitrate solution to **X**, a white precipitate is formed.
C. On adding dilute sulphuric acid to **X**, a colourless gas is evolved which can decolourize acidified potassium permanganate solution.
D. On adding dilute nitric acid to **X**, a reddish-brown gas is evolved.

CE91_14

Sulphur dioxide is passed into a test tube containing potassium dichromate solution acidified with dilute sulphuric acid. The colour of the solution gradually changes from orange to green.

Which of the following statements concerning the above experiment is correct?

A. Sulphur dioxide is oxidizing to sulphate.
B. The green colour is due to the presence of $Cr^{2+}(aq)$ ions.
C. The dilute sulphuric acid acts as a catalyst.
D. The oxidation number of chromium changes from +7 to +2 in the reaction.

CE91_17

When concentrated sulphuric acid is added to hydrated copper(II) sulphate crystals, which of the following would be observed?

A. The crystals dissolve to form a blue solution.
B. The crystals change to a white solid.
C. The crystals change to a black solid.
D. There is no visible change.

CE91_37

Which of the following oxidation numbers can nitrogen display in its compounds?

(1) −3
(2) +2
(3) +3
(4) +4

A. (1) and (4) only
B. (2) and (3) only
C. (1), (2) and (4) only
D. (1), (2), (3) and (4)

CE91_43

$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$

Which of the following statements concerning the above reaction are correct?

(1) $I^-(aq)$ acts as a reducing agent.
(2) Chlorine is a stronger oxidizing agent than iodine.
(3) The reaction is a displacement reaction.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE91_44

Which of the following gases can be dried by concentrated sulphuric acid?

(1) hydrogen chloride
(2) ammonia
(3) sulphur dioxide

A. (3) only
B. (1) and (2) only
C. (1) and (3) only
D. (2) and (3) only

CE92_08

The manufacture of sulphuric acid can be represented by the following flow diagram:

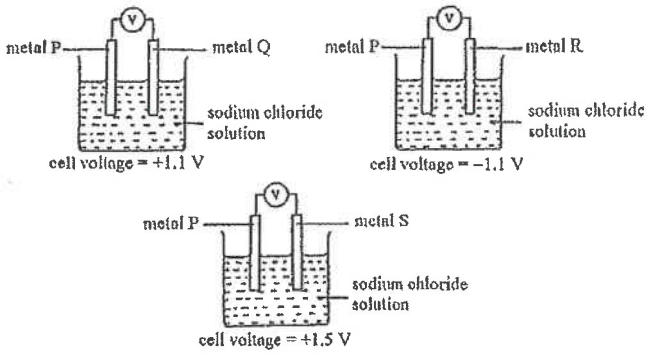
$$S \xrightarrow{\text{Stage I}} SO_2 \xrightarrow{\text{Stage II}} SO_3 \xrightarrow{\text{Stage III}} H_2S_2O_7 \xrightarrow{\text{Stage IV}} H_2SO_4$$

Which stage involves the greatest change in the oxidation number of sulphur?

A. Stage I
B. Stage II
C. Stage III
D. Stage IV

CE92_09

Directions: Q.9 and Q.10 refer to the following diagrams:



Which of the following represents the correct order of activity of the metals P, Q, R and S?

A. R, P, Q, S
B. Q, P, R, S
C. P, Q, S, R
D. P, R, S, Q

CE92_10

Which of the two metals used as electrodes would give the largest cell voltage?

A. Q and R
B. Q and S
C. S and R
D. S and P

CE92_11

Consider the following flow diagram:

$$CuO(s) \xrightarrow{\text{Reactant X}} Cu(s) \xrightarrow{\text{Reactant Y}} Cu^{2+}(aq)$$

Which of the following combinations is correct?

	Reactant X	Reactant Y
A.	$H_2(g)$	dilute H_2SO_4
B.	$CO(g)$	dilute HNO_3
C.	$NH_3(g)$	dilute HCl
D.	$C(s)$	concentrated HCl

CE92_12

Using 1 mole of reactant, which of the following chemical changes involves the highest number of electrons?

A. $CrO_4^{2-}(aq) \longrightarrow Cr^{3+}(aq)$
B. $Cr_2O_7^{2-}(aq) \longrightarrow Cr^{3+}(aq)$
C. $MnO_4^-(aq) \longrightarrow Mn^{2+}(aq)$
D. $MnO_4^-(aq) \longrightarrow MnO_2(aq)$

CE92_13

When 2 moles of oxygen gas are collected at the anode during the electrolysis of dilute sulphuric acid, the number of moles of electrons released at the anode is

A. 2.
B. 4.
C. 6.
D. 8.

CE92_15

Which of the following substances react with hot concentrated sulphuric acid?

(1) sulphur
(2) sodium nitrate
(3) hydrated copper(II) sulphate

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE92_16

When sulphur dioxide is bubbled into sodium hydroxide solution for a long time, the final product is

A. sodium sulphite.
B. sodium sulphate.
C. sodium hydrogensulphite.
D. sodium hydrogensulphate.

CE92_35

Which of the following reagents can be used to distinguish between $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ ions?

(1) ammonia solution
(2) concentrated nitric acid
(3) acidified potassium permanganate solution

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE92_37

Which of the following aqueous solutions, when electrolyzed using carbon electrodes, will liberate only gaseous products at both electrodes?

(1) KOH(aq)
(2) $AgNO_3(aq)$
(3) $MgCl_2(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE92_38

Which of the following statements concerning the reaction between dry chlorine and hot iron wire is/are correct?

(1) Iron(II) chloride is formed.
(2) A solid product is obtained after cooling to room temperature.
(3) Chlorine is reduced.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

CE92_40

Which of the following can be used to distinguish between dilute hydrochloric acid and dilute nitric acid?

(1) copper
(2) silver nitrate solution
(3) sodium hydrogencarbonate solution

A. (2) only
B. (1) and (2) only
C. (1) and (3) only
D. (2) and (3) only

CE92_50

1st statement	2nd statement
When concentrated sulphuric acid is poured onto a piece of cotton cloth, the piece of cloth becomes charred.	Concentrated sulphuric acid is a strong oxidizing agent.

CE93_05

Directions: Q.5 and Q.6 refer to the following experiment:

A silver coin, with a mass of 12.00 g, was dissolved completely in concentrated nitric acid. When excess potassium chloride solution was added to the resulting solution, 14.35 g of a white precipitate were obtained.

Which of the following equation correctly represents the reaction between silver and concentrated nitric acid?

A. $Ag + 2H^+ + NO_3^- \longrightarrow Ag^+ + NO_2 + H_2O$
B. $Ag + 4H^+ + NO_3^- \longrightarrow Ag^+ + 4NO_2 + O_2 + 2H_2O$
C. $3Ag + 4HNO_3 \longrightarrow 3AgNO_3 + NO + 2H_2$
D. $Ag + 4HNO_3 \longrightarrow AgNO_3 + 3NO_2 + 2H_2O$

CE93_06

What is the percentage by mass of silver in the coin?
(Relative atomic masses: Cl = 35.5, Ag = 108)

A. 45
B. 60
C. 75
D. 90

CE93_12

A mixture contains copper powder and zinc powder. In order to remove the zinc powder, the mixture is heated with an acid and filtered. Which of the following acids should be used?

A. Dilute nitric acid.
B. Concentrated nitric acid.
C. Dilute sulphuric acid.
D. Concentrated sulphuric acid.

CE93_15

The oxidation number of copper remains unchanged when

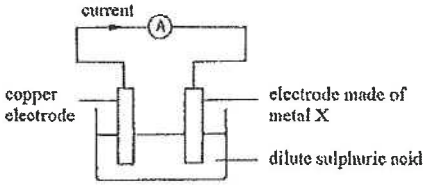
A. magnesium ribbon is added to copper(II) sulphate solution.
B. sodium carbonate solution is added to copper(II) sulphate solution.
C. carbon is heated with copper(II) oxide.
D. copper foil is burnt in chlorine.

CE93_16

In which of the following equations does the underlined substance undergo reduction?

A. $2H_2O + 2\underline{K} \longrightarrow 2KOH + H_2$
B. $Fe_2(SO_4)_3 + 2\underline{KI} \longrightarrow 2FeSO_4 + K_2SO_4 + I_2$
C. $2H_2S + \underline{SO_2} \longrightarrow 3S + 2H_2O$
D. $NaClO + \underline{SO_2} + H_2O \longrightarrow NaCl + H_2SO_4$

CE93_17



With reference to the above diagram, which of the following statements is correct?

A. The electrode made of metal X is the positive pole.
B. Copper is at a higher position in the electrochemical series than metal X.
C. The mass of the copper electrode decreases.
D. The mass of the electrode made of metal X decreases.

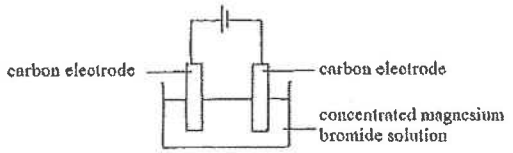
CE93_22

Which of the following reactions would produce a halogen?

(1) sodium chloride + concentrated sulphuric acid
(2) sodium bromide + concentrated sulphuric acid
(3) sodium iodide + concentrated sulphuric acid

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

CE93_19



In the above experiment, which of the following major products will be liberated at the electrode?

	cathode	anode
A.	magnesium	oxygen
B.	magnesium	bromine
C.	hydrogen	bromine
D.	hydrogen	oxygen

CE93_24

There is a gradual change in the properties of halogens from chlorine to iodine. Which of the following properties are in the order

chlorine < bromine < iodine?

(1) oxidizing power
(2) density
(3) boiling point

A. (1) and (2) only
B. (2) and (3) only
C. (1) and (3) only
D. (1), (2) and (3)

CE93_44

Which of the following statements is **INCORRECT**?

A. Tin is used for making food cans.
B. Sulphuric acid is used for making soap.
C. Ammonium chloride is used for making dry cells.
D. Chlorine is used for sterilizing drinking water.

CE93_45

1st statement	2nd statement
Concentrated sulphuric acid can be used to prepare nitric acid.	Sulphuric acid is more volatile than nitric acid.

CE94_04

Both rubidium (Rb) and sodium are elements in Group I of the Periodic Table, but rubidium is more reactive than sodium. When a rubidium hydroxide solution is electrolyzed using platinum electrodes, hydrogen gas is liberated at the cathode.

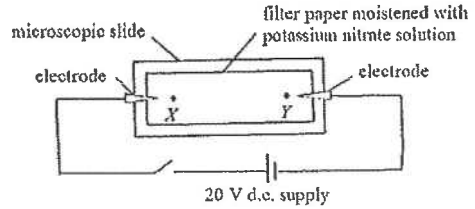
Which of the following statements is a correct explanation for the phenomenon described above?

A. The $H^+(aq)$ ion accepts an electron more readily than the $Rb^+(aq)$ ion.
B. The $H^+(aq)$ ion is more mobile than the $Rb^+(aq)$ ion and migrates faster to the cathode.
C. Rubidium is first liberated, but it reacts immediately with water to give hydrogen gas.
D. The concentration of $H^+(aq)$ ions is higher than that of $Rb^+(aq)$ ions in the rubidium hydroxide solution.

CE94_06

Directions: Q.6 and Q.7 refer to the following experiment:

A drop of silver nitrate solution and a drop of sodium iodine solution are placed respectively at *X* and *Y* as shown in the diagram below:



After the circuit has been closed for some time, a coloured patch is formed between *X* and *Y*.

What is the colour of the patch?

A. brown
B. purple
C. yellow
D. black

CE94_07

The main aim of this experiment is to show that

A. ions exist in silver nitrate solution and sodium iodine solution.
B. sodium ions can react with nitrate ions.
C. silver ions can react with iodine ions.
D. potassium nitrate is an electrolyte.

CE94_10

On strong heating, a solid X decomposes to give a solid residue and a brown gas. The solid residue can react with concentrated nitric acid with evolution of a brown gas. X is probably

A. $AgNO_3$.
B. $Cu(NO_3)_2$.
C. $NaNO_3$.
D. $Zn(NO_3)_2$.

CE94_12

In which of the following experiments will a redox reaction occur?

A. adding copper turnings to iron(II) nitrate solution.
B. adding bromine water to potassium chloride solution.
C. adding iron fillings to silver nitrate solution.
D. adding sodium chloride solution to silver nitrate solution.

CE94_13

When a substance X is electrolyzed using platinum electrodes, a gas is collected at each electrode. X may be

A. silver nitrate solution.
B. potassium chloride solution.
C. molten sodium chloride.
D. molten copper(II) chloride.

CE94_15

Which of the following is NOT a suitable method of preparation?

A. preparation of carbon dioxide from calcium carbonate and dilute sulphuric acid.
B. preparation of hydrogen from iron and dilute sulphuric acid.
C. preparation of sulphur dioxide from sodium sulphite and dilute hydrochloric acid.
D. preparation of nitrogen dioxide from zinc and concentrated nitric acid.

CE94_34

Which of the following reagents can be used to distinguish between sodium sulphite solution and sodium sulphate solution?

(1) barium chloride solution
(2) acidified potassium permanganate solution
(3) potassium iodide solution

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE94_38

Concentrated sulphuric acid turns blue litmus paper red and then black. On the basis of these colour changes, which of the following deductions concerning concentrated sulphuric acid are correct?

(1) It contains $H^+(aq)$ ions.
(2) It is an oxidizing agent.
(3) It is a dehydrating agent.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE94_49

1st statement	2nd statement
Iron reacts with chlorine to form iron(II) chloride.	Iron is a reducing agent in this reaction.

CE95_07

Which of the following substances, when mixed, would undergo a chemical reaction?

A. copper and zinc sulphate solution
B. calcium chloride solution and magnesium nitrate solution
C. lead(II) solution and sodium hydroxide solution
D. bromine water and sodium chloride solution

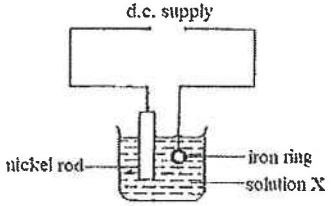
CE95_10

In which of the following equation does the underlined substance become reduced?

A. $\underline{CuSO_4} + Zn \longrightarrow ZnSO_4 + Cu$
B. $\underline{2FeCl_2} + Cl_2 \longrightarrow 2FeCl_3$
C. $\underline{Pb(OH)_2} + 2HNO_3 \longrightarrow Pb(NO_3)_2 + 2H_2O$
D. $\underline{MgCO_3} + 2HCl \longrightarrow MgCl_2 + CO_2 + H_2O$

CE95_11

A student tries to electroplate an iron ring with nickel using the set-up shown below.



Which of the following combinations is correct?

	Solution X	Anode	Cathode
A.	Iron(II) sulphate solution	Iron ring	Nickel rod
B.	Iron(II) sulphate solution	Nickel rod	Iron ring
C.	Nickel(II) sulphate solution	Iron ring	Nickel rod
D.	Nickel(II) sulphate solution	Nickel rod	Iron ring

CE95_13

The reaction of cane sugar and concentrated sulphuric acid may be represented by the following equation.

$$C_{12}H_{22}O_{11}(s) \xrightarrow{\text{conc. } H_2SO_4} 12C(s) + 11H_2O(l)$$

In this reaction, concentrated sulphuric acid acts as

A. a strong acid
B. an oxidizing agent
C. a drying agent
D. a dehydrating agent

CE95_30

$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$

Which of the following statements is/are correct?

(1) Carbon monoxide is an oxidizing agent.

(2) The oxidation number of carbon changes from +2 to +4.

(3) The oxidation number of iron changes from +2 to 0.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

CE95_33

Which of the following statements concerning a silver oxide cell is/are correct?

(1) The cell is rechargeable.

(2) The cell can maintain a steady voltage during discharge.

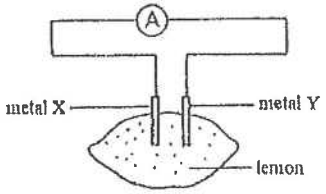
(3) The positive electrode of the cell is silver oxide.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

CE95_37

In the set-up shown below metal X is more reactive than metal Y.



Which of the following statements concerning this set-up is/are correct?

(1) Electrolysis occurs inside the lemon.

(2) Chemical energy is changed into electrical energy.

(3) Electron flows from metal Y to metal X in the external circuit.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

CE95_39

Which of the following substances can conduct electricity?

(1) molten zinc chloride

(2) an aqueous solution of magnesium sulphate

(3) a mixture of ethanol and water

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

CE95_40

Which of the following methods can produce hydrogen?

(1) adding zinc to water

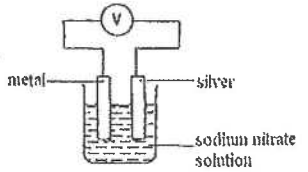
(2) electrolyzing dilute sulphuric acid

(3) adding magnesium to dilute hydrochloric acid

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

CE96_07



Which of the following metals would produce the smallest voltage in the above set-up?

A. iron B. aluminium

C. copper D. magnesium

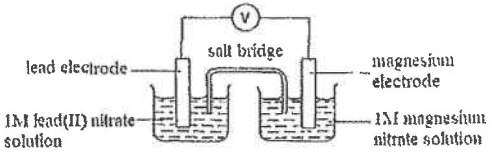
CE96_09

Which of the following experiments can be used to show that concentrated sulphuric acid is a dehydrating agent?

A. adding it to copper(II) oxide powder B. adding it to copper(II) sulphate crystals

C. adding it to calcium carbonate powder D. adding it to sodium chloride crystals

CE96_27



Which of the following statements concerning the above set-up is correct?

A. Electrons flow from the lead electrode to the magnesium electrode through the external circuit.

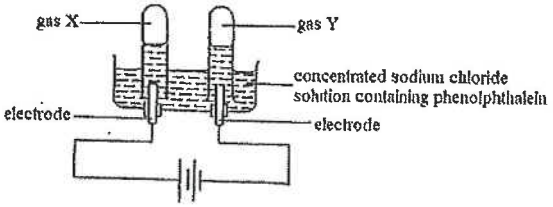
B. Electrons flow through the salt bridge.

C. The mass of the lead electrode remains unchanged.

D. Oxidation occurs at the magnesium electrode.

CE96_30

Directions: CE96_30 and CE96_31 refer to the following experiment.



Which of the following combinations is correct?

	Gas X	Gas Y
A.	chlorine	hydrogen
B.	chlorine	oxygen
C.	hydrogen	chlorine
D.	oxygen	hydrogen

CE96_31

Which of the following statements concerning the above experiment is/are correct?

(1) Platinum electrodes should be used.
(2) The concentration of $Na^+(aq)$ ions around the cathode increases.
(3) The solution changes from colourless to pink.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE96_35

In which of the following processes will lead be produced?

(1) the electrolysis of lead(II) bromide.
(2) heating lead(II) oxide strongly.
(3) adding magnesium to lead(II) nitrate solution.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE96_38

Which of the following substances are commonly found in the waste water produced by electroplating factories?

(1) acids
(2) alkalis
(3) cyanides

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE96_42

X is an element. It can form a cation X^{2+} which has an electronic arrangement 2, 8, 8. Which of the following statements concerning X are correct?

(1) X is a strong oxidizing agent.
(2) X is in Period 4 of the Periodic Table.
(3) X burns in oxygen with a brick red flame.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE96_46 [OUT]

1st statement	2nd statement
Zinc-carbon dry cells are rechargeable.	The electrolyte used in zinc-carbon dry cells is potassium hydroxide.

CE97_04

Which of the following statements concerning the elements in the third period of the Periodic Table is correct?

A. Both sulphur and chlorine can be reduced by aqueous sodium sulphite.
B. Magnesium is a stronger reducing agent than sodium.
C. Phosphorous and chlorine form a covalent compound.
D. Magnesium burns in oxygen to form an acidic oxide.

CE97_07

During the electrolysis of 1M copper(II) chloride solution using copper electrodes, which of the following changes would occur at the electrodes?

	Cathode	Anode
A.	hydrogen liberated	chlorine liberated
B.	copper deposited	chlorine liberated
C.	copper dissolved	copper deposited
D.	copper deposited	copper dissolved

CE97_08

Which of the following conversions involves the smallest change in oxidation number of the underlined element?

A. $\underline{C}(s) \longrightarrow \underline{C}O_2(g)$
B. $\underline{N}O_3^-(aq) \longrightarrow \underline{N}O_2(g)$
C. $\underline{S}O_3^{2-}(aq) \longrightarrow \underline{S}O_4^{2-}(aq)$
D. $\underline{Mn}O_4^-(aq) \longrightarrow \underline{Mn}^{2+}(aq)$

CE97_09

Metal X reacts with dilute nitric acid to give a colorless solution. When sodium hydroxide solution is added to the solution, a white precipitate which dissolves in excess sodium hydroxide solution is formed. X is probably

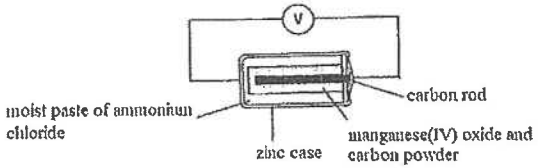
A. copper.
B. iron.
C. lead.
D. magnesium.

CE97_10

Which of the following combinations is **INCORRECT**?

	Chemical	Method of storage
A.	calcium	under water
B.	potassium	under paraffin oil
C.	ethanol	in a cool place
D.	potassium permanganate solution	in a brown bottle

CE97_11 [OUT]



A zinc-carbon cell is connected to a voltmeter as shown in the above diagram. Which of the following statements concerning the set-up is **INCORRECT**?

A. Electrons flow from the zinc case to the carbon rod in the external circuit.
B. The zinc case gradually becomes thinner as the cell discharges.
C. Manganese(IV) oxide acts as an oxidizing agent.
D. Ammonium chloride acts as a reducing agent.

CE97_29

An iron nail is heated with concentrated sulphuric acid. Which of the following combinations is correct?

	Gas given off	Color of solution formed
A.	hydrogen	pale green
B.	hydrogen	yellow
C.	sulphur dioxide	pale green
D.	sulphur dioxide	yellow

CE97_36

Which of the following substances can be used to distinguish between concentrated nitric acid and concentrated sulphuric acid?

(1) sodium carbonate powder
(2) copper turnings
(3) cane sugar

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE97_39

Concentrated sulphuric acid is corrosive to skin because

(1) it is a dehydrating agent.
(2) it is an oxidizing agent.
(3) each molecule of sulphuric acid has two ionizable hydrogen atoms.

Which of the above statements are correct?

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

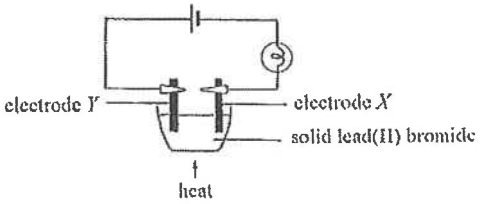
CE97_50

1st statement	2nd statement
Concentrated hydrochloric acid can react with silver.	Concentrated hydrochloric acid is a strong oxidizing agent.

CE98_04

Directions: Questions 4 and 5 refer to the following experiment:

The circuit shown below is set up and the solid lead(II) bromide is heated until it becomes molten.



Which of the following statements concerning the experiment is **INCORRECT**?

A. The bulb lights up.
B. A reddish brown gas is liberated at electrode X.
C. Electrodes X and Y can be made of nichrome.
D. Oxidation occurs at electrode Y.

CE98_05

Which of the following can be deduced from the experimental results?

A. Solid lead(II) bromide contains mobile ions.
B. Molten lead(II) bromide contains delocalized electrons.
C. Molten lead(II) bromide can be decomposed by electricity.
D. Solid lead(II) bromide is a covalent compound but molten lead(II) bromide is an ionic compound.

CE98_06

A part of the Periodic Table is shown below.

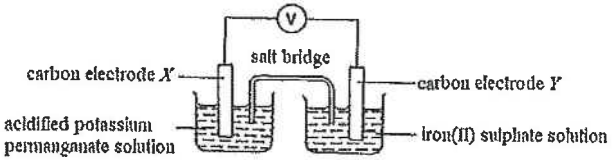
	Group I	II	III	IV	V	VI	VII	0
1								*a*
Period 2	*b*			*c*			*d*	
3							*e*	

Which of the following statements is correct?

A. The outermost electron shell of an atom of *a* is an octet structure.
B. The metallic character of the Period 2 elements increases from *b* to *d*.
C. *c* forms an ionic compound with *d*.
D. *e* is a strong oxidizing agent.

CE98_21

Consider the following experiment.



Which of the following statements concerning the above experiment is correct?

A. Permanganate ions migrate into the salt bridge.
B. Electrons flow from electrode *X* to electrode *Y* in the external circuit.
C. Carbon electrodes are used because they are chemically inert.
D. The half equation for the change occurring at electrode *Y* is $Fe^{2+} + 2e^- \longrightarrow Fe$.

CE98_22

In which of the following reactions does the underlined substance act as a reducing agent?

A. $\underline{SO_2} + 2H_2S \longrightarrow 2S + 2H_2O$
B. $\underline{Pb(NO_3)_2} + H_2SO_4 \longrightarrow PbSO_4 + 2HNO_3$
C. $2\underline{HCl} + MgO \longrightarrow MgCl_2 + H_2O$
D. $2\underline{KBr} + Cl_2 \longrightarrow 2KCl + Br_2$

CE98_38

Which of the following experiments would produce sulphur dioxide?

(1) heating iron pyrites in air
(2) heating a mixture of iron and dilute sulphuric acid
(3) heating a mixture of copper and concentrated acid

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE99_07

Substance X gives identical product(s) when treated with dilute sulphuric acid or concentrated sulphuric acid. X may be

A. zinc.
B. cane sugar.
C. ammonia.
D. hydrated copper(II) sulphate crystals.

CE99_09

In which of the following reactions is the underlined reactant reduced?

A. $\underline{Cu^{2+}} + 2OH^- \longrightarrow Cu(OH)_2$
B. $\underline{SO_2} + 2Mg \longrightarrow 2MgO + S$
C. $2\underline{NH_3} + 3CuO \longrightarrow 3Cu + N_2 + 3H_2O$
D. $\underline{Zn} + 2AgNO_3 \longrightarrow Zn(NO_3)_2 + 2Ag$

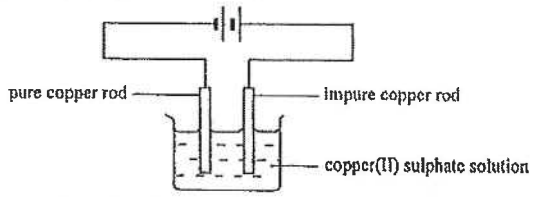
CE99_10

Which of the following statements concerning bromine and chlorine is INCORRECT?

A. They exist as diatomic molecules.
B. Their atoms have the same number of outermost shell electrons.
C. They form ions with a single negative charge.
D. Bromine is a stronger oxidizing agent than chlorine.

CE99_12

Consider the electrolysis experiment shown below:



Which of the following statements concerning this experiment is correct?

A. The mass of the impure copper rod decreases.
B. The blue colour of the copper(II) sulphate solution gradually fades off.
C. Oxidation takes place at the pure copper rod.
D. The electrolysis process can enhance the corrosion resistance of copper.

CE99_15

Potassium permanganate solution acidified with dilute sulphuric acid is a commonly-used oxidizing agent. Dilute nitric acid is not used to acidify potassium permanganate solution because

A. nitric acid is more expensive than sulphuric acid.
B. dilute nitric acid is an oxidizing agent and would react with the reducing agent.
C. nitric acid decomposes more readily than sulphuric acid.
D. dilute nitric acid would react with potassium permanganate solution.

CE99_18

Which of the following processes would NOT produce hydrogen gas?

A. adding calcium to water
B. adding magnesium to dilute hydrochloric acid
C. adding copper to dilute nitric acid
D. passing steam over red hot iron

CE99_24

In an experiment, sulphur dioxide is passed into an iodine solution which is prepared by dissolving some iodine in potassium iodide solution. Which of the following statements concerning this experiment is correct?

A. The colour of the iodine solution changes from purple to colourless.
B. A brown solid is formed.
C. A displacement reaction occurs.
D. Sulphur dioxide is oxidized to sulphate ions.

CE99_33

Which of the following reactions will occur when aluminium powder is added to silver nitrate solution?

(1) displacement
(2) anodization
(3) redox

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE99_36

The equation below represents the reaction of chlorine with hot concentrated potassium hydroxide solution:

$$3Cl_2(g) + 6KOH(aq) \longrightarrow 5KCl(aq) + KClO_3(aq) + 3H_2O(l)$$

Which of the following statements concerning this reaction is/are correct?

(1) Potassium hydroxide acts as a reducing agent.
(2) The oxidation number of chlorine changes from 0 to −1.
(3) The oxidation number of chlorine changes from 0 to +5.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE99_38

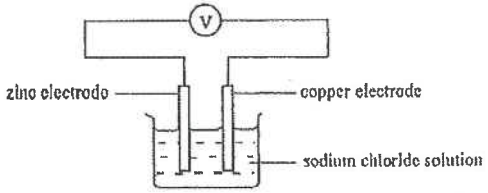
Which of the following reagents is/are commonly stored in brown bottles?

(1) potassium permanganate solution
(2) concentrated sulphuric acid
(3) concentrated nitric acid

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE99_40

Consider the following chemical cell:



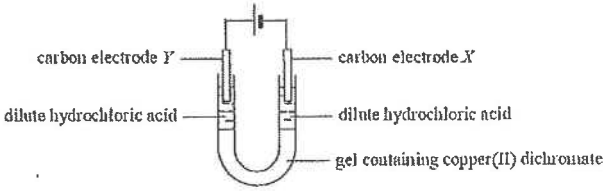
Which of the following changes would lead to an increase in the voltage of the cell?

(1) The zinc electrode is replaced with a magnesium electrode.
(2) The copper electrode is replaced with an iron electrode.
(3) The sodium chloride solution is replaced with a sugar solution.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE99_42

Consider the following experiment:



Which of the following statements concerning the experiment are correct?

(1) Gas bubbles are evolved at electrode *X*.
(2) An orange colour gradually appears in the solution around electrode *Y*.
(3) The experiment can be used to show that ions migrate towards oppositely charged electrodes.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE00_05

Which of the following gases are the major products liberated in the electrolysis of concentrated sodium chloride solution using carbon electrodes?

	Cathode	Anode
A.	hydrogen	chlorine
B.	chlorine	hydrogen
C.	hydrogen	oxygen
D.	oxygen	hydrogen

CE00_16

Consider the following equation:

$3Zn(s) + 2NO_3^-(aq) + 8H^+(aq) \longrightarrow 3Zn^{2+}(x) + 2NO(y) + 4H_2O(z)$

Which of the following combinations is correct?

	x	y	z
A.	aq	g	aq
B.	aq	g	l
C.	aq	aq	l
D.	l	g	aq

CE00_28

Which of the following changes is NOT a redox reaction?

A. $Fe_2(SO_4)_3 + H_2S \longrightarrow 2FeSO_4 + S + H_2SO_4$

B. $2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

C. $CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$

D. $2KClO_3 \longrightarrow 2KCl + 3O_2$

CE00_30

In which of the following substances does nitrogen has the smallest oxidation number?

A. NH_3 B. NO

C. N_2O D. N_2

CE00_31

Which of the following uses of sulphuric acid is/are correct?

(1) manufacture of soaps

(2) manufacture of paint additives

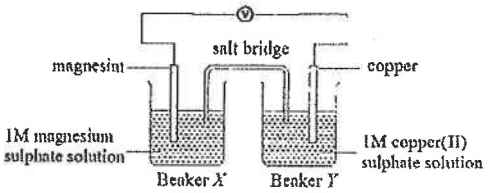
(3) manufacture of fertilizers

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

CE00_35

Consider the chemical cell shown below:



Which of the following statements concerning the cell is/are correct?

(1) Oxidation takes place at the copper electrode.

(2) The concentration of magnesium ions in beaker *X* increases.

(3) The salt bridge allows electrons to flow from one electrode to the other electrode.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

CE00_43 [OUT]

Which of the following statements concerning a zinc-carbon cell are correct?

(1) The ammonium chloride in the cell acts as an electrolyte.

(2) The manganese(IV) oxide in the cell acts as an oxidizing agent.

(3) The zinc case of the cell acts as the positive terminal.

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

CE00_44

Which of the following statements concerning sulphur dioxide are correct?

(1) It can be prepared by heating copper turnings with concentrated sulphuric acid.

(2) It is denser than air.

(3) It can be absorbed by sodium hydroxide solution.

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

CE00_45

1st statement	2nd statement
Concentrated sulphuric acid can turn a piece of filter paper black.	Concentrated sulphuric acid is a strong oxidizing agent.

CE01_07

Which of the following statements concerning water is correct?

A. It reacts with calcium to give a colourless gas.

B. It is a strong electrolyte.

C. It turns anhydrous cobalt(II) chloride from pink to blue.

D. It is immiscible with methanol.

CE01_08

Which of the following statements concerning the formation of chloride ions from chlorine atoms is correct?

A. The number of shells occupied by electrons in a chlorine atom equals that in a chloride ion.
B. The atomic number of chlorine increases by 1.
C. The mass number of chlorine increases by 1.
D. The change is an oxidation.

CE01_11

Which of the following pairs of solutions, when mixed, would produce a precipitate?

A. lead(II) nitrate and sodium hydroxide
B. copper(II) sulphate and sodium nitrate
C. zinc chloride and potassium nitrate
D. iron(II) sulphate and acidified potassium permanganate

CE01_19

Consider the half equations of a redox reaction:

$$8H^+(aq) + MnO_4^-(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$
$$C_2O_4^{2-}(aq) \longrightarrow 2CO_2(g) + 2e^-$$

How many moles of $MnO_4^-(aq)$ ions will react completely with one mole of $C_2O_4^{2-}(aq)$ ions?

A. 0.4 B. 1.0
C. 2.5 D. 5.0

CE01_22

Which of the following equations represents a redox reaction?

A. $NH_4^+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O(l)$
B. $2CrO_4^{2-}(aq) + 2H^+(aq) \longrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$
C. $2FeSO_4(s) \longrightarrow Fe_2O_3(s) + SO_3(g) + SO_2(g)$
D. $2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$

CE01_24

Consider the half equation:

$$IO_3^-(aq) + xH_2O(l) + ye^- \longrightarrow I^-(aq) + zOH^-(aq)$$

Which of the following combinations is correct?

	x	y	z
A.	1	2	2
B.	2	4	4
C.	3	6	6
D.	4	8	8

CE01_29

The oxidation number of lead in $[Pb(OH)_4]^{2-}$ is

A. –2. B. +2.
C. +4. D. +6.

CE01_35

Which of the following statements concerning the reaction of iron(II) carbonate with 1M sulphuric acid is/are correct?

(1) Sulphuric acid acts as an acid.
(2) Sulphuric acid acts as an oxidizing agent.
(3) Sulphuric acid acts as a dehydrating agent.

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

CE01_43

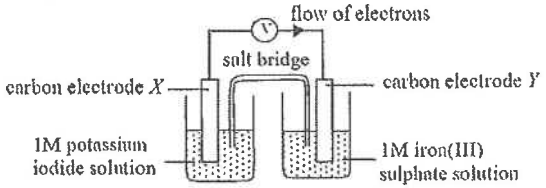
Which of the following are correct descriptions of the uses of sulphuric acid?

(1) treatment of metal surfaces in the electroplating industry
(2) manufacture of paint additives
(3) manufacture of fertilizers

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

CE01_44

Consider the set-up shown below:



Which of the following statements are correct?

(1) The solution around electrode *X* turns brown.
(2) The mass of electrode *X* remains unchanged.
(3) Reduction occurs at electrode *Y*.

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

CE02_06

Compound *X* dissolves in water to give a colourless solution. When chlorine gas is bubbled into the solution, the solution turns brown. *X* is probably

A. ammonium iodide. B. iron(II) sulphate.
C. sodium sulphite. D. potassium hydroxide.

CE02_07

Sodium chromate, Na_2CrO_4, dissolves in water to give a yellow solution. When dilute hydrochloric acid is added to the solution, the following reaction occurs:

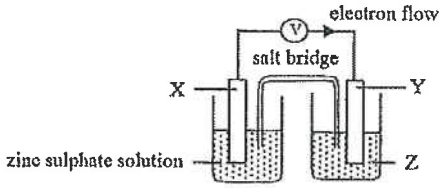
$$2CrO_4^{2-}(aq) + 2H^+(aq) \longrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$$

Which of the following statements concerning this reaction is correct?

A. The colour of the solution changes from yellow to green.
B. Chromate ions act as a reducing agent.
C. The oxidation number of oxygen remains unchanged during the reaction.
D. The reaction is a neutralization.

CE02_10

Consider the set-up below:



Electrons flow from *X* to *Y* in the external circuit. Which of the following combinations is correct?

	X	*Y*	*Z*
A.	carbon	silver	silver nitrate solution
B.	zinc	magnesium	magnesium sulphate solution
C.	carbon	carbon	copper(II) sulphate solution
D.	zinc	carbon	silver nitrate solution

CE02_13

Which of the following equations represents a redox reaction?

A. $Ca(HCO_3)_2 + 2HCl \longrightarrow CaCl_2 + 2CO_2 + 2H_2O$
B. $PCl_3 + Cl_2 \longrightarrow PCl_5$
C. $Fe^{3+} + 3OH^- \longrightarrow Fe(OH)_3$
D. $Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$

CE02_18

The symbol of vanadium is V. What is the oxidation number of vanadium in NH_4VO_3?

A. −1
B. +3
C. +5
D. +6

CE02_19

Which of the following acids, when heated with copper, would produce a gas?

A. dilute nitric acid
B. dilute hydrochloric acid
C. dilute sulphuric acid
D. concentrated ethanoic acid

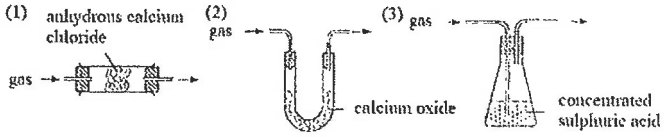
CE02_30

Starch, a natural polymer, is a carbohydrate. When concentrated sulphuric acid is added dropwise to some starch, a black substance is formed. The reaction involved is

A. dehydration.
B. depolymerisation.
C. redox reaction.
D. neutralization.

CE02_38

Which of the following set-ups can be used to dry moist sulphur dioxide gas?



A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE02_39

Which of the following statements concerning Group VII elements and their ions are correct?

(1) Chlorine has the highest oxidizing power among chlorine, bromine and iodine.
(2) Iodide ions have the highest reducing power among chloride, bromide and iodide ions.
(3) Bromine is a volatile liquid at room temperature and pressure.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE02_41

When sulphur dioxide is bubbled into water, a colourless solution is formed. Which of the following statements concerning the solution are correct?

(1) The solution conducts electricity better than water.
(2) The solution can change iron(III) sulphate solution from yellow to green.
(3) The solution can change potassium bromide solution from colourless to brown.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE02_47

1st statement	2nd statement
During electrolysis, oxidation takes place at the cathode.	Cations accept electrons and are discharged at the cathode.

CE03_03

When a small piece of calcium metal is put into a trough of water, a reaction occurs. Which of the following statements concerning this reaction is correct?

A. It is an endothermic reaction.
B. It is a redox reaction.
C. A slight explosion occurs.
D. The calcium metal burns spontaneously in water.

CE03_04

Which of the following statements concerning nitric acid is INCORRECT?

A. It is manufactured from ammonia.
B. It is used to make explosives.
C. It is used to make fertilizers.
D. It is a dehydrating agent.

CE03_07

Which of the following statements concerning halogens is INCORRECT?

A. Compounds of fluorine are added to tap water to help prevent tooth decay.
B. Chlorine is used as a sterilizing agent.
C. Bromine is a volatile liquid.
D. Iodine vapour is brown in colour.

CE03_13

Which of the following substances will NOT react with bromine water?

A. propene
B. sulphur dioxide
C. potassium iodide solution
D. ammonium chloride solution

CE03_15

In the electrolysis of a copper(II) sulphate solution, copper is used as the anode and carbon as the cathode. Which of the following statements concerning this electrolysis is correct?

A. The concentration of $Cu^{2+}(aq)$ ions in the solution remains unchanged.
B. The concentration of $H^{+}(aq)$ ions in the solution increases.
C. $O_2(g)$ is liberated at the anode.
D. $H_2(g)$ is liberated at the cathode.

CE03_16

Which of the following conversions is NOT a reduction?

A. $Fe_2O_3 \longrightarrow Fe$
B. $Cu(OH)_2 \longrightarrow CuO$
C. $CH_3CO_2H \longrightarrow CH_3CH_2OH$
D. $H_2SO_4 \longrightarrow SO_2$

CE03_18

Consider the following **information about three** elements, *X*, *Y* and *Z*.

Element	Atomic number
X	12
Y	16
Z	17

Which of the following statements concerning *X*, *Y* and *Z* is correct?

A. *X* reacts with *Z* to form an ionic compound.
B. *Y* is a stronger oxidizing agent than *Z*.
C. *X* has a simple molecular structure.
D. *Y* can conduct electricity in the molten state.

CE03_23

Consider the following equation:

$$5H_2S + 2KMnO_4(aq) + 3H_2SO_4(aq) \longrightarrow 5S(x) + 8H_2O(y) + 2MnSO_4(z) + K_2SO_4(aq)$$

Which of the following combinations is correct?

	X	Y	Z
A.	s	aq	aq
B.	s	l	aq
C.	aq	aq	s
D.	aq	l	s

CE03_35 [OUT]

Which of the following is/are advantage(s) of using alkaline cells over zinc-carbon cells in cassette players?

(1) Alkaline manganese cells have longer life time.
(2) Alkaline manganese cells are rechargeable.
(3) Alkaline manganese cells give a more steady voltage over discharge.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE05SP_17

Consider the following equation:

$$O_2(g) + 4Fe(OH)_2(x) \longrightarrow 2Fe_2O_3(y) + 4H_2O(z)$$

Which of the following combinations is correct?

	X	Y	Z
A.	s	s	l
B.	s	aq	aq
C.	aq	s	aq
D.	aq	aq	l

CE05SP_31

Caesium (Cs) is a group I element in the Periodic Table and its relative atomic mass is greater than that of potassium. Which of the following statements concerning caesium is INCORRECT?

A. Caesium is a weaker reducing agent than potassium.
B. Caesium reacts violently with water.
C. Caesium is a soft metal.
D. Caesium reacts with oxygen to form an oxide with formula Cs_2O.

CE05SP_40

Which of the following statements concerning nitric acid is/are correct?

(1) Nitric acid is a stronger acid.
(2) Dilute nitric acid reacts with copper to give hydrogen.
(3) Concentrated nitric acid is a dehydrating agent.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE04_05

Which of the following statements concerning nitric acid is correct?

A. Nitric acid can be used as a fertilizer.
B. Nitrogen monoxide is a raw material in the manufacture of nitric acid.
C. In the laboratory, concentrated nitric acid is commonly stored in brown bottles.
D. The following hazard warning label should be displayed on a bottle of concentrated nitric acid.

CE04_07

In which of the following compounds does sulphur exhibit the lowest oxidation number?

A. $Na_2S_2O_3$
B. $MgSO_4$
C. $KHSO_3$
D. $H_2S_2O_7$

CE04_13

Which of the following combinations concerning the uses of metals is correct?

	Metal	Use
A.	cadmium	making rechargeable cells
B.	copper	making fuse in electric plugs
C.	chromium	making duralumin
D.	zinc	making cans for canned food

CE04_14

Chlorine can be prepared from concentrated hydrochloric acid and potassium permanganate according to the following equation:

$$2KMnO_4 + xHCl \longrightarrow 2KCl + 2MnCl_2 + yH_2O + zCl_2$$

What is the value of z?

A. 4
B. 5
C. 8
D. 10

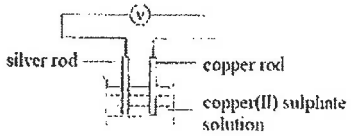
CE04_18

Which of the following reagents can be used to distinguish sodium bromide solution from sodium chloride solution?

A. bromine water
B. chlorine water
C. 1,1,1-trichloroethane
D. potassium fluoride solution

CE04_24

Which of the following combinations concerning the set-up shown below is correct after a current has flowed through the external circuit for some time?



	Mass of anode	Colour intensity of the copper(II) sulphate solution
A.	increases	no change
B.	decreases	no change
C.	increases	decreases
D.	decreases	decreases

CE04_32

Which of the following substances can decolourise acidified potassium permanganate solution?

(1) sodium nitrate solution
(2) sodium sulphite solution
(3) chlorine water

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE04_34

Which of the following substances, when dissolved in water, gives a solution with pH greater than 7?

(1) chlorine
(2) calcium oxide
(3) sulphur dioxide

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE04_38

A counterfeit gold coin is made from an alloy of copper and zinc. Which of the following methods can be used to show that the coin is NOT made of pure gold?

(1) determining its density
(2) treating it with dilute nitric acid
(3) treating it with dilute hydrochloric acid

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE04_39

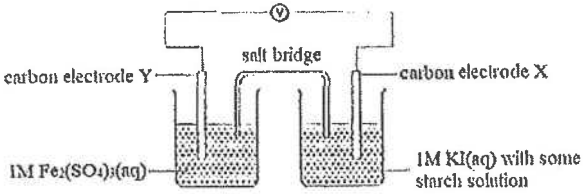
Which of the following gases can act as reducing agents?

(1) ammonia
(2) hydrogen
(3) fluorine

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE04_40

Consider the chemical cell shown below:



Which of the following statements concerning the cell are correct?

(1) Electrons flow from electrode X to electrode Y in the external circuit.
(2) Oxidation occurs at electrode Y.
(3) A blue colour appears in the KI(aq) after the cell has operated for some time.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE04_43

In which if the following processes would hydrogen be produced?

(1) electrolysis of an aqueous solution of potassium bromide
(2) passing steam over heated iron powder
(3) adding zinc granules to dilute ethanoic acid.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE05_08

Which of the following is NOT a redox reaction?

A. $NH_4NO_3 \longrightarrow N_2O + 2H_2O$
B. $NH_3 + HNO_3 \longrightarrow NH_4NO_3$
C. $N_2O_4 + H_2O \longrightarrow HNO_2 + HNO_3$
D. $4HNO_3 \longrightarrow 2H_2O + 4NO_2 + O_2$

CE05_15

$$ZnS \xrightarrow{\text{Stage 1}} SO_2 \xrightarrow{\text{Stage 2}} SO_3 \xrightarrow{\text{Stage 3}} H_2S_2O_7 \xrightarrow{\text{Stage 4}} H_2SO_4$$

Which of the following stages involves the largest change in oxidation number of sulphur?

A. Stage 1
B. Stage 2
C. Stage 3
D. Stage 4

CE05_25

Which of the following processes involve chemical changes?

(1) mixing sea water with silver nitrate solution
(2) evaporation of sea water
(3) electrolysis of sea water

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE05_26

An aqueous solution of a compound reacts with dilute hydrochloric acid to give a gas. This aqueous solution does not give a precipitate with sodium hydroxide solution. What could the compound be?

(1) potassium sulphite
(2) iron(II) sulphate
(3) ammonium carbonate

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE05_30

1st statement	2nd statement
Iodine can displace chlorine from potassium chloride solution.	Iodine is a stronger oxidizing agent than chlorine.

CE05_31

In which of the following combinations will oxygen be produced as the major product at the anode during electrolysis?

	electrolyte	cathode	anode
A.	0.1 M $CuCl_2$	platinum	platinum
B.	0.1 M $CuCl_2$	copper	copper
C.	5 M HCl	platinum	platinum
D.	5 M HCl	copper	copper

CE05_33

When a metal X is warmed with an acid Y, they react to form a colourless solution and a brown gas. Which of the following combinations is correct?

	X	Y
A.	zinc	concentrated nitric acid
B.	copper	concentrated sulphuric acid
C.	zinc	concentrated sulphuric acid
D.	copper	concentrated nitric acid

CE05_36

Which of the following properties of Group I elements decreases down the group?

A. melting point
B. reducing power
C. reactivity with water
D. tendency to form cations

CE05_48

1st statement	2nd statement
Anodization is a method used to enhance the corrosion resistance of aluminium.	By anodization, an oxide layer is formed to protect the aluminium.

CE06_03

What is the oxidation number of cobalt in $Co(NH_3)_4Cl_2$?

A. –2
B. 0
C. +2
D. +6

CE06_21

When substance X is treated with an aqueous solution of iron(II) sulphate, the iron(II) ions act as oxidizing agent. X may be

A. concentrated hydrochloric acid.
B. aqueous ammonia.
C. acidified potassium permanganate solution.
D. zinc granules.

CE06_27

Which of the following reactions involve oxidation and reduction?

(1) $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$
(2) $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \longrightarrow 2PbSO_4(s) + 2H_2O(l)$
(3) $H_2O_2(aq) + H_2SO_4(aq) + 2KI(aq) \longrightarrow K_2SO_4(aq) + I_2(aq) + 2H_2O(l)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE06_29

1st statement	2nd statement
Potassium is a stronger reducing agent than sodium.	Potassium atoms lose electrons more readily than sodium atoms.

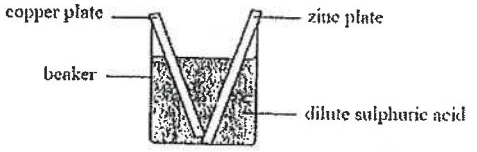
CE06_32

Which of the following combinations is correct for a zinc-carbon cell? [OUT]

	Anode	Cathode	Electrolyte
A.	zinc	graphite	manganese(IV) oxide
B.	zinc	graphite	ammonium chloride
C.	graphite	zinc	manganese(IV) oxide
D.	graphite	zinc	ammonium chloride

CE06_33

In an experiment, a copper plate and a zinc plate are placed in a beaker containing dilute sulphuric acid. The two metal plate are touching each other as shown in the diagram below:

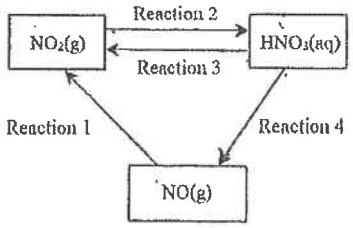


Which of the following statements correctly describes the observation in the experiment?

A. The solution in the beaker turns blue.
B. The mass of the zinc plate remains unchanged.
C. A white precipitate is formed in the beaker.
D. Gas bubbles are formed on the surface of the copper plate.

CE06_38

Consider the conversions between three nitrogen compounds shown in the flow diagram below:

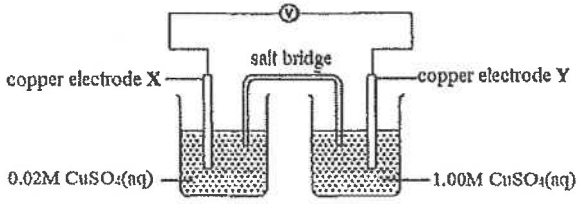


Which of the following statements is correct?

A. *Reaction 1* occurs spontaneously when nitrogen monoxide is exposed to air.
B. The oxidation number of nitrogen remains unchanged in *Reaction 2*.
C. *Reaction 3* can be brought about by adding very dilute nitric acid to magnesium.
D. *Reaction 4* can be brought about by adding concentrated nitric acid to copper.

CE06_40

The set-up below shows a chemical cell connected to a voltmeter:



In the set-up, electrons flow in such a direction that the concentration of $Cu^{2+}(aq)$ ions in each half cell becomes the same eventually.

Which of the following statements concerning the set-up is correct?

A. The salt bridge allows electrons to flow from one half cell to the other.
B. Oxidation occurs at Y.
C. Electrons flow from Y to X in the external circuit.
D. The mass of X will decrease but the mass of Y will increase.

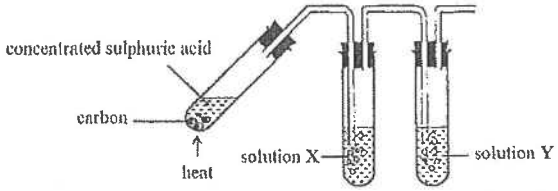
CE07_19

Chlorine is bubbled into an aqueous solution P for some time. The colour of P gradually changes to brown. P is NOT likely to be

A. calcium hydroxide solution.
B. potassium iodide solution.
C. iron(II) chloride solution.
D. zinc bromide solution.

CE07_20

Directions: Questions 20 and 21 refer to the following experiment.



Which of the following combinations of solution X and solution Y can be used to show that sulphur dioxide and carbon dioxide are produced?

	Solution X	Solution Y
A.	bromine water	calcium hydroxide solution
B.	iron(II) sulphate solution	calcium hydroxide solution
C.	acidified potassium dichromate solution	sodium hydroxide solution
D.	acidified potassium permanganate solution	sodium hydroxide solution

CE07_21

Which of the following statements concerning the reaction between carbon and concentrated sulphuric acid are correct?

(1) The oxidation number of carbon changes from 0 to +4.
(2) The oxidation number of hydrogen in sulphuric acid remains unchanged.
(3) Concentrated sulphuric acid acts both as a dehydrating agent and an oxidizing agent.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE07_22

Which of the following statements concerning chlorine, bromine and iodine is/are correct?

(1) They are all coloured substances.
(2) Their reactivity increases with relative atomic mass.
(3) They all react with sodium sulphite solution.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE07_24

Consider the redox reaction represented by the equation below:

$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

Which of the following statements is/are correct?

(1) The oxidation number of sulphur in $S_2O_3^{2-}(aq)$ is +3.
(2) One of the half equations of this reaction is $2S_2O_3^{2-}(aq) \longrightarrow S_4O_6^{2-}(aq) + 2e^-$
(3) $I_2(aq)$ is oxidized by $S_2O_3^{2-}(aq)$ in the reaction.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE07_25

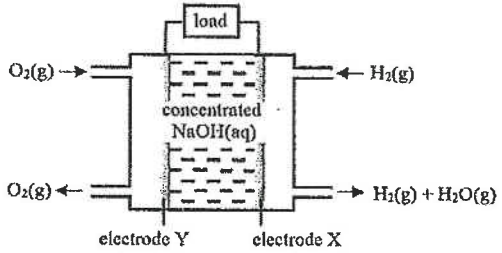
Which of the following processes would produce sulphur dioxide?

(1) roasting iron pyrite in air.
(2) heating zinc with concentrated sulphuric acid
(3) mixing dilute hydrochloric acid with sodium sulphite

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE07_36

The following diagram represents a chemical cell called fuel cell.



Hydrogen and oxygen are passed into the fuel cell. The half equations for the chemical changes occurring at electrode X and electrode Y are listed below:

at X: $H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-$

at Y: $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

Which of the following statements concerning the fuel cell is correct?

A. Reduction occurs at X.
B. A current flows from X to Y through the external circuit.
C. Both $H_2(g)$ and $O_2(g)$ function as fuels in the cell.
D. The fuel cell is an environmentally-friendly chemical cell.

CE07_37

Which of the following mixtures can produce chlorine?

A. chlorine bleach and lemon juice
B. sodium chloride and vinegar
C. polyvinyl chloride and caustic soda
D. hydrochloric acid and limestone

CE07_41

Which of the following items does NOT require the use of the products obtained from electrolysis of brine?

A. manufacture of soaps
B. manufacture of polyethene
C. manufacture of bleaches
D. manufacture of hydrochloric acid

CE07_43

Which of the following bonds or attractive forces exist in ammonium nitrate?

(1) ionic bond
(2) covalent bond
(3) van der Waals' forces

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE07_44 [OUT]

Which of the following statements concerning a zinc-carbon cell are correct?

(1) Manganese(IV) oxide acts as the anode.
(2) Ammonium chloride acts as an electrolyte.
(3) Zinc acts as the negative electrode.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE07_45

Using carbon as electrodes, which of the following solutions would give hydrogen upon electrolysis?

(1) 1 M silver nitrate solution
(2) 2 M sodium hydroxide solution
(3) 3 M calcium chloride solution

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE07_46

Which of the following statements concerning the reaction of concentrated nitric acid with copper is/are correct?

(1) A colourless gas is evolved.
(2) One mole of $NO_3^-(aq)$ ions requires one mole of electrons for reduction.
(3) It involves a displacement reaction.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE08_04

Consider the ionic equation below:

$$2MnO_4^- + x\ Sn^{2+} + y\ H^+ \longrightarrow 2Mn^{2+} + x\ Sn^{4+} + 8H_2O$$

What is the value of x?

A. 2
B. 4
C. 5
D. 7

CE08_05

In which of the following compounds is the oxidation number of nitrogen lowest?

A. NH_4Cl
B. $NaNO_2$
C. NH_2OH
D. $Pb(NO_3)_2$

CE08_11

In which of the following processes does sulphur dioxide act as a reducing agent?

A. passing sulphur dioxide into water
B. passing sulphur dioxide into iodine solution
C. passing sulphur dioxide into iron(II) sulphate solution
D. passing sulphur dioxide into sodium hydroxide solution

CE08_13

Which of the following statements concerning the reaction between acidified potassium permanganate solution and excess propene is INCORRECT?

A. The oxidation number of manganese changes from +7 to +2.
B. The reaction occurred is an addition reaction.
C. The acidified potassium permanganate solution decolourised.
D. The structure of the organic product is $CH_2(OH)CH_2CH_2OH$.

CE08_21

Which of the following substances, when mixed with bromine water, would form a colourless solution?

(1) sodium sulphite
(2) sodium chloride
(3) sodium iodide

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE08_23

Which of the following is/are related to the use of silver oxide cells in watches?

(1) Silver oxide cells are rechargeable.
(2) Silver oxide cells are small in size.
(3) Silver is an expensive metal.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE08_24

When chlorine reacts with methane under sunlight, which of the following compounds can be formed?

(1) chloromethane
(2) dichloromethane
(3) hydrogen chloride

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE08_28

1st statement	2nd statement
The bleaching action of sodium sulphite lasts longer than that of sodium hypochlorite.	Sodium sulphite bleaches by oxidation while sodium hypochlorite bleaches by reduction.

CE08_34

From which of the following processes can lead be obtained in a school laboratory?

A. Lead(II) oxide is heated strongly.
B. Lead(II) oxide is mixed with carbon.
C. Dilute lead(II) nitrate solution is electrolyzed.
D. Zinc is added to dilute lead(II) nitrate solution.

CE08_36

Which of the following processes does NOT involve redox reaction(s)?

A. bromination of methane
B. electrolysis of sea water
C. thermal decomposition of limestone
D. removal of air pollutants in car exhaust by catalytic convertor

CE08_38

Which of the following statements concerning concentrated sulphuric acid is INCORRECT?

A. Concentrated sulphuric acid can be used as a drying agent for ammonia.
B. Adding concentrated sulphuric acid to sugar will give a steamy fume.
C. Blue litmus paper will finally turn black when dropper into concentrated sulphuric acid.
D. When a beaker of concentrated sulphuric acid is left in air, the volume of liquid inside the beaker increases gradually.

CE08_40

A compound is composed of element Z and hydrogen. Electrolysis of this compound under molten state produces the same number of Z atoms at the cathode as hydrogen molecules at the anode. The following half equation shows the change occurring at the anode:

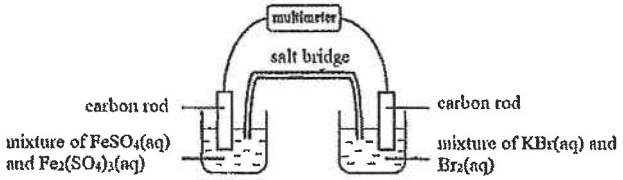
$2H^- \longrightarrow H_2 + 2e^-$

What is the oxidation number of Z in the compound?

A. −2
B. −1
C. +1
D. +2

CE08_44

The following diagram shows the set-up of a chemical cell.



Given that $Br_2(aq)$ is a stronger oxidizing agent than $Fe^{3+}(aq)$, which of the changes represented by the following half equations would occur if the cell is producing a current?

(1) $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
(2) $Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$
(3) $2Br^-(aq) \longrightarrow Br_2(aq) + 2e^-$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE08_48

Upon electrolysis, which of the following solutions would give hydrogen at carbon cathode and oxygen at platinum anode?

(1) very dilute sodium chloride solution
(2) dilute copper(II) sulphate solution
(3) concentrated potassium sulphate solution

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE09_02

In which of the following reactions does nitrogen exhibit three different oxidation numbers in the species involved?

A. $NH_4NO_3 \longrightarrow N_2O + 2H_2O$
B. $8NH_3 + 3Cl_2 \longrightarrow 6NH_4Cl + N_2$
C. $Mg + 4HNO_3 \longrightarrow Mg(NO_3)_2 + 2NO_2 + 2H_2O$
D. $3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

CE09_04

The table below shows whether displacement reaction occurs between metals W, X, Y and Z with their ions. '✓' represents that displacement reaction occurs, while 'X' represents that displacement reaction does not occur.

	W	X	Y	Z
$W^{2+}(aq)$		X	✓	✓
$X^+(aq)$	✓		✓	✓
$Y^{2+}(aq)$	X	X		✓
$Z^+(aq)$	X	X	X	

Which of the following is the strongest reducing agent?

A. X
B. X^+
C. Z
D. Z^+

CE09_13

A drunken driver breathes into a device containing dichromate ions. The oxidation number of chromium would change from

A. +6 to +3.
B. +3 to +6.
C. +3 to +2.
D. +2 to +3.

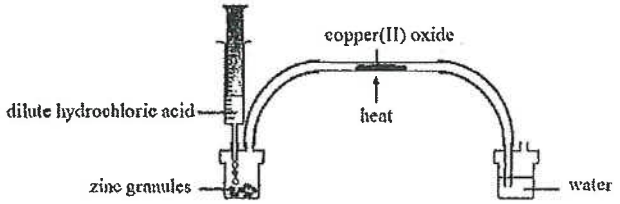
CE09_14

Which of the following is NOT an industrial product made from sulphuric acid?

A. fertilizer
B. paint additive
C. soapless detergent
D. sulphur dioxide preservative

CE09_17

This question refers to the following micro-scale experiment.



Which of the following types of reaction is/are involved in the experiment?

(1) redox reaction
(2) neutralization
(3) thermal decomposition

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE09_24

Which of the following substances can react with acidified potassium permanganate solution?

(1) propene
(2) potassium iodide solution
(3) sodium sulphite solution

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE09_30

1st statement	2nd statement
When sulphur dioxide is added to sodium bromide solution, the mixture obtained is colourless.	Sulphur dioxide can act as a bleaching agent.

CE09_31

Which of the following statements concerning ammonium iodide is correct?

A. Ammonium iodide solution is a weak alkali.
B. Ammonium iodide solution is brown in colour.
C. Reaction will occur when ammonium iodide is mixed with chlorine water.
D. No reaction will occur when ammonium iodide is heated with sodium hydroxide.

CE09_34 [OUT]

Which of the following would NOT occur when a zinc-carbon cell is supplying electricity?

A. Water is produced.
B. Zinc case becomes thinner.
C. Ammonium ions are consumed.
D. Manganese compound is oxidized.

CE09_38

In an experiment of electroplating nickel on a copper object, which of the following combinations is correct?

	Anode	Cathode	Electrolyte
A.	copper object	nickel	$CuSO_4(aq)$
B.	copper object	nickel	$NiSO_4(aq)$
C.	nickel	copper object	$CuSO_4(aq)$
D.	nickel	copper object	$NiSO_4(aq)$

CE09_39

Which of the following processes would NOT give an obvious colour change?

A. Bubble ethene into bromine water.
B. Add potassium chloride solution to bromine water.
C. Add concentrated nitric acid to iron(II) sulphate solution.
D. Electrolyze concentrated potassium iodide solution using platinum electrodes.

CE09_42

Which of the following acids can react with silver?

(1) dilute sulphuric acid
(2) concentrated nitric acid
(3) concentrated hydrochloric acid

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE09_44

In the electrolysis of a copper(II) sulphate solution using copper cathode and graphite anode, which of the following would change?

(1) pH of the solution
(2) colour of the solution
(3) mass of the graphite anode

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

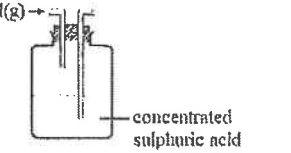
CE09_49

1st statement	2nd statement
Sulphates can be oxidized to sulphites.	Oxidation number of sulphur in sulphates is higher than the oxidation number of sulphur in sulphites.

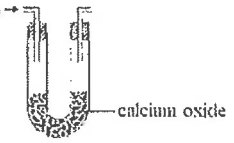
CE10_05

Which of the following set-ups can be used to dry hydrogen chloride gas?

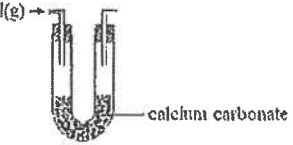
A. $HCl(g)$ → concentrated sulphuric acid



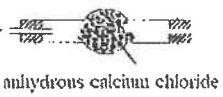
B. $HCl(g)$ → calcium oxide



C. $HCl(g)$ → calcium carbonate



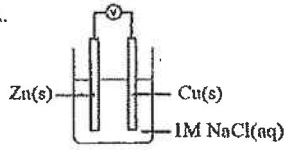
D. $HCl(g)$ → anhydrous calcium chloride



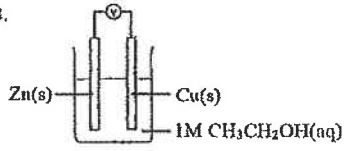
CE10_09

In which of the following set-ups would the voltmeter display the greatest magnitude of voltage reading?

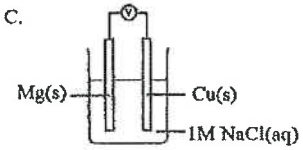
A.



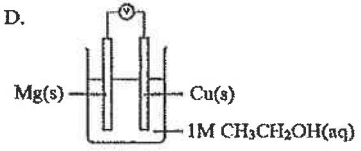
B.



C.



D.



CE10_11

In which of the following species does the underlined element have an oxidation number of +3?

A. $\underline{O}_3$
B. $H_3\underline{P}O_4$
C. $\underline{N}H_4^+$
D. $\underline{N}O_2^-$

CE10_24

Which of the following is/are redox reaction(s)?

(1) $CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$
(2) $2CrO_4^{2-} + 2H^+ \longrightarrow Cr_2O_7^{2-} + H_2O$
(3) $2KNO_3 \longrightarrow 2KNO_2 + O_2$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE10_30

1st statement	2nd statement
Bromine water can react with NaI(aq).	The reducing power of I^-(aq) ion is stronger than that of Br^-(aq) ion.

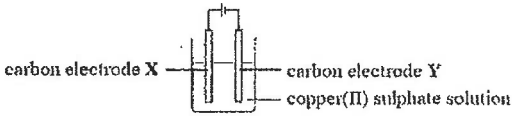
CE10_32

Which of the following processes gives hydrogen gas as the major product?

A. adding iron to dilute nitric acid.
B. adding copper to dilute sulphuric acid.
C. passing stem over heated zinc granules.
D. electrolysis of brine using mercury as the cathode.

CE10_34

In an experiment to study the electrolysis of copper(II) sulphate solution, the set-up used is shown below:



Which of the following statements concerning the above experiment is correct?

A. Reduction occurs at X.
B. Hydrogen gas is evolved at Y.
C. The pH of the solution increases gradually.
D. The colour of the solution remains unchanged.

CE10_36

Consider the experimental set-ups shown in the figures below:

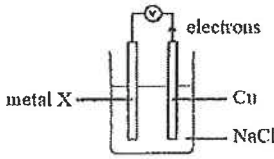


Figure 1

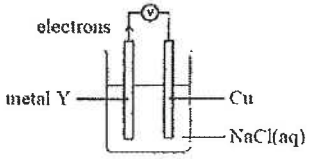


Figure 2

In Figure 1, if Cu is replaced by Y, which of the following statements is correct?

A. Chlorine gas will be evolved at Y.
B. A solid will be deposited on the surface of Y.
C. A greater magnitude of voltage will be recorded.
D. Electrons will flow from X to Y through the external circuit.

CE10_43

Solution Y is added dropwise to a solution of NaOH containing several drops of phenolphthalein. The mixture suddenly changes from pink to colourless. Which of the following substances may Y be?

(1) HCl(aq)
(2) KCl(aq)
(3) Cl_2(aq)

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE10_47

Which of the following reagents can convert iron(II) ions to iron(III) ions?

(1) chlorine water
(2) dilute nitric acid
(3) potassium bromide solution

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE10_48

Which of the following experiments would give a colour change?

(1) Sulphur dioxide is passed into a test tube containing bromine water.
(2) Sulphur dioxide is passed into a gas jar containing moist red flower petals.
(3) Sulphur dioxide is passed into a conical flask containing potassium iodide solution.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE10_49 [OUT]

	1st statement	2nd statement
	When using a zinc-carbon cell in electrolysis, the carbon electrode of the cell is connected to the cathode of the electrolytic cell.	In a circuit using zinc carbon cell to supply electricity, electrons in the external circuit flow to the carbon electrode of the zinc-carbon cell.

CE11_06

Which of the following processes does NOT involve redox reaction?

A. rusting of iron nails
B. thermal decomposition of calcium carbonate
C. adding zinc granules to concentrated hydrochloric acid
D. adding magnesium ribbons to copper(II) sulphate solution

CE11_07

Both D and E are metals. D reacts with ESO_4 solution according to the following equation:

$$D(s) + ESO_4(aq) \longrightarrow DSO_4(aq) + E(s)$$

If D and E are used as the electrodes in a lemon cell, which of the following statements concerning the lemon cell during discharge is correct?

A. Electrons flow from E to D in the external circuit.
B. $D^{2+}(aq)$ ions are found in the lemon juice.
C. E acts as the negative electrode.
D. D acts as the cathode.

CE11_09

Which of the following statements concerning the conversion of an iodine atom to an iodide ion is correct?

A. The conversion is a reduction.
B. The atomic number of iodine increases by 1.
C. The number of occupied electron shells in an iodine atom is less than that in an iodide ion.
D. The number of occupied electron shells in an iodine atom is greater than that in an iodide ion.

CE11_11

The following three chlorine-containing species are arranged according to the increasing order of oxidation number of chlorine:

HCl, J, $HClO_3$

Which of the following species may NOT be J?

A. Cl_2
B. ClO_2^-
C. Cl_2O_7
D. HOCl

CE11_14

Consider the following equation:

$$p\,ClO_3^- + q\,SO_2 + r\,H_2O \longrightarrow p\,Cl^- + q\,SO_4^{2-} + 2r\,H^+$$

Which of the following combinations is correct?

	p	q	r
A.	1	2	2
B.	1	3	3
C.	2	3	2
D.	1	2	3

CE11_20

Which of the following gases can be dried by using concentrated sulphuric acid?

(1) ammonia
(2) sulphur dioxide
(3) hydrogen chloride

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE11_21

Consider the redox reaction represented by the equation below:

$$PbO_2 + NO_2^- + 2H^+ \longrightarrow Pb^{2+} + NO_3^- + H_2O$$

Which of the following statements is/are correct?

(1) NO_2^- is reduced.
(2) PbO_2 is reduced.
(3) H^+ is neither oxidized nor reduced.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE11_26

$SO_2(g)$ is passed into each of the following solutions. In which of the solutions will a colour change be observed?

(1) $Br_2(aq)$
(2) $FeSO_4(aq)$
(3) acidified $KMnO_4(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE11_32 [OUT]

Which of the following statements concerning zinc-carbon cell is correct?

A. Zinc-carbon cell is rechargeable.
B. The positive electrode of zinc-carbon cell is carbon rod.
C. Zinc-carbon cell is a dry cell which does not contain water.
D. A zinc-carbon cell of larger size produces a higher voltage than a smaller one.

CE11_35

Which of the following statements concerning a working electrolytic cell is correct?

A. Water must be present in the electrolytic cell.
B. The electrolytic cell liberates electrical energy.
C. The electrodes in the electrolytic cell must be metal.
D. Redox reaction must be involved in the electrolytic cell.

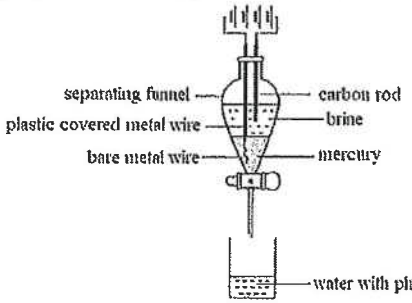
CE11_37

In the electrolysis of concentrated potassium chloride solution using carbon electrodes, gaseous products are liberated at both electrodes. After a short period of time, what is the theoretical volume ratio of *the gas collected at the cathode* to *the gas collected at the anode*?

A. 1 : 1
B. 1 : 2
C. 1 : 4
D. 2 : 1

CE11_44

The following diagram shows the set-up of an experiment.



After some time, the tap of the separating funnel is opened to run some mercury from the separating funnel into a beaker containing water with phenolphthalein. Which of the following statements concerning the experiment is/are correct?

(1) Mercury in the separating funnel can increase the electrical conductivity of the brine.
(2) The water with phenolphthalein turns red.
(3) The carbon rod acts as the cathode.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE11_49

1st statement	2nd statement
2M nitric acid can react with copper but 2M ethanoic acid cannot.	2M nitric acid is a stronger acid than 2M ethanoic acid.

AL07(I)_03

The reaction shown below takes place in liquid ammonia:

$$NH_4Br + KNH_2 \longrightarrow KBr + 2NH_3$$

Which one of the following best describes the reaction?

A. Displacement
B. Neutralization
C. Redox
D. Substitution

ASL09(I)_03

Which one of the products listed below is NOT obtained industrially from the electrolysis of brine?

A. Hydrogen
B. Oxygen
C. Sodium chlorate(I)
D. Sodium hydroxide

ASL12(I)_03

In which of the following species does hydrogen have an oxidation of −1?

A. CaH_2
B. CH_4
C. H_2O
D. NH_3

ASL13(I)_03

Which of the following product(s) is/are obtained when chlorine gas is bubbled into a hot concentrated solution of sodium hydroxide?

A. NaClO only
B. NaCl and NaClO
C. $NaClO_3$ only
D. NaCl and $NaClO_3$

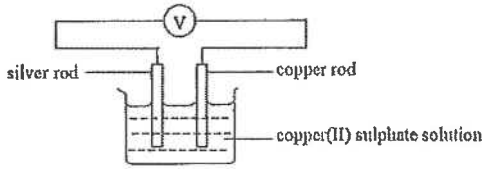
DSE11SP_02

In which of the following compounds does sulphur exhibit the lowest oxidation number?

A. $Na_2S_2O_3$
B. $MgSO_4$
C. $KHSO_3$
D. $H_2S_2O_7$

DSE11SP_12

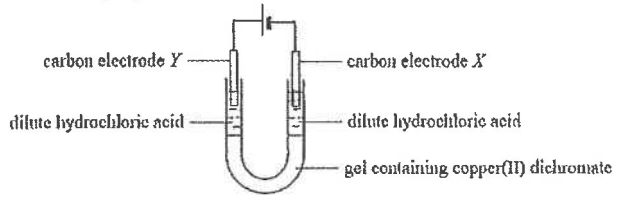
Which of the following combinations concerning the set-up shown below is correct after a current has flowed through the external circuit for some time?



	Mass of anode	Color of copper(II) sulphate solution
A.	Increases	No change
B.	Decreases	No change
C.	Increases	Becomes lighter
D.	Decreases	Becomes lighter

DSE11SP_21

Consider the following experiment:



Which of the following statements concerning the experiment are correct?

(1) Gas bubbles are evolved at electrode *X*.
(2) An orange color gradually appears in the solution around electrode *Y*.
(3) The experiment can be used to show that ions migrate towards oppositely charged electrodes.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE11SP_23

1st statement	2nd statement
Bromine water can be used to distinguish between sodium sulphate and sodium sulphite solution.	Bromine can be reduced by sodium sulphite to colorless bromide, but not by sodium sulphate.

DSE12PP_14

Consider the following chemical equation:

$$p SO_2(aq) + q Ce^{4+}(aq) + r H_2O(l) \longrightarrow p SO_4^{2-}(aq) + q Ce^{3+}(aq) + 2r H^+(aq)$$

(Ce is the chemical symbol for cerium.)

Which of the following combinations is correct?

	p	*q*	*r*
A.	1	1	1
B.	1	1	2
C.	1	2	2
D.	2	1	2

DSE12PP_22

Consider the electrolysis experiments using the following combinations of electrolyte solution

	Electrolyte solution	Anode	Cathode
(1)	Copper(II) sulphate solution	Copper	Copper
(2)	Copper(II) chloride solution	Graphite	Graphite
(3)	Potassium sulphate solution	Platinum	platinum

In which of these experiments will the concentration of the electrolyte solution remain UNCHANGED?

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12PP_23

Which of the following statements about lithium-ion batteries is/are correct?

(1) In lithium-ion batteries, the electrolyte is a lithium salt in water.
(2) Lithium-ion batteries are rechargeable.
(3) The disposal of lithium-ion batteries causes less harm to the environment than that of nickel-cadmium batteries.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12_06

What is the oxidation number of Cu in $Cu(NH_3)_4Cl_2$?

A. 0
B. +2

C. +4 D. +6

DSE12_13

The tendency of being reduced of six ionic species increase in the order as shown below:

$$Ba^{2+}(aq) < Na^{+}(aq) < Mg^{2+}(aq) < H^{+}(aq) < Cu^{2+}(aq) < Hg^{2+}(aq)$$

Which of the following statements is correct?

A. Ba(s) does NOT react with $H^{+}(aq)$
B. Na(s) has a stronger reducing power than Hg(l)
C. $Hg^{2+}(aq)$ is the weakest oxidizing agent among the six species.
D. Displacement reaction occurs when Cu(s) is immersed in $MgSO_4(aq)$

DSE12_18

Which of the following statements concerning a hydrogen-oxygen fuel cell is/are correct?

(1) It produces non-polluting product.
(2) The membrane in it selectively allows hydroxide ions to pass through.
(3) It can continuously produce electricity as long as hydrogen and oxygen are supplied under operating conditions.

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE12_30

Which of the following ions can act as both an oxidizing agent and a reducing agent?

A. $Fe^{2+}(aq)$ B. $Cu^{2+}(aq)$
C. $Cr_2O_7^{2-}(aq)$ D. $MnO_4^{-}(aq)$

DSE13_16

$$2IO_3^{-}(aq) + wH_2O_2(aq) + xH^{+}(aq) \longrightarrow I_2(aq) + yO_2(g) + zH_2O(l)$$

Which of the following is the correct combination of the reaction coefficients y and z?

	y	z
A.	4	5
B.	5	4
C.	5	6
D.	6	5

DSE13_17

Potassium peroxodisulphate ($K_2S_2O_8$) can be obtained from the electrolysis of a saturated solution of potassium hydrogensulphate ($KHSO_4$).

Which of the following correctly describes the oxidation number of sulphur in $KHSO_4$, and the electrode at which $K_2S_2O_8$ is produced during the electrolysis?

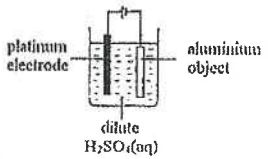
	Oxidation number of S	Electrode at which $K_2S_2O_8$ is produced
A.	+6	Anode
B.	+6	Cathode
C.	+4	Anode

D. +4 Cathode

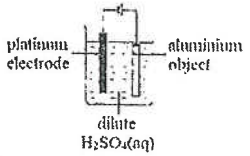
DSE13_06

Which of the set-ups shown below can best be used to anodize an aluminum object?

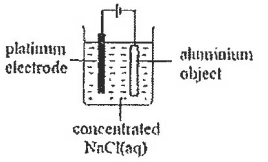
A.



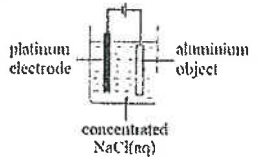
B.



C.



D.



DSE13_21

Which of the following is/are secondary cell(s)?

(1) Alkaline manganese cell
(2) Lithium ion cell
(3) Nickel metal hydride cell

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE13_22

Which of the following reagents can be used to distinguish between sodium sulphite and sodium sulphate?

(1) Iron(II) chloride solution
(2) Acidified potassium permanganate solution
(3) Concentrated nitric acid

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE14_15

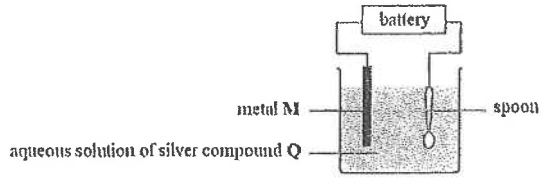
Which of the following hazard warning labels should be displayed on both the reagent bottle storing concentrated sulphuric acid and the reagent bottle storing concentrated hydrochloric acid?

(1) (2) (3)

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE14_11

The diagram below shows a set-up in which silver is being plated on a spoon:



Which of the following statements concerning the above set-up is correct?

A. M must be silver.
B. Q can be silver chloride.
C. The spoon is connected to the negative pole of the battery.
D. Electrons flow from metal M to the spoon through the solution.

DSE14_16 [OUT]

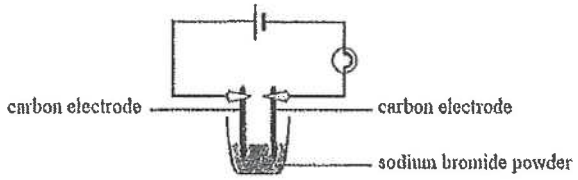
Which of the following statements concerning a zinc-carbon cell is / are correct?

(1) The zinc case would become thinner when being used.
(2) Its voltage remains unchanged when being used.
(3) It can be recharged after use

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE14_20

The diagram below shows the set-up of an experiment:



Which of the following methods may light up the light bulb?

(1) heating the sodium bromide powder until molten
(2) adding deionized water to the sodium bromide powder
(3) replacing the sodium bromide powder with bromine liquid

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE15_02

Which of the following processes would NOT give oxygen?

A. Heating mercury(II) oxide strongly
B. Electrolysis of dilute sulphuric acid
C. Fractional distillation of liquefied air
D. Passing steam over heated magnesium

DSE15_06

The conversion of nitrogen gas to nitric acid involves the following steps:

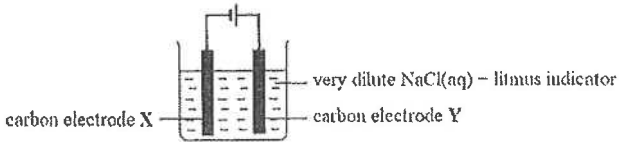
$$N_2 \xrightarrow{\text{Step 1}} NH_3 \xrightarrow{\text{Step 2}} NO \xrightarrow{\text{Step 3}} NO_2 \xrightarrow{\text{Step 4}} HNO_3$$

In which step is nitrogen reduced?

A. Step 1
B. Step 2
C. Step 3
D. Step 4

DSE15_13

An electrolysis experiment is conducted using the set-up shown below:

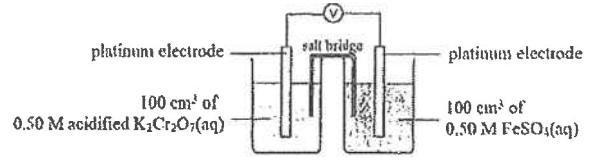


What are the expected colors around X and Y after the experiment has been conducted for some time?

	X	Y
A.	Yellow	Red
B.	Red	Blue
C.	Blue	Red
D.	Red	Yellow

DSE15_16

Consider the following set-up at the start of an experiment:



After a period of time, the concentration of $K_2Cr_2O_7(aq)$ drops to 0.47 M. What is the concentration of $FeSO_4(aq)$ at that time?

A. 0.53 M
B. 0.47 M

C. 0.41 M D. 0.32 M

DSE15_17

$$4KI(aq) + 2CO_2(g) + O_2(g) \longrightarrow 2K_2CO_3(aq) + 2I_2(aq)$$

Which of the following statements concerning the above reaction is / are correct?

(1) KI(aq) is oxidized by $O_2(g)$.
(2) KI(aq) is oxidized by $CO_2(g)$.
(3) The yellow color is due to the $K_2CO_3(aq)$ formed.

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

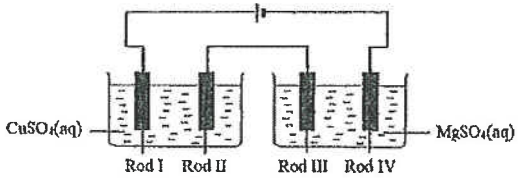
DSE16_11

In which of the following substances does nitrogen have the highest oxidation number?

A. NF_3 B. N_2H_4
C. $NaNH_2$ D. $HONH_2$

DSE16_12

The diagram below shows the set-up used in an electroplating experiment involving four iron rods:

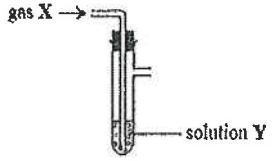


On which of the following iron rods would a metal be plated?

A. Rod I B. Rod II
C. Rod III D. Rod IV

DSE16_13

Gas X is bubbled steadily into solution Y as shown in the diagram below:



In which of the following combinations would NOT have a visible change in solution Y?

	Gas X	Solution Y
A.	$Cl_2(g)$	KI(aq)
B.	$O_2(g)$	$FeSO_4(aq)$
C.	$CO_2(g)$	acidified $KMnO_4(aq)$
D.	$SO_2(g)$	acidified $Na_2Cr_2O_7(aq)$

DSE16_14

Which of the following is NOT a redox reaction?

A. $2AgBr(s) \longrightarrow 2Ag(s) + Br_2(g)$
B. $SO_2(g) + 2H_2S(g) \longrightarrow 3S(s) + 2H_2O(l)$
C. $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$
D. $Ca(HCO_3)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$

DSE16_15

The following equations shows the reaction when a secondary cell is discharging:

$$2NiO(OH)(s) + Cd(s) + 2H_2O(l) \longrightarrow 2Ni(OH)_2(s) + Cd(OH)_2(s)$$

Which of the following half equations shows the change at the negative electrode when the cell is being recharged?

A. $Cd(s) + 2OH^-(aq) \longrightarrow Cd(OH)_2(s) + 2e^-$
B. $Cd(OH)_2(s) + 2e^- \longrightarrow Cd(s) + 2OH^-(aq)$
C. $Ni(OH)_2(s) + OH^-(aq) \longrightarrow NiO(OH)(s) + H_2O(l) + e^-$
D. $NiO(OH)(s) + H_2O(l) + e^- \longrightarrow Ni(OH)_2(s) + OH^-(aq)$

DSE16_20

Pb is an element in Group IV of the Periodic Table and can form Pb^{2+} ion. Which of the following statements are correct?

(1) The change from Pb^{2+} ion to Pb atom is a reduction.
(2) Both Pb atom and Pb^{2+} ion have the same number of protons.
(3) Both Pb atom and Pb^{2+} ion have the same number of occupied electron shells.

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE16_23

1st statement	2nd statement
During anodization, the aluminium oxide on the surface of aluminium is reduced to metal.	The corrosion resistance of aluminium can be enhanced by anodization.

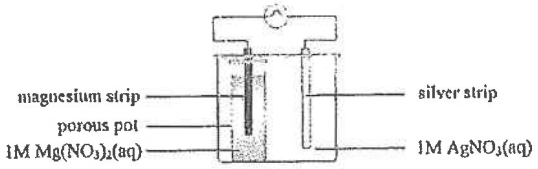
DSE17_08

Which of the following statements concerning hydrogen-oxygen fuel cell is INCORRECT?

A. It contains a catalyst.
B. Water is formed during discharge.
C. Oxygen gas is passed to the anode.
D. Hydrogen gas acts as the reducing agent.

DSE17_04

The diagram below shows a set-up with the bulb lights up:



Which of the following statements concerning the set-up is correct?

A. Silver ions migrate towards the porous pot.
B. The mass of he magnesium strip decreases.
C. Heat energy is converted into electrical energy.
D. Hydrogen ions are discharged on the silver strip.

DSE17_11

Which of the following statements concerning zinc is correct?

A. It forms a soluble oxide when placed in NH_3(aq).
B. It acts as a reducing agent when placed in HCl(aq).
C. It undergoes oxidation when placed in $MgCl_2$(aq).
D. It forms an acidic solution when placed in hot H_2O(l).

DSE17_15

Consider the following chemical equation:

$$3Ni(OH)_2(s) + xHCl(aq) + yAuCl_4^-(aq) \longrightarrow 3NiCl_4(aq) + yAu(s) + zCl^-(aq) + 6H_2O(l)$$

Which of the following combinations is correct?

	x	y	z
A.	4	2	2
B.	6	2	2
C.	4	3	3
D.	6	3	3

DSE17_23

What would be observed when a few drops of concentrated nitric acid is added to KI(aq)?

(1) A brown solution is formed.
(2) A brown precipitate is formed.
(3) A reddish brown gas is released.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE18_12

Which of the following is NOT a redox reaction?

A. $2Mg + SO_2 \longrightarrow 2MgO + S$
B. $CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$
C. $Cu_2O + H_2SO_4 \longrightarrow CuSO_4 + Cu + H_2O$
D. $3CuS + 8HNO_3 \longrightarrow 3CuSO_4 + 8NO + 4H_2O$

DSE18_21 [OUT]

Which of the following statements concerning a zinc-carbon cell is/are INCORRECT?

(1) The graphite rod is inserted in a mixture of graphite powder and MnO_2.
(2) Potassium hydroxide acts as an electrolyte.
(3) Ammonia form around the cathode.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

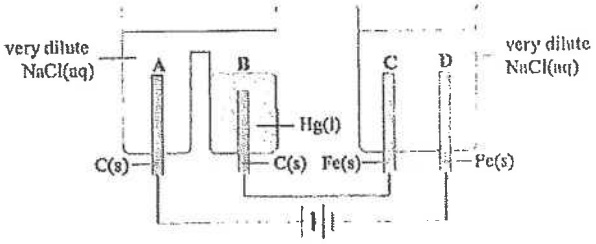
DSE19_03

Which of the following processes does NOT involve oxidation and reduction?

A. Red wine turning sour
B. Removing rust using white vinegar
C. Combusting natural gas in a power station
D. Removing nitrogen oxides in the catalytic converter of a car

DSE19_11

Consdier the following electrolytic cells:

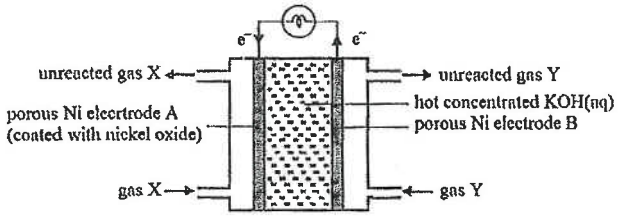


What would happen during electrolysis ?

A. Oxygen forms around A
B. Chlorine forms around B
C. Hydrogen forms around C
D. Iron(II) ions form around D.

DSE19_12

Which of the following statements concerning the fuel cell below that can form water is INCORRECT?



A. It is a primary cell.
B. Ni also acts as a catalyst.
C. X can be obtained from fractional distillation of liquid air.
D. The rquation for the change at electrode B is: $4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$

DSE19_14

Consider the following reaction:

$$(NH_4)_2Cr_2O_7(s) \longrightarrow Cr_2O_3(s) + N_2(g) + 4H_2O(g)$$

Which of the following statements is /are correct?

(1) The oxidation number of chromium decreases.
(2) Only covalent bonds are broken and formed.
(3) Green solid turns to orange solid.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE19_19

In which of the following reactions does the underlined chemical acts as a reducing agent?

(1) $2\underline{C_4H_{10}} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$
(2) $\underline{Ba(NO_3)_2} + Na_2SO_4 \longrightarrow BaSO_4 + 2NaNO_3$
(3) $\underline{Zn(OH)_2} + 2NaOH \longrightarrow Na_2Zn(OH)_4$

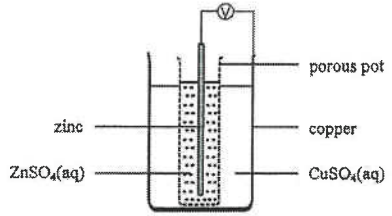
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE20_5

5. Which of the following statements concerning francium (atomic number = 87) is correct ?

A. Francium has a higher melting point than potassium.
B. Francium forms cations more readily than potassium.
C. Francium is a weaker oxidising agent than potassium.
D. Francium has a fewer number of occupied electron shells than potassium.

9. Refer to the following chemical cell :



Which of the following statements is correct ?

A. Copper is the cathode of the cell.
B. Zinc ions act as the oxidising agent in the cell.
C. Only zinc ions can pass through the porous pot.
D. Electrons flow from copper to zinc through the external circuit.

DSE20_12

12. Refer to the following half equations :

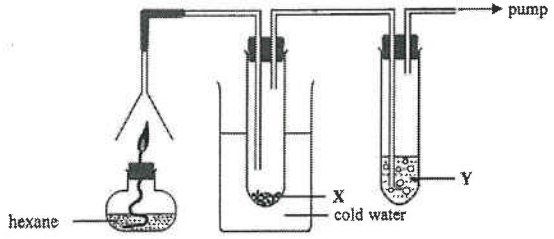
$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$
$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

What is the minimum volume of 0.010 M acidified $KMnO_4(aq)$ required to completely oxidise 15.00 cm^3 of 0.020 M $Na_2C_2O_4(aq)$?

A. 6.00 cm^3
B. 12.00 cm^3
C. 15.00 cm^3
D. 75.00 cm^3

DSE20_14

14. The set-up below is used to show that hexane (C_6H_{14}) contains carbon and hydrogen. What are X and Y ?



	X	Y
A.	$PbSO_4(s)$	limewater
B.	$NaOH(s)$	bromine water
C.	anhydrous $CoCl_2(s)$	limewater
D.	anhydrous $CuSO_4(s)$	bromine water

DSE20_19

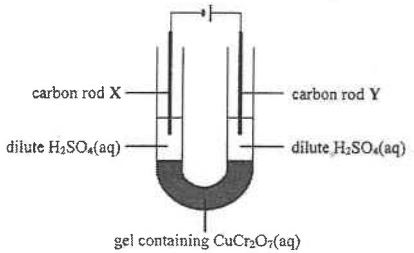
19. Which of the following processes can form a halogen ?

(1) Electrolyse concentrated KCl(aq).
(2) Add $Na_2SO_4(s)$ to concentrated HBr(aq).
(3) Add KI(s) to acidified $KMnO_4(aq)$.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE21_02

2. Consider the following experimental set-up :



Which of the following statements is correct when an electric current passes through the circuit ?

A. Blue colour is observed in the dilute $H_2SO_4(aq)$ around **Y**.
B. Gas bubbles are observed in the dilute $H_2SO_4(aq)$ around **Y**.
C. Orange colour is observed in the dilute $H_2SO_4(aq)$ around **X**.
D. Electrons flow from **X** to **Y** through the external circuit.

DSE21_07

7. The oxidation number of Pb in $Pb_{10}(VO_4)_6F_2$ is +2. What is the oxidation number of V ?

A. –3
B. +2
C. +4
D. +5

DSE21_09

9. Gases discharged from coal-fired power plants contain SO_2. SO_2 is also regarded as an air pollutant. What is the most suitable way to remove the SO_2 before discharging these gases into the atmosphere ?

A. Pass these gases through calcium oxide.
B. Pass these gases through concentrated sulphuric acid.
C. Cool these gases to liquefy SO_2 for subsequent removal.
D. Pass these gases through an organic solvent such as hexane.

DSE21_22

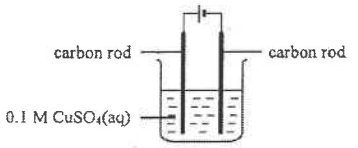
22. Which of the following statements concerning hydrogen-oxygen fuel cells are correct ?

(1) When used to power vehicles, they are more environmentally friendly than using petrol engine.
(2) When used in space stations, they can produce drinking water in addition to energy.
(3) When used as a back-up power source in hospitals, they do not produce noise pollution.

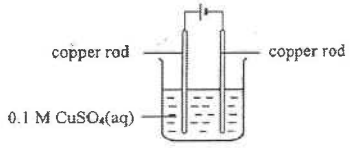
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE21_23

23. Consider the following two electrolytic cells :



Electrolytic cell 1



Electrolytic cell 2

During electrolysis, which of the following would occur in **Electrolytic cell 1** but not in **Electrolytic cell 2** ?

(1) Gas bubbles are given out.
(2) The blue solution becomes paler.
(3) A reddish brown solid is deposited.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE21_27

27. Copper(II) oxide can catalyse the decomposition of hydrogen peroxide to form oxygen and water. In an experiment, hydrogen peroxide solution is shaken with copper(II) oxide in a test tube. What would be observed in the test tube after the completion of the reaction ?

A. a pale blue liquid
B. a blue solid and a colourless liquid
C. a black solid and a colourless liquid
D. a reddish brown solid and a colourless liquid

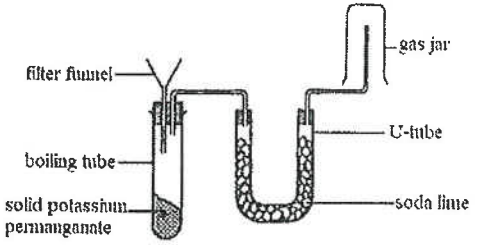
Structural Questions

CE90_02a(i)

A teacher asked a student to describe an experiment to illustrate a redox reaction using concentrated hydrochloric acid.

The following is the student's answer. There are three mistakes in this answer, two of which have been underlined by the teacher.

'Set up the apparatus in a fume cupboard as shown in the diagram below. Pour concentrated hydrochloric acid into a filter funnel. Pass the gas generated through a U-tube containing soda lime to dry the gas and to remove hydrochloric acid fumes. Collect the gas by downward displacement of air.'



(1) Write a balanced equation with state symbols for this redox reaction.

(2) Explain why this reaction is an example of a redox reaction in terms of changes in oxidation number of the reactants.

(4 marks)

CE90_04a

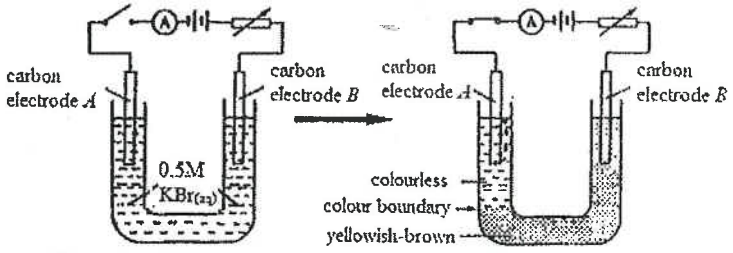


Diagram I: before electrolysis

Diagram II: after electrolysing for some time

Diagram I shows a set-up for the electrolysis of 0.5M potassium bromide solution. After passing electricity for some time, gas bubbles were observed at electrode A, while the solution around electrode B turned yellowish-brown. This colouration gradually extended to the bottom of the U-tube and a steady colour boundary was formed as shown in diagram II.

(i) Which of the electrodes was the cathode?

(ii) Name the gas produced at electrode A, and suggest a chemical test to identify this gas.

(iii) Write half equations for the reactions that occurred during electrolysis at electrodes A and B.

(v) Name the electrolysis product responsible for producing the yellowish-brown colour and explain why the colour extended to the bottom of the U-tube.

(vi) (1) What ions would migrate from the solution around electrode A towards electrode B during electrolysis?

(10 marks)

CE91_02c

Iron sheets can be tin-plated by electrolysis of either tin(II) or tin(IV) compounds before they are used to make food cans.

(i) In the above electrolysis, what material should be used as the anode?

(ii) Based on the quantity of electricity consumed, determine whether the use of a tin(II) or tin(IV) compound is more economical in the electrolysis process.

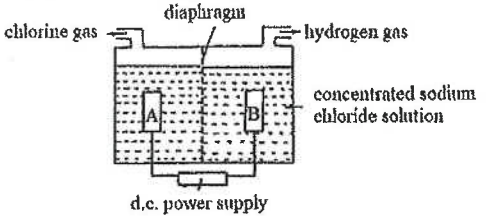
(iii) Give one reason to explain why iron is first tin-plated before food cans are made from it.

(iv) If the tin-plated iron sheet has been scratched to expose the iron, can it still be used to make a food can? Explain.

(6 marks)

CE92_05a

Sodium hydroxide can be manufactured by the electrolysis of concentrated sodium chloride solution in the following set-up, where A and B are inert electrodes.



(i) Explain which electrode, A or B, is the cathode.

(ii) Using the concept of preferential discharge of ions, explain the electrode reactions and why sodium hydroxide can be manufactured by the above electrolysis.

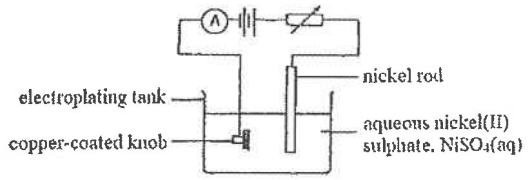
(6 marks)

CE03_02a

Turning knobs on radios are often made of plastics plated with metal coatings.

(ii) What is the purpose of plating the knobs with metals?

The plastic knobs are first coated with copper and then electroplated with nickel. The electroplating can be conducted using the following set-up:



(iii) Why is the plastic knob first coated with copper before electroplating?

(iv) Write an ionic equation for the reaction that occurs at the cathode during electroplating.

(3 marks)

CE94_01c

The table below lists some information about three metals X, Y and Z.

Metal	X	Y	Z
Atomic number	12	20	–
Action of cold water	No apparent change	A colourless gas slowly evolves	No apparent change
Action of 0.1M hydrochloric acid	A colourless gas evolves	–	No apparent change

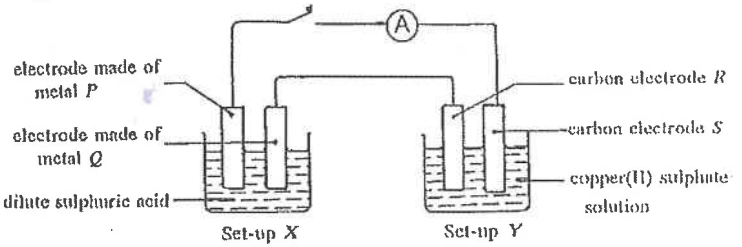
When Z is heated with concentrated sulphuric acid, a colourless gas evolves and the solution turns blue.

(i) What gas is evolved? Suggest a chemical test for the gas.

(ii) What would be observed if a piece of metal X is added to the blue solution?

(4 marks)

CE94_07a



In the above diagram, P and Q are two different metals. When the circuit is closed, a current flows in the external circuit. After some time, 0.36 g of copper is deposited on the carbon electrode R.

(i) (1) What is the direction of electron flow in the external circuit? Explain your answer.

(ii) After the circuit has been closed for some time, what would be observed

(1) at the carbon electrode S?

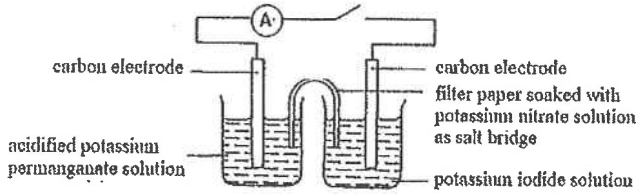
(2) in the copper(II) sulphate solution?

(iii) What is the function of set-up X in this experiment?

(iv) Which of the metals, P or Q, occupies a higher position in the electrochemical series? Explain you answer.

(7 marks)

CE95_09b



When the circuit in the set-up shown above is closed, the acidified potassium permanganate solution loses its colour gradually.

(i) Write a half equation for the reaction that occurs in the acidified potassium permanganate solution. Explain whether the permanganate ion is oxidized or reduced.

(ii) What would be observed in the potassium iodide solution after some time? Write a half equation for the reaction that would occur.

(iii) Identify the direction of electron flow in the external circuit.

(iv) Write an ionic equation for the reaction that occurs when an acidified potassium permanganate solution and a potassium iodide solution are mixed together.

(v) (1) What is the function of the salt bridge in the set-up?

(2) Explain whether a sodium sulphite solution can be used instead of a potassium nitrate in the salt bridge.

(8 marks)

CE96_06a

The table below lists the oxidation number of iron in two compounds:

Compound	Iron(II) sulphate	Iron(III) sulphate
Oxidation number	+2	+3

(i) (1) What would be observed when sodium hydroxide solution is added to iron(II) sulphate solution? Write an ionic equation for the reaction involved.

(2) Explain whether this reaction is a redox reaction.

(ii) When iron(II) sulphate solution is mixed with dilute sulphuric acid and a small amount of a purple solution, a reaction occurs and the oxidation number of iron changes from +2 to +3.

(1) Suggest what the purple solution may be.

(2) What would be observed in this reaction? Write an ionic equation for the reaction involved.

(iii) When iron(II) sulphate solution reacts with an element X, the oxidation number of iron changes from +2 to 0.

(1) Suggest what X may be.

(2) What would be observed in this reaction? Explain whether iron(II) sulphate solution acts as a reducing agent or an oxidizing agent in this reaction.

(10 marks)

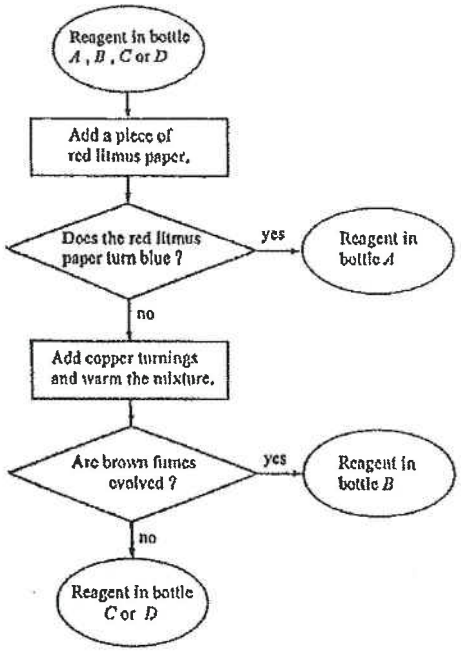
CE96_06b

A, B, C and D are four unlabeled bottles, each containing one of the following reagents:

2M ammonia solution, 2M ethanoic acid,

2M hydrochloric acid, 2M nitric acid

The following scheme is used to identify the four reagents:



(i) What is the reagent in bottle *A*? Explain why this reagent turns red litmus paper blue.

(ii) What is the reagent in bottle *B*? Write a chemical equation for the reaction between this reagent and copper turnings, and a chemical equation for the information of the brown fumes.

(iii) (1) Suggest a test to distinguish between the reagents in bottles *C* and *D*. (Smelling the reagents in NOT an acceptable answer.)

(2) State the observable change in this test and explain your answer.

(8 marks)

CE96_08b(iii)

The diagram below shows a ten dollar coin which is made of two alloys, *X* and *Y*.

When alloy *X* is heated with concentrated sulphuric acid, a bluish-green solution is formed and a colourless gas is evolved.

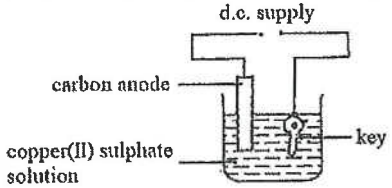
(1) Suggest ONE metal that may be present in *X*. Explain your answer.

(2) What is the colourless gas? Suggest a chemical test for the gas.

(4 marks)

CE96_09b

A student carried out a copper-plating experiment in the laboratory using the set-up shown below:



(i) Explain why copper(II) sulphate solution can conduct electricity.

(ii) What would be observed at the carbon anode during the experiment? Write a half equation for the reaction involved.

(iii) In the copper-plating industry, a metal is used as the anode instead of carbon. What is this metal? Explain your answer.

(iv) In a copper-plating factory, the waste water is treated with sodium hydroxide solution to remove the copper(II) ions present before discharge.

(1) Suggest TWO reasons why it is necessary to remove the copper(II) ions from the waste water before discharge.

(2) 20.0 dm^3 of a sample of waste water require 3.5 dm^3 of 8.0 M sodium hydroxide solution for complete removal of the copper(II) ions present.
Calculate the concentration, in mol dm^{-3}, of copper(II) ions in the sample.

(10 marks)

CE97_04

Briefly describe how you would conduct an experiment, using the materials and apparatus below, to nickel-plate a clean metal spoon. (Diagrams are NOT required). State the expected observation of the experiment.

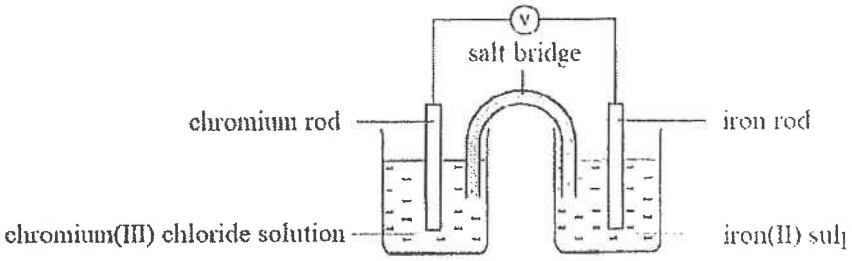
a clean metal spoon, a nickel plate, nickel(II) sulphate crystals,

a large beaker of distilled water, a d.c. power supply and connecting wires

(8 marks)

CE97_06a

A student used the following experimental set-up to study the migration of ions.



The student placed a drop of potassium dichromate solution at A and a drop of a deep blue solution at C. It is solutions do not react and the deep blue colour of the solution at C is due to the cation present.

(i) Write the formula of the ion responsible for the orange colour of potassium dichromate.

(ii) Why was the filter paper moistened with sodium sulphate solution?

(iii) An electric current was passed through the circuit for some time.

(1) What would be the colour change at A?

(2) What would be the colour change at B? Explain your answer.

(iv) Using the same apparatus and materials, suggest how you could show that the colour changes in diffusion.

CE97_08a

A class of students visited a chemical plant which manufactures chlorine by the electrolysis of brine. Some of the chlorine produced is used to make chlorine bleach. At the end of the visit, each student was given a bottle of chlorine bleach as a gift.

(i) Explain, in terms of preferential discharge of ions, how chlorine is produced in the electrochemical process.

(ii) The students found some metal cylinders containing chlorine in the chemical plant. The students were told that these cylinders would be used in water treatment plants.

(1) Which one of the following hazard warning labels should be displayed on the metal cylinders?

A B C D

(2) Explain why chlorine is used in water treatment plants.

(5 marks)

CE97_08b

Read the following paragraph concerning chromium and answer the questions that follow:

The Greek word "*chrōma*" means colour. Many chromium-containing compounds and chromium-containing gemstones are beautifully coloured. The oxidation number of chromium in its compounds can be +2, +3 and +6.

(ii) Potassium dichromate is an oxidizing agent. The oxidation number of chromium in potassium dichromate is +6.

(1) Name ONE compound which can be oxidized by potassium dichromate.

(2) State the condition(s) under which the compound reacts with potassium dichromate.

(3) What product is formed from the compound in the redox reaction?

(iii) In the presence of a dilute acid, chromium(II) ions react with atmospheric oxygen to form chromium(III) ions and water.

(1) Write the half equation for the formation of chromium ions.

(2) Write the half equation for the formation of water.

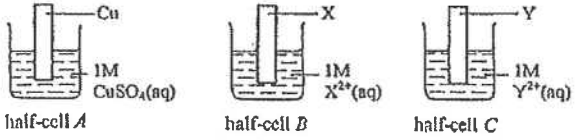
(3) Write the overall equation for the reaction.

(iv) Suggest TWO ways in which chromium can be used to prevent the corrosion of iron.

(8 marks)

CE97_09b

X and Y are different metals. A student studied the reactivity of X, Y and copper by setting up two electrochemical cells using the following materials and apparatus:



half-cell *A* half-cell *B* half-cell *C*

strips of filter paper

saturated solution of potassium nitrate

connecting wires with crocodile clips

The results of the experiment are tabulated below:

Electrochemical cell	Direction of electron flow in the external circuit
formed by connecting half-cells A and C	Y to Cu
formed by connecting half-cells B and C	X to Y

(i) What is the meaning of the term 'saturated solution'?

(ii) Explain the use of the strips of filter paper in the experiment.

(iii) The student had to use an additional instrument to determine the direction of electron flow in the external circuit.

(1) What instrument did the student use?

(2) Draw a labelled diagram to show the set-up for the experiment, using half-cells A and C.

(iv) Arrange X, Y and copper in the order of increasing reactivity. Explain your answer.

(v) What would be observed when a piece of copper foil is immersed in an aqueous solution containing 1 mol dm^{-3} of Y^{2+} ions? Explain your answer.

(9 marks)

CE98_02

For each of the following experiments, state the expected observation and write a relevant chemical equation.

(c) A sodium sulphate solution is added to an iodine solution (iodine dissolved in aqueous potassium iodide).

(2 marks)

CE98_06b

The table below includes some information about three types of dry cells. The voltage of each type of cell is 1.5V.

Type	Voltage over discharge	Price per cell / $	Shelf life / year	Life / minutes
Zinc-carbon cell (AA size)	falls quite rapidly	2.5	1.5	70
Alkaline manganese cell (AA size)	remains steady	5.0	3	90
Silver oxide cell (button type)	remains steady	8.0	2	30

(The life of a cell has been determined from its use in a test with a motorized toy.)

(i) Decide and explain which type of cell should be used in a small CD-player (Discman).

(ii) A package of 24 zinc-carbon cells is now being offered at a special price of $49.90. Assuming that your radio consumes one zinc-carbon cell per month, would you buy a package of these specially-priced cells for the use of your radio? Explain your answer.

(iii) The half-equations below show the changes at the two electrodes, A and B, of a silver oxide cell during discharge:

A : $Zn(s) + 2OH^-(aq) \longrightarrow ZnO(s) + H_2O(l) + 2e^-$

B : $Ag_2O(s) + H_2O(l) + 2e^- \longrightarrow 2Ag(s) + 2\,OH^-(aq)$

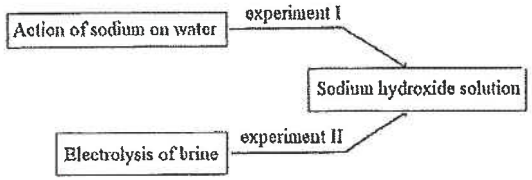
(1) Decide and explain which electrode, A or B, is the anode.

(2) Write the overall equation for the reaction that would occur in the cell during discharge.

(7 marks)

CE98_09b

Each of the following experiments produces a sodium hydroxide solution.



(i) What would be observed when a small piece of sodium is added to water?

(ii) Explain whether experiment I or experiment II is preferred for preparing a sodium hydroxide solution.

(iii) During the electrolysis of brine, chlorine and hydrogen are liberated at the anode and cathode respectively. A sodium hydroxide solution remains in the electrolytic cell after some time.

(1) Explain why hydrogen, instead of sodium is liberated at the cathode.

(2) Suppose that 50.0 cm^3 of hydrogen is liberated at the cathode at room temperature and pressure. Deduce the theoretical volume of chlorine liberated at the anode under the same conditions.

(3) Explain why a sodium hydroxide solution remains in the electrolytic cell.

(iv) Draw a labelled diagram to show the laboratory set-up for the electrolysis of brine and the collection of the gaseous products.

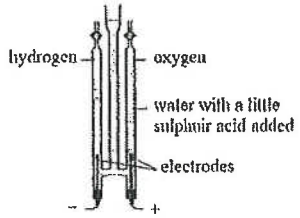
(10 marks)

CE99_06a

Water is a compound of hydrogen and oxygen. Under suitable conditions, 80.0 cm^3 of hydrogen and 60.0 cm^3 of oxygen (with one of the reactants in excess) react to give water. The volumes of both gases are measured at room temperature and pressure.

(i) Draw the electronic diagram of water, showing electrons in the *outermost shells* only.

(iii) Water can be decomposed by electrolysis with the following set-up to give hydrogen and oxygen.



(1) Explain why a little sulphuric acid has been added to the water used.

(2) Suggest a suitable material for the electrodes.

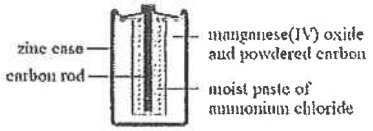
(3) Write the half-equation for the formation of oxygen.

(4) Suggest a chemical test for *each* product obtained in the electrolysis.

(8 marks)

CE99_08a [OUT, except (v)]

The diagram below shows the longitudinal section of a zinc-carbon cell.



(i) Write a half-equation for the reaction that occurs at the zinc case of the cell during discharge.

(ii) State the function of following substances in a zinc-carbon cell.

(1) carbon rod

(2) manganese(IV) oxide

(iii) Suggest a chemical test to show the presence of ammonium ions in the moist paste of ammonium chloride.

(iv) Explain whether you agree with the following statement.

'Zinc-carbon cells cause more environmental problems than nickel-cadmium cells do.'

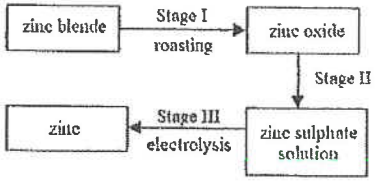
(v) Complete and balance the following half-equations for the reactions that occur at the electrodes of a nickel-cadmium cell.

$Cd + OH^- \longrightarrow Cd(OH)_2$

$NiO_2 + H_2O \longrightarrow Ni(OH)_2 + OH^-$ (10 marks)

CE00_06a

The flow diagram below shows the stages involved in the extraction of zinc from zinc blende, ZnS.



(i) The reaction in Stage I gives, apart from zinc oxide, a gaseous product.

(1) Write the chemical equation for the reaction.

(2) Give ONE industrial use of the gaseous product.

(ii) Suggest how zinc oxide can be converted to zinc sulphate solution in Stage II.

(iii) The zinc sulphate solution obtained contains ions of other metals. During the electrolysis in Stage III, zinc metal is liberated at one of the electrodes.

(1) Suggest ONE way to remove ions of metals which are less reactive than zinc from the zinc sulphate solution before electrolysis.

(2) Why is it not necessary to remove ions of metals which are more reactive than zinc from the solution?

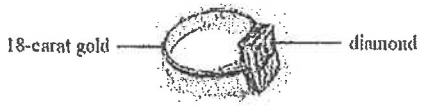
(3) Write half equations for the reactions occurring at the anode and cathode during the electrolysis.

(iv) Give ONE use of zinc in daily life.

(8 marks)

CE01_07c

The photograph below shows a diamond ring:



(i) Explain why gold and diamond each has a high melting point.

(ii) 18-carat gold is an alloy of gold. Suggest ONE reason why 18-carat gold instead of pure gold is used in making the ring.
(You are NOT required to consider the price of the materials.)

(iii) In an experiment, a piece of 18-carat gold was heated with concentrated nitric acid. A bluish green solution was formed.

(1) Suggest another metal that may be present in the 18-carat gold. Explain your answer with the help of a chemical equation.

(2) State another observation in the experiment.

(7 marks)

CE01_08a

A part of the Periodic Table is shown below:

		Group							
		I	II	III	IV	V	VI	VII	0
Period	2	Li	Be	B	C	N	O	F	Ne
	3	Na	Mg	Al	Si	P	S	Cl	Ar
	4	K	Ca					Br	Kr
	5								Xe

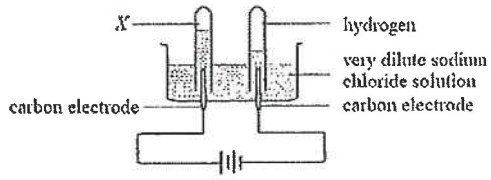
(ii) For each of the following pairs of elements, suggest ONE reaction in which both elements behave similarly. In each case, write a chemical equation for the reaction involving either one of the elements.

(2) chlorine and bromine

(2 marks)

CE01_09

(a) A student used the set-up shown below to prepare hydrogen and chlorine by electrolysis of a very dilute sodium chloride solution. Contrary to the student's expectation, a colourless gas X instead of chlorine was liberated at the anode.



(i) What is X?

(ii) Suggest a chemical test for X.

(2 marks)

(b) The experiment in (a) was then modified so that hydrogen and chlorine were produced at the cathode and anode respectively.

(i) Suggest how the experiment could be modified.

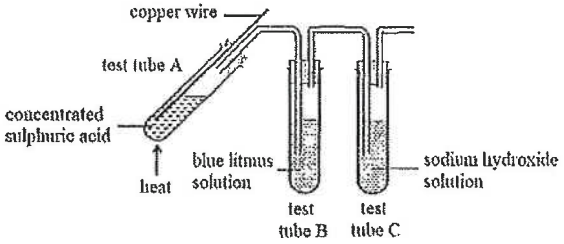
(ii) Deduce the ratio of the theoretical volumes of hydrogen and chlorine produced.

(iii) With the help of a chemical equation, explain why the volume of chlorine collected is significantly smaller than the theoretical volume.

(6 marks)

CE01_09c

The diagram below shows the set-up used in an experiment to study the reaction of copper with concentrated sulphuric acid.



(i) During the experiment, a black substance was formed on the surface of the copper wire. What is the black substance?

(ii) What other changes would be observed in test tube A? Write the chemical equation for the reaction that occurred.

(iii) State the observation in test tube B. Explain your answer.

(iv) What is the use of the sodium hydroxide solution in test tube C? State the potential hazard if sodium hydroxide solution is not used.

(8 marks)

CE02_02

For each of the following experiments, state an expected observation and write a chemical equation for the reaction involved.

(b) Excess iron(II) sulphate solution is added to an acidified potassium permanganate solution.

(c) Chlorine gas is bubbled into a sodium bromide solution.

(4 marks)

CE02_03 [OUT]

Consider the substances listed below:

ammonia, manganese(IV) oxide, potassium hydroxide,
sodium benzoate, sodium dichromate, sodium nitrite

(b) Which substance is used in zinc-carbon cells? State its function.

(2 marks)

CE02_04

Using the electrolysis of copper(II) chloride solution as an example, briefly discuss the factors affecting the discharge of ions in electrolysis.

(6 + 3 marks)

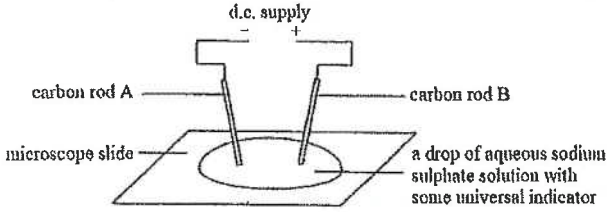
CE02_06a

(iii) Explain why molten magnesium chloride can conduct electricity.

(1 mark)

CE02_09c [Similar as DSE13_09]

A student used the set-up shown below to conduct a microscale experiment on electrolysis.



(i) (1) The initial colour of the drop shown above was green. State the colour change of the liquid around carbon rod A after a current was passed through the circuit for some time. Explain your answer with the help of a half equation.

(2) A gas was liberated at carbon rod B. What was the gas? Explain its formation.

(ii) Some objects readily available in daily life contain carbon rods which can be used in this experiment. Suggest ONE such object.

(iii) The use of microscale experiments in studying chemistry is becoming more popular nowadays. Suggest TWO advantages of carrying out experiments in microscale.

(8 marks)

CE03_04

Candidates are required to give paragraph-length answers. 3 of the marks for each of these two questions will be awarded for the effective communication of knowledge in Chemistry.

Discuss the similarities and differences in chemical properties of concentrated sulphuric acid and dilute sulphuric acid. Illustrate your answer using appropriate examples.

(6 + 3 marks)

CE03_06c

Ammonia reacts with copper(II) oxide upon heating. The products are nitrogen, copper and water.

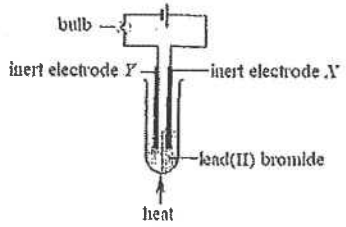
(i) State whether or not the reaction is a redox. Explain your answer in terms of oxidation number change.

(ii) Write the chemical equation for the reaction of ammonia with copper(II) oxide.

(3 marks)

CE03_07a [Similar to DSE16_08]

The set-up shown below is used to investigate the electrical conductivity of lead(II) bromide.



When the lead(II) bromide becomes molten, the bulb lights up.

(i) What would be observed at electrode X? Write the half equation for the reaction involved.

(ii) State ONE potential hazard when carrying out the experiment.

(iii) State what will happen to the bulb when heating is stopped and the molten lead(II) bromide is allowed to cool down gradually to room temperature. Explain your answer.

(6 marks)

CE04_06a

Water (H_2O) is an oxide of hydrogen. Electrolysis of water in the presence of sulphuric acid gives hydrogen and oxygen in a volume ratio of 2:1.

(i) Suggest suitable electrodes to be used in the electrolysis.

(ii) Write the half equation for the reaction at the cathode and that at the anode during the electrolysis.

(iii) What is the function of sulphuric acid in the electrolysis?

(iv) Is it possible to deduce the formula of water from the results of the electrolysis? Explain your answer.

(6 marks)

CE04_06b

Hydrogen peroxide (H_2O_2) is another oxide of hydrogen.

(i) What is the oxidation number of oxygen in hydrogen peroxide?

(ii) Draw the electronic diagram of a molecule of hydrogen peroxide, showing electrons in the *outermost shells* only.

(iii) In the presence of a dilute acid, hydrogen peroxide oxidizes iron(II) ions and it is reduced to water.

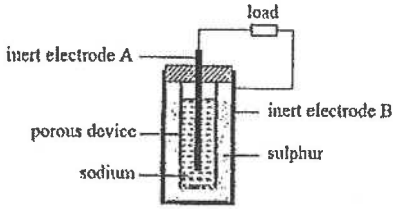
(1) Write the half equation for the reduction of hydrogen peroxide.

(2) State the expected observation and write a chemical equation for the reaction involved.

(5 marks)

CE03_09a

The diagram below shows a sodium-sulphur cell connected to an external circuit. This cell operates at a high temperature of about 370°C, which is above the melting point of sodium and sulphur.



(i) State and explain the direction of electron flow in the external circuit when the cell is discharged. Write half equations for the reactions at electrodes A and B.

(ii) Suggest TWO functions of the porous device.

(iii) Suggest why it is necessary for the cell to operate at a high temperature.

(iv) Sodium-sulphur cells are rechargeable and are used in power stations to reduce the wastage of electricity generated. Suggest why these cells can be used to reduce the wastage of electricity.

(8 marks)

CE04_02

For each of the following pairs of substances, suggest a chemical test to distinguish one substance from the other and state the expected observations.

(c) dilute sulphuric acid and dilute nitric acid

(2 marks)

CE04_07c

State what would be observed in each of the following experiments and explain your answer.

(i) A beaker containing some concentrated sulphuric acid was left in air for a long period of time.

(2 marks)

CE05_04

The wastewater generated from an electroplating factory contains dichromate ions. Before the wastewater is discharged, it is treated in two stages as described below to remove the chromium-containing substances.

Stage 1: Treat the wastewater with excess sodium sulphate solution in the presence of acid to reduce the dichromate ions to chromium ions.

Stage 2: Add a suitable chemical to the treated wastewater from *Stage 1* to precipitate the chromium(III) ions.

(a) Why is it necessary to remove chromium-containing substances from the wastewater?

(1 mark)

(b) In *Stage 1*, the sulphite ions are oxidized to sulphate ions by the dichromate ions.

(i) Write the half equation for the oxidation of sulphite ions.

(ii) Write the half equation for the reduction of dichromate ions.

(3 marks)

(c) Suggest a suitable chemical for the precipitation of chromium(III) ions in *Stage 2*.

(1 mark)

CE05_07

A chemical cell can be made from two metal strips and a lemon. Given the following materials and equipment, outline how you can set up a chemical cell with the *maximum* output voltage.

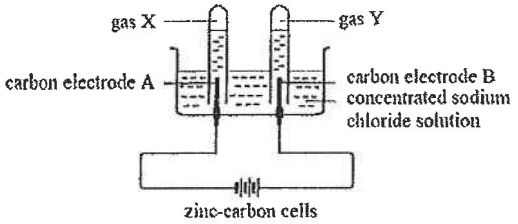
a lemon, a copper strip, a magnesium strip, a zinc strip, a multimeter and several connecting wires

(Your answer should include variables that need to be controlled.)

(6 + 3 marks)

CE05_09

An experiment was carried out to study the electrolysis of a concentrated sodium chloride solution using several zinc-carbon cells as a source of electricity. The following diagram shows the set-up used:



(a) (i) What is gas X?

(ii) Give ONE use of X in industry.

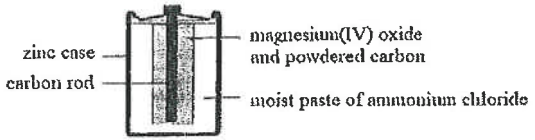
(2 marks)

(b) (i) What is gas Y?

(ii) If the electrolysis is repeated using a very dilute sodium chloride solution, another gas will be liberated at carbon electrode B. Suggest an explanation for this phenomenon.

(3 marks)

(c) With reference to the longitudinal section of a zinc-carbon cell shown below, suggest how chemical energy is converted to electrical energy when the cell is producing a current. [OUT]



(3 marks)

CE06_05

Silicon occurs in nature as silicon dioxide in sand and quartz. The extraction of silicon from silicon dioxide involves the following three stages:

Stage 1: $SiO_2(s) \xrightarrow[\text{heat}]{C(s)} Si(s)$

Stage 2: $Si(s) \xrightarrow[\text{heat}]{Cl_2(g)} SiCl_4(l)$

Stage 3: $SiCl_4(l) \xrightarrow[\text{heat}]{H_2(g)} Si(s)$

(a) What type of structure does quartz have?

(1 mark)

(b) The purpose of *Stage 1* is to convert silicon dioxide to silicon. The silicon obtained contains silicon carbide, SiC, as an impurity.

The structure of silicon carbide is similar to that of diamond. Draw the three-dimensional structure of silicon carbide.

(1 mark)

(c) The purpose of *Stage 2* and *Stage 3* is to purify the silicon obtained in *Stage 1*.

(i) Is silicon oxidized or reduced in the reaction in *Stage 2*? Explain your answer.

(ii) Draw the electronic diagram for $SiCl_4$, showing electrons in the *outermost shells* only.

(iii) The reaction in *Stage 3* produces silicon and hydrogen chloride. Suggest why the silicon obtained after *Stage 3* is of high purity.

(3 marks)

(d) Calculate the theoretical mass of silicon that can be obtained from 950 g of silicon dioxide.

(2 marks)

CE06_07

The following two methods can be used to convert copper metal into copper(II) nitrate solution:

Method 1: $Cu(s) \longrightarrow CuO(s) \xrightarrow{\text{dilute } HNO_3(aq)} Cu(NO_3)_2(aq)$

Method 2: $Cu(s) \xrightarrow{\text{dilute } HNO_3(aq)} Cu(NO_3)_2(aq)$

(a) Refer to *Method 1*.

(i) Suggest how copper metal can be converted into copper(II) oxide. Stage the expected observation in the reaction that you have suggested.

(ii) Name the type of reaction that occurs between copper(II) oxide and dilute nitric acid.

(3 marks)

(b) In *Method 2*, the reaction of copper metal with dilute nitric acid gives copper(II) nitrate, nitrogen monoxide and water. Write the chemical equation for this reaction.

(2 marks)

(c) Which of these methods would you recommend for the conversion of copper metal into copper(II) nitrate solution? Justify your answer with TWO reasons.

(2 marks)

CE06_08

'Elements in Group VII of the Periodic Table exhibit similar chemical properties. However, their reactivity decreases down the group.'

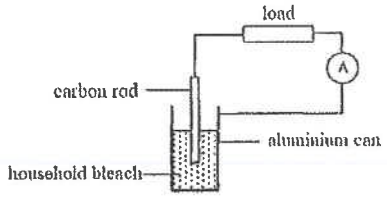
Elaborate the first statement above using two reactions of halogens. Also outline an experiment to illustrate the second statement.

(You are suggested to use chlorine and bromine as examples of halogens in answering this question.)

(6 + 3 marks)

CE06_10

A student used an aluminium can, a carbon rod and household bleach to make a chemical cell. The diagram below shows the set-up of the cell connected to a load and an ammeter.



(a) The materials used by the student to make the cell are readily available at home. Suggest ONE household item

(i) which contains a carbon rod.

(ii) which includes an aluminium can.

(2 marks)

(b) When the cell is producing a current, the aluminium can undergoes oxidation to give aluminate ions, $Al(OH)_4^-(aq)$, while at the carbon rod the hypochlorite ions undergo reduction in the presence of water to give chloride ions and hydroxide ions.

Given that household bleach is alkaline, write half equations for

(i) the oxidation of the aluminium metal, and

(ii) the reduction of the hypochlorite ions.

(2 marks)

(c) The student also used the above set-up to investigate the relation between the current produced by the cell and the concentration of hypochlorite ions in the bleach.

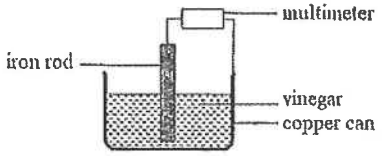
(i) Suggest TWO conditions which should be kept constant when conducting this investigation.

(ii) The student noticed that the current produced by the cell increases with the concentration of hypochlorite ions in the bleach. Suggest an explanation for the phenomenon.

(3 marks)

CE07_04

A student learnt from a book that an ancient chemical cell could be made by immersing an iron rod in a liquid placed inside a copper can. The liquid used was vinegar but not wine. The diagram below shows the set-up designed by him in simulating the cell.



(a) Explain, in terms of structure of property of particles, why the liquid inside the ancient chemical cell was vinegar but not wine.

(2 marks)

(b) The student found that the iron rod dissolved gradually, and colourless gas bubbles were given out on the inner wall of the copper can.

(i) Write a half equation, involving iron, for the reaction that occurred at the iron rod.

(ii) Write a half equation for the reaction that occurred on the inner wall of the copper can.

(2 marks)

(c) The student found that colourless gas bubbles were also given out at the surface of the iron rod that immersed in vinegar. Explain the observation.

(1 mark)

CE07_09

A certain brand of rust remover contains an acid of high concentration. The rust remover can be used for removing tough rust stains; while the rust remover, after dilution, can be used for removing comparatively light rust stains.

Write some instructions, with reasons, on how the rust remover can be used safely at home. Two sentences have been given below as an introduction.

The rust remover should be kept out of reach from children as it contains an acid of high concentration. The rust remover should not be swallowed because it is harmful.

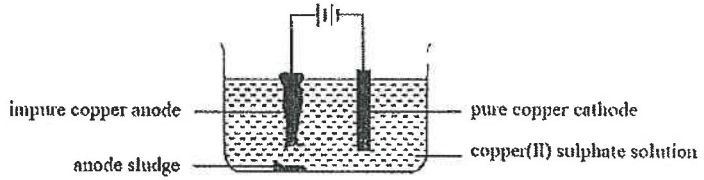
(6 + 3 marks)

CE07_11 [OUT, except (a)]

In a chemical plant, extraction of copper from its ores involves roasting copper(I) sulphide with air inside a high temperature furnace. Copper(I) sulphide reacts with oxygen in air according to the following equation:

$$Cu_2S + O_2 \longrightarrow 2Cu + SO_2$$

The copper so extracted contains impurities including metals such as silver, iron, zinc and gold. The impure copper is then purified by electrolysis as illustrated in the diagram below:



(a) With reference to the reaction between copper(I) sulphide and oxygen, identify the species undergoing oxidation and the species undergoing reduction. Explain your answers in terms of changes in oxidation numbers.

(2 marks)

(b) Explain briefly how impure copper can be purified by electrolysis as illustrated in the diagram above. [OUT]

(2 marks)

(c) Insoluble impurities deposit under the impure copper anode as 'anode sludge'. According to the information given, suggest what substances the anode sludge would contain. Explain your answer. [OUT]

(2 marks)

(d) 'The concentration of copper(II) ions in copper(II) sulphate solution remains UNCHANGED in the above electrolysis.' Is this statement correct? Explain your answer. [OUT]

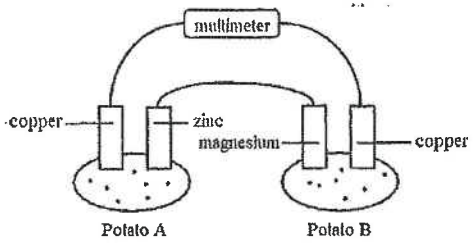
(2 marks)

(e) State TWO advantages of building a factory in which contact process is carried out near the chemical plant mentioned above.

(2 marks)

CE08_05

The diagram below shows a set-up with metal strips inserted in fresh potatoes. The multimeter reading in the set-up is +0.75V.



(a) State, with explanation, the direction of electron flow across the connecting wire between zinc strip and magnesium strip.

(1 mark)

(b) (i) Which metal strip in Potato B is anode? Why?

(ii) Write the half equation for the change occurred at the anode in Potato B.

(2 marks)

(c) Which two metal strips should be interchanged in order to increase the multimeter reading?

(1 mark)

(d) Explain why fresh potatoes should be used in the set-up.

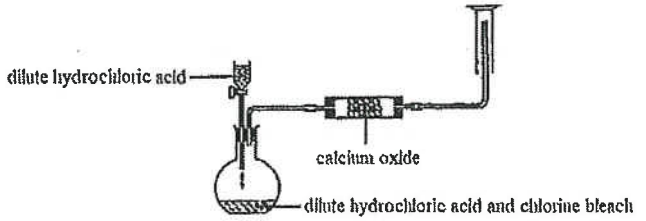
(1 mark)

(e) What will the multimeter reading be if the zinc strip in Potato A is replaced by another magnesium strip, while the other three metal strips remain unchanged?

(1 mark)

CE08_06

A student prepares dry chlorine gas by adding dilute hydrochloric acid to chlorine bleach using the following set-up:



(a) **There are two mistakes in the above** set-up. Complete the following table.

	Statet the mistake and explain why it is wrong	Suggest a method for correction
Mistake 1		
Mistake 2		

(4 marks)

(b) Suggest a safety precaution in performing the experiment other than wearing protective gloves and safety spectacles.

(1 mark)

(c) (i) Write an ionic equation for the reaction involved in the preparation of chlorine.

(ii) Explain, in terms of oxidation number, which species involved in the reaction in (i) is an oxidizing agent.

(3 marks)

CE09_06

Under suitable conditions, concentrated sulphuric acid can react with glucose and copper turnings respectively.

(a) State the observation and write a chemical equation for the reaction between concentrated sulphuric acid and glucose.

(2 marks)

(b) (i) State the observation and write a chemical equation for the reaction between hot concentrated sulphuric acid and copper turnings.

(ii) Hot concentrated sulphuric acid reacts with copper turnings inside a test tube. Describe how you should clean the test tube after the reaction.

(4 marks)

CE09_13

Electrolysis can be applied to enhance the corrosion resistance of iron. Describe the chemical principle involved in this application. Your description should include the chemical reactions involved, and the use of appropriate electrodes and electrolyte.
(Diagrams are NOT required.)

(6+3 marks)

CE10_03

A is an alkanol with three carbon atoms and one oxygen atom in its molecule. A reacts with acidified potassium dichromate solution to form compound B. In the presence of a small amount of concentrated sulphuric acid, A reacts with B to form compound C. C can be separated from the reaction mixture and has a pleasant smell.

(a) Write the structural formulae of A, B and C.

(3 marks)

(b) State the expected observation for the reaction of A with acidified potassium dichromate solution.

(1 mark)

(c) Suggest a method to separate C from the reaction mixture.

(1 mark)

(d) A compound has the same molecular formula as A but a different structure from A. Suggest a structural formula for this compound.

(1 mark)

CE10_05

The virus H1N1 can cause influenza. It has an oil-based coating.

(a) Washing hands with soapy detergent can help reduce influenza infection caused by the virus H1N1. Suggest why soapy detergent can destroy the virus.

(1 mark)

(b) Chlorine bleach can also help reduce influenza infection caused by the virus H1N1.

(i) What type of reaction is involved when chlorine bleach acts on the virus?

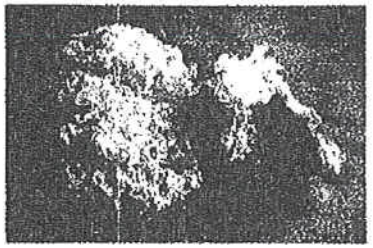
(ii) Explain why it is NOT appropriate to add acid to the chlorine bleach used in (i).

(iii) The concentration of sodium hypochlorite in a brand of chlorine bleach is 0.50 M. 1 volume of the bleach is diluted with 49 volumes of water. Calculate the molarity of sodium hypochlorite in the diluted bleach.

(4 marks)

CE10_07

Some people would use sulphur dioxide to treat food, such as the snow fungus shown below. They would make sulphur dioxide by burning sulphur in air.



(a) Suggest a purpose of treating snow fungus with sulphur dioxide.

(1 mark)

(b) Excessive intake of sulphur dioxide is hazardous to health. Suggest and explain how the sulphur dioxide in snow fungus can be removed before cooking.

(2 marks)

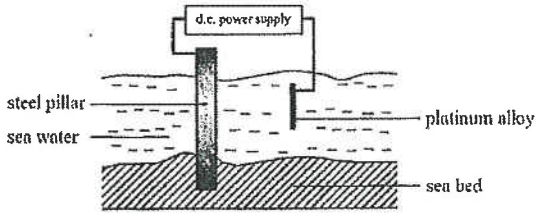
(c) Sulphur dioxide can also be obtained from the reaction of concentrated sulphuric acid with copper. Draw a labelled diagram to show the set-up in preparing and collecting sulphur dioxide from this reaction in a school laboratory.

(3 marks)

CE10_09

For question 9, candidates are required to give answers in paragraph form. For this question, 6 marks will be awarded for chemical knowledge and 3 marks for effective communication.

The following diagram shows a system used in some piers for slowing down the rusting of steel pillars.

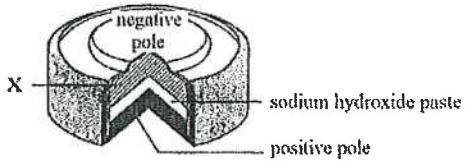


Design an experiment performed in a laboratory to show that such a system can slow down the rusting of steel in sea water. Labelled diagrams of the set-up, expected observation and the chemical principle involved should be included in your answer.

(6 + 3 marks)

CE10_11

The diagram below shows a kind of traditional 'button cell' making from mercury(II) oxide, zinc powder and sodium hydroxide paste:



When the cell is producing a current, the overall cell reaction can be represented by the following chemical equation:

$$Zn + HgO \longrightarrow ZnO + Hg$$

(a) Explain whether mercury(II) oxide or zinc powder should be at the region labelled X.

(1 mark)

(b) What is the function of the sodium hydroxide paste in the cell?

(1 mark)

(c) Why should this kind of button cell be banned in the market?

(1 mark)

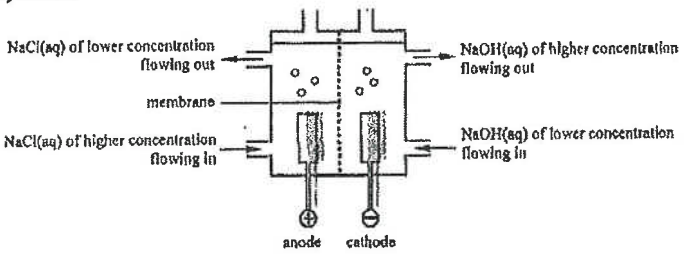
(d) Explain whether the cell can work if mercury(II) oxide is replaced by manganese oxide, while other materials remain unchanged.

(1 mark)

(e) Explain the change of the maximum voltage supplied by the cell if zinc powder is replaced by copper powder, while other materials remain unchanged.

(1 mark)

(f) The following diagram shows the electrolytic cell used in the manufacture of sodium hydroxide:



(i) Write a half equation for the anodic reaction.

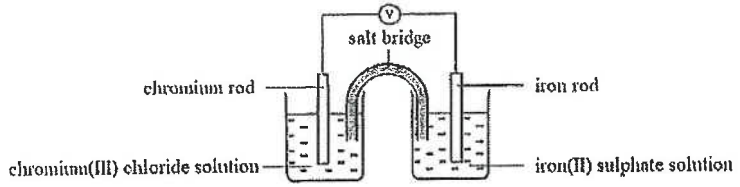
(ii) Write a half equation for the cathodic reaction.

(iii) It is known that only cations can pass through the membrane. Explain why sodium hydroxide solution of higher concentration is eventually obtained.

(4 marks)

CE11_04

The diagram below shows the set-up of a simple chemical cell. As time goes by, the colour of iron(II) sulphate solution in the beaker gradually fades out.



(a) State, with explanation, the direction of electron flow in the external circuit.

(2 marks)

(b) Write a half equation for the change occurring at the chromium rod.

(1 mark)

(c) (i) Chromium is one of the components of stainless steel. Suggest how chromium can prevent iron in stainless steel from rusting.

(ii) Coating chromium on iron-made objects can prevent the objects from rusting. Name this coating process and explain how this process can prevent rusting.

(3 marks)

CE11_05

(a) Sulphur dioxide reacts with sodium carbonate solution to form sodium hydrogensulphite ($NaHSO_3$). $NaHSO_3$ is commonly added to red wine for preventing the ethanol in the wine from turning to ethanoic acid.

(i) State the oxidation number of sulphur in $NaHSO_3$.

(ii) In terms of oxidation and reduction, explain how $NaHSO_3$ can prevent ethanol from turning to ethanoic acid.

(iii) 0.1 mole of sulphur dioxide is dissolved in excess sodium carbonate solution to form $NaHSO_3$ solution. Calculate the mass of $NaHSO_3$ formed. (Assume that sulphur dioxide is completely converted to $NaHSO_3$.)

(4 marks)

(b) Sodium hydrogensulphite ($NaHSO_3$) reacts with zinc to form sodium hydrosulphite ($Na_2S_2O_4$) and zinc hydroxide only. $Na_2S_2O_4$ is commonly used to bleach paper.

(i) Write a chemical equation for the reaction of $NaHSO_3$ with zinc.

(ii) What is the role of zinc in the reaction?

(2 marks)

CE11_10a

A very dilute sodium chloride solution is electrolyzed using inert electrodes for a long period of time.

(i) State the expected observation at the cathode. Explain your answer.

(ii) State ALL expected observations at the anode. Explain your answer.

(iii) Explain whether the resulting solution is acidic, alkaline or neutral.

(6 marks)

CE11_10b

A type of breathalyzer for investigating drink-driving consists of a chemical cell. The breath of the driver is allowed to get into contact with one of the electrodes of the cell. If the breath contains ethanol, the ethanol would be converted to ethanoic acid at this electrode and an electric current would be produced.

(i) Explain whether the above mentioned electrode acts as the anode or cathode of the chemical cell.

(ii) Write a half equation for the change occurring at this electrode.

(iii) Explain how this type of breathalyzer could estimate the amount of ethanol in the breath of the driver.

(3 marks)

AL95(II)_03 [OUT]

The electromotive force of a new zinc-carbon dry cell is 1.5 V. When it is producing an electric current, the following changes occur at the two electrodes:

Anode:	$Zn(s)$ reacts to give $Zn^{2+}(aq)$.
Cathode:	$MnO_2(s)$ and $NH_4Cl(aq)$ react to give $Mn_2O_3(s)$ and $NH_3(g)$.

(a) Write half equations for the reactions at the anode and at the cathode, and the equation for the overall reaction that occurs in the dry cell.

(3 marks)

(b) Explain why the electromotive force of the dry cell drops,

(1) after it has been used for some time;

(1.5 marks)

(2) after it has been stored for a long time without being used.

(1 mark)

ASL99(I)_07 (modified)

In a factory, steel handles are nickel-plated in an electroplating bath containing the following substances:

$NiSO_4$, Na_2SO_4 and H_3BO_3

(a) Write a half equation for the reaction occurring on the surface of a steel handle during the electroplating process.

(1 mark)

(b) State the function of each of the following substances in the electroplating bath:

(i) Na_2SO_4

(1 mark)

(ii) H_3BO_3

(1 mark)

(c) It is known that 4.50×10^{21} electrons have passed through the external circuit during the electroplating process. Assuming that the current efficiency is 100%, calculate the thickness of nickel deposited on the steel handle with a surface area of 20.0 cm^2.
(Relative atomic mass: Ni = 58.7; Density of nickel = 8.90 g cm^{-3};
Avogadro's constant = 6.02×10^{23} mol^{-1})

(3 marks)

(d) Suggest a method to remove nickel(II) ions from the waste electrolytic solution.

(1 mark)

ASL00(I)_02

In the laboratory, there are three bottles labelled A, B and C. Each bottle contains one of the following reagents:

$Cl_2(aq)$, NaI(aq) and KBr(aq)

Three tests were carried out using the reagents in the bottles. The results are summarized in the table below:

Test	Observation
Mixing reagent in bottle A with reagent in bottle B	No observable change
Mixing reagent in bottle A with reagent in bottle C	Mixture turned brown
Mixing reagent in bottle B with reagent in bottle C	Mixture turned brown

(a) Deduce which bottle contains $Cl_2(aq)$. Write the relevant chemical equations.

(3 marks)

(b) If hexane is also provided, suggest how you would carry out an experiment to identify the contents of the other two bottles.

(2 marks)

(c) State ONE safety precaution which should be taken when performing the experiment you have suggested in (b).

(1 mark)

ASL00(I)_03

The waste water from an electroplating factory contains chromium in the form of dichromate(VI) ions. In order to remove chromium from the waste water, green vitriol, $FeSO_4 \cdot 7H_2O$, was first added to reduce the dichromate(VI) ions to chromium(III) ions:

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

The chromium(III) ions formed were then precipitated as hydroxide.

(a) Suggest ONE reason why it is necessary to remove chromium from the waste water.

(1 mark)

(b) A sample of the waste water of volume 1.0×10^5 dm^3 contains 1.2×10^{-4} mol dm^{-3} of dichromate(VI) ions. Calculate the minimum mass of green vitriol required in the waste water treatment process.

(3 marks)

(c) Suggest an appropriate reagent for the precipitation reaction.

(1 mark)

(d) Name TWO chemicals present in the precipitate formed.

(2 marks)

ASL00(I)_05

Car bumpers made of steel are usually plated with chromium. Prior to the chromium-plating process, the bumpers are first coated with a layer of nickel.

(a) Why are the car bumpers coated with a layer of nickel prior to the chromium-plating process?

(1 mark)

(b) Give TWO properties of chromium which make it suitable for plating car bumpers.

(2 marks)

(c) A chromium-plating bath consists of an aqueous solution of CrO_3 and H_2SO_4. What is the function of H_2SO_4 in this bath?

(1 mark)

(d) A car bumper with a total surface area of 3.0×10^3 cm^2 is chromium-plated using a current of 35 A.

(i) A car bumper with a total surface area of 3.0×10^3 cm^2 is chromium-plated using a current of 35 A.
It is known that 4.5×10^{23} electrons have passed through the external circuit during the electroplating process. Assuming that the current efficiency is 100%, calculate the thickness of chromium deposited on the car bumper.
(Relative atomic mass: Cr = 52.0; Density of chromium = 7.2 g cm^{-3};
Avogadro's constant = 6.02×10^{23} mol^{-1})

(3 marks)

(ii) If a current much larger than 35 A is used, what would be the effect on the quality of the chromium layer plated onto the bumper?

(1 mark)

ASL00(II)_10 (modified)

(a) Write the electron arrangement of an iron atom in its ground state.

(1 mark)

(b) With reference to the structure of iron, explain why iron is an electrical conductor.

(2 marks)

(c) When iron is heated with dry chlorine, a dark brown solid **X** is formed.

(i) What is **X**?

(1 mark)

(ii) Explain why the chlorine used should be dry.

(1 mark)

(d) When an acidified solution of **X** is heated with some iron filings, a pale green solution **Y** is formed. Write a chemical equation for the reaction involved.

(1 mark)

(e) State the expected observation when sodium hydroxide solution is added separately to

(i) an acidified solution of **X**, and

(1 mark)

(ii) the pale green solution **Y**.

(1 mark)

ASL00(II)_11

Suggest a chemical test to distinguish one solution from the other in each of the following pairs. Equations should be given where appropriate.

$Na_2SO_3(aq)$ and $Na_2SO_4(aq)$

(3 marks)

AL01(I)_04

The overall reaction occurring in a Leclanche cell when delivering a current can be represented by the equation:

$$2MnO_2(s) + 2NH_4Cl(aq) + Zn(s) \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l) + ZnCl_2(aq)$$

(a) Write half equations for the anodic and cathodic reactions. [Same as DSE16_08c]

(2 marks)

(b) If the cell contains 25.0 g of $MnO_2(s)$, calculate the theoretical mass of Zn(s) that would be consumed for the $MnO_2(s)$ to undergo complete reaction.

(2 marks)

ASL01(I)_06 [Similar to DSE15_07(a)]

Steel objects are nickel-plated in an electroplating factory. Prior to the nickel-plating process, the steel objects are treated with an emulsion of kerosene and sodium hydroxide, then with dilute hydrochloric acid.

(a) Explain why the steel objects are treated with

(i) an emulsion of kerosene and sodium hydroxide,

(1 mark)

(ii) dilute hydrochloric acid.

(1 mark)

(b) A hollow cylindrical anode, which surrounds the steel object, is used in the nickel-plating process.

(i) Why is the anode in the shape of a hollow cylinder?

(1 mark)

(ii) Write the half equation for the anodic reaction.

(1 mark)

(c) Suggest one reason why the current efficiency of the nickel-plating process is not 100%.

(1 mark)

(d) State one environmental problem associated with the electroplating industry and suggest a possible solution.

(2 marks)

AL01(I)_07

Suggest a method to remove stains of colloidal sulphur in a conical flask. State the chemistry involved.

(2 marks)

AL02(II)_03

A hydrogen-oxygen fuel cell uses concentrated potassium hydroxide solution as electrolytes and nickel as electrodes.

(a) Draw a labeled diagram to show the design of the fuel cell.

(2 marks)

(b) Briefly describe how the cell works, giving the equations for the electrode half reactions.

(2 marks)

(c) State one advantage of using fuel cells over using batteries.

(1 mark)

ASL02(II)_11

Chlorine gas can be generated by the reaction of dilute hydrochloric acid with chlorine bleach.

(a) (i) Name the active ingredient in chlorine bleach.

(1 mark)

(ii) Write a chemical equation for the reaction of dilute hydrochloric acid with chlorine bleach.

(1 mark)

(b) The chlorine gas generated is bubbled into two test tubes, each containing one of the following solutions:

(i) iron(II) sulphate(VI) solution

(2 marks)

(ii) potassium bromide solution

(2 marks)

In each case, state an expected observation and write a chemical equation for the reaction involved.

ASL02(II)_12

In an electroplating factory, steel objects are plated with rhodium (Rh). Prior to the electroplating process, the steel objects are pretreated by immersing them firstly in a warm mixture of kerosene and sodium hydroxide solution, and subsequently in dilute hydrochloric acid. The steel objects are then plated with rhodium using an electrolytic bath containing an aqueous solution of a rhodium salt and dilute sulphuric(VI) acid.

(a) State the function of each of the following substances in the pretreatment process:

(i) Kerosene

(1 mark)

(ii) Sodium hydroxide solution

(1 mark)

(b) Why are the steel objects treated with dilute hydrochloric acid before they are electroplated?

(1 mark)

(c) Suggest TWO reasons why dilute sulphuric(VI) acid is used in the electrolytic bath.

(2 marks)

(d) It is known that 2.40×10^{23} electrons have passed through the external circuit during the electroplating process, causing 0.17 g of rhodium to be deposited on a steel object. If the current efficiency is 83%, calculate the oxidation state of rhodium in the rhodium salt. (Relative atomic mass: Rh = 102.9; Avogadro's constant = 6.02×10^{23} mol^{-1})

(3 marks)

(e) Suggest ONE reason why the current efficiency in the electroplating process is less than 100%.

(1 mark)

ASL03(I)_03

(a) (i) Arrange chlorine, bromine and iodine in order of increasing oxidizing power.

(1 mark)

(ii) Suggest how the above order can be established experimentally.

(2 marks)

(b) What is the meaning of the term 'disproportionation'? Illustrate your answer using a reaction involving chlorine.

(2 marks)

AL03(II)_04 (modified)

Carbon monoxide is a highly toxic gas and is also an indoor air pollutant. The level of indoor carbon monoxide can be monitored by the use of carbon monoxide detectors. One type of carbon monoxide detectors uses an electrochemical sensing method. The detector contains two inert electrodes coated with platinum which catalyzes the reaction of carbon monoxide with oxygen in the atmosphere. The anodic and cathodic reactions are as follows:

Anode:	$CO(g) + H_2O(l) \longrightarrow CO_2(g) + 2H^+(aq) + 2e^-$
Cathodic:	$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O(l)$

(a) Why is carbon monoxide toxic?

(2 marks)

(b) Outline how the carbon monoxide detector can detect the indoor carbon monoxide level.

(2 marks)

(c) Describe one situation in which the indoor carbon monoxide level would increase suddenly.

(1 mark)

ASL04(I)_02

For each of the following statements, state whether it is true or false. If you consider the statement to be false, then you have to give an example to support your answer.

Any halogen can exhibit more than one oxidation state in its compounds.

(1 mark)

AL04(II)_05

The active ingredient of household bleach is sodium chlorate(I) which is manufactured from chlorine.

(a) With the help of a chemical equation, suggest how sodium chlorate(I) can be obtained from chlorine.

(2 marks)

(b) Household bleach diluted by a volume ratio of 1 : 99 is widely used as an effective and inexpensive disinfectant during the recent SARS epidemic outbreak. A certain brand of household bleach contains 6.0 g of sodium chlorate(I) per 100 cm^3 of the bleach. Calculate the concentration of sodium chlorate(I), in mol dm^{-3}, in the diluted bleach.

(2 marks)

(c) Write the help of chemical equation(s), suggest why household bleach should not be used together with toilet cleans which contains sodium hydrogensulphate(V).

(2 marks)

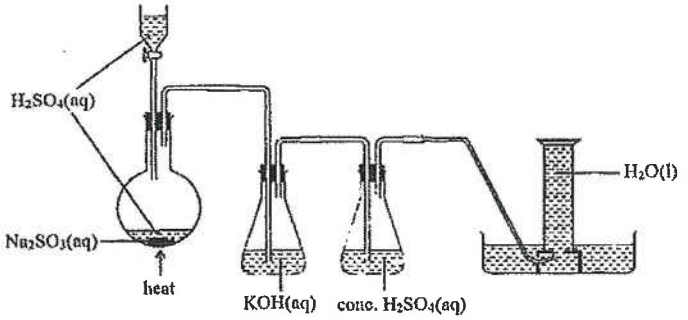
AL05(I)_07b

Sulphur dioxide can be prepared by reacting sodium sulphate(IV) solid with dilute sulphuric(VI) acid.

(i) Write the balanced equation for the reaction.

(1 mark)

(ii) A student suggested to use the set-up shown below to prepare a dry sample of sulphur dioxide from sodium sulphate(IV) solid.



Point out two mistakes in the above set-up, and suggest the corresponding rectifications.

(4 marks)

(iii) Suggest a chemical test for sulphur dioxide.

(2 marks)

ASL05(I)_07

An electroplating factory produces nickel-plated plastic handles for drawers. In the manufacturing process, the plastic handles are coated firstly with copper and then plated with nickel using an electrolytic bath containing nickel(II) sulphate(VI) and boric acid.

(a) (i) Why is it necessary to coat the handles with copper before they are nickel-plated?

(1 mark)

(ii) Suggest a reason for plating the handles with nickel.

(1 mark)

(b) Write the half equation for the cathodic reaction during nickel-plating process.

(1 mark)

(c) Boric acid is added to the electrolytic bath to maintain its pH within a range of 4 to 6.

(i) Why is it necessary to maintain the pH of the electrolytic bath within a small range?

(2 marks)

(ii) Suggest how boric acid functions in the bath.

(1 mark)

(d) Suggest why it is NOT recommended to use a high current density in the nickel-plating process. [Similar to DSE12_05]

(1 mark)

AL05(II)_02

The following three redox reactions take place at room temperature:

(1) $KMnO_4(s)$ reacts with concentrated HCl(aq) to give $Cl_2(g)$.

(2) $Fe^{2+}(aq)$ reacts with $Cl_2(g)$ to give $Fe^{3+}(aq)$.

(3) Acidified $KMnO_4(aq)$ is decolorized by $SO_2(g)$

(a) Write a balanced equation for each of the three reactions described above.

(3 marks)

(b) Is it possible to predict from the above information whether any reaction would occur in the following experiments? Explain your answer. If it is possible to predict a reaction, write the chemical equation for the reaction.

(i) Adding $FeSO_4(aq)$ to acidified $KMnO_4(aq)$.

(2 marks)

(ii) Passing $SO_2(g)$ into $Fe^{3+}(aq)$.

(2 marks)

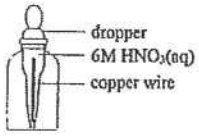
AL05(II)_04

The reaction of moderately concentrated nitric(V) acid (about 6 M) with copper gives nitrogen monoxide.

(a) Write the chemical equation for this reaction.

(1 mark)

(b) Instead of using a test tube, a teacher carried out a demonstration of the reaction using a reagent bottle as shown below. The dropper had a copper wire inside and was filled with 6 M $HNO_3(aq)$ as shown.



(i) Describe and explain the expected observations.

(3 marks)

(ii) Suggest one advantage of using this set-up in the demonstration.

(1 mark)

AL06(I)_03b

Write chemical equations for the following reactions.

(a) The reaction of S(s) with concentrated HNO_3 to give $SO_4^{2-}(aq)$ and $NO_2(g)$

(1 mark)

(b) The reaction of $Mn^{2+}(aq)$ with $O_2(g)$ under alkaline conditions to give $Mn(OH)_3(s)$

(1 mark)

(c) The disproportionation of $MnO_4^{2-}(aq)$ in water to give $MnO_4^-(aq)$ and $MnO_2(s)$

(1 mark)

ASL06(I)_03b

Account for each of the following statements.

(i) When concentrated sulphuric(VI) acid is added to sodium iodide solid, violet fumes are formed.

(2 marks)

(ii) Concentrated hydrochloric acid is used, not concentrated sulphuric(VI) acid, in flame tests.

(2 marks)

AL06(II)_04

The overall reaction for the discharging process of a lead-acid cell can be presented by the following equation:

$$PbO_2(s) + Pb(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \longrightarrow 2PbSO_4(s) + 2H_2O(l)$$

(a) Write the half equation of the cathode reaction and that of the anodic reaction during discharge for a lead-acid cell.

(2 marks)

(b) Based on the above information, explain why a lead-acid cell is rechargeable.

(1 mark)

(c) A lead-acid accumulator used in automobiles consists of six-lead-acid cells connect in series. Suggest why

(i) the state of charge of a lead-acid accumulator can be estimated by measuring the density of the acid in the accumulator, and

(1 mark)

(ii) an excessively high voltage should not be used to charge a lead-acid accumulator.

(1 mark)

AL07(I)_02

Write the Lewis structures of SO_4^{2-} and $S_2O_3^{2-}$ ions, and give the oxidation states of all sulphur atoms in each of these ions.

(4 marks)

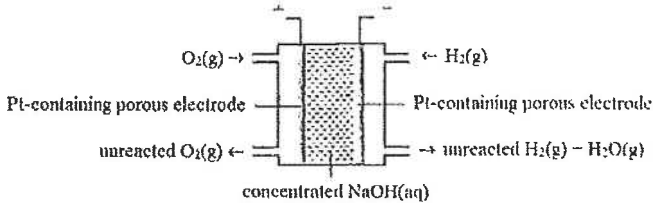
AL08(I)_01

Excess $NH_3(g)$ reacts with $Cl_2(g)$ in two steps to give $N_2(g)$ and $NH_4Cl(s)$. It is known that $NH_3(g)$ functions as reducing agent and as a base in the reaction. For each step, write the chemical equation and state the function of $NH_3(g)$.

(3 marks)

AL08(I)_02 [Similar to DSE13_10]

The diagram below shows the design of a hydrogen-oxygen fuel cell:



(a) Describe the working principle of the fuel cell.

(3 marks)

(b) One advantage of using hydrogen-oxygen fuel cells is that they do not emit air pollutants. Suggest ONE other advantage of using hydrogen-oxygen fuel cells.

(1 mark)

AL08(I)_02

Three reagent bottles each containing 0.5 M KI(aq), 14 M $HNO_3(aq)$ and 0.02 M $KMnO_4(aq)$ have been kept in the laboratory for a long time. The table below lists the observation for each of the bottles.

Solution	Observation
0.5 M KI(aq)	The liquid is pale yellow
14 M $HNO_3(aq)$	There are brown fumes above the yellow liquid.
0.02 M $KMnO_4(aq)$	There are brown stains on the interior wall of the bottle.

In each case, account for the observation and write the relevant chemical equation(s).

(6 marks)

ASL08(I)_02

Three reagent bottles each containing 0.5 M KI(aq), 14 M $HNO_3(aq)$ and 2 M NaOH(aq) have been kept in the laboratory for a long time. The table below lists the observation for each of the bottles.

Solution	Observation
0.5 M KI(aq)	The liquid is pale yellow
14 M $HNO_3(aq)$	There are brown fumes above the yellow liquid.
2 M NaOH(aq)	White powder is found around the stopper.

In each case, account for the observation and write the relevant chemical equation(s).

(6 marks)

AL09(I)_02

The compound $(CN)_2$ resembles the halogens in many ways and is often described as 'pseudohalogen'.

(a) Draw the Lewis structure of $(CN)_2$.

(1 mark)

(b) Deduce the physical state of $(CN)_2$ at room temperature.

(1 mark)

(c) Write the chemical equation for the reaction expected when $(CN)_2$ is added to dilute NaOH(aq) at room temperature.

(1 mark)

AL09(I)_07d

Suggest the most appropriate hazard warning label that should be displayed on a bottle of $NaClO_3(s)$.

(1 mark)

AL09(II)_03

Account for the following: "$FeSO_4(aq)$ gives a brown precipitate upon standing in air for a long time".

(2 marks)

AL10(I)_03

State the expected observation in the following experiments, and account for the observation with the aid of chemical equation(s).

Adding excess $H_2SO_4(aq)$ to $K_2CrO_4(aq)$, and then excess $FeSO_4(aq)$ to the resulting solution.

(3 marks)

AL10(I)_07b

State under what circumstances the following practice would be adopted and explain your answer.

"The use of concentrated H_3PO_4 instead of concentrated H_2SO_4 in the preparation of hydrogen halides from the corresponding sodium halides."

(2 marks)

AL12(I)_02

(b) (ii) What is the oxidation state of vanadium in $VOBr_2$?

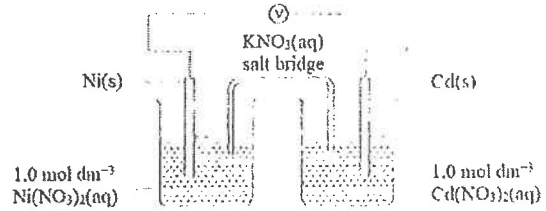
(1 mark)

(iii) Write a balanced equation for the reaction between $VO_2^+(aq)$ and Z(s) in an acidic medium to give $V^{2+}(aq)$ and $Zn^{2+}(aq)$.

(1 mark)

AL12(II)_07

(a) Consider the electrochemical cell shown below:



State and explain the direction of migration of $NO_3^-(aq)$ ions in the salt bridge.

(1 mark)

(b) Nickel-cadmium (NiCd) battery is a type of rechargeable battery. Its working principle is based on the following electrochemical reaction in an alkaline condition:

$$2NiO(OH)_2(s) + Cd(s) + 2H_2O(l) \longrightarrow 2Ni(OH)_2(s) + Cd(OH)_2(s)$$

(i) Write the half equation for the anodic reaction and that for the cathodic reaction when NiCd battery is producing current.

(2 marks)

(ii) NiCd battery maintains a steady voltage during discharge. Explain.

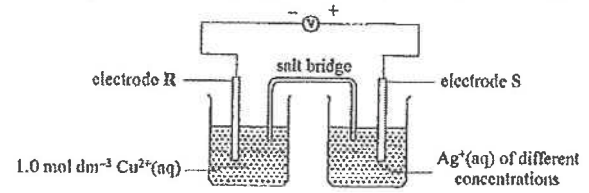
(1 mark)

(c) Nowadays, lithium-ion (Li-ion) batteries are more commonly used than NiCd batteries in portable electronic devices. Suggest ONE advantage of using Li-ion batteries over using NiCd batteries.

(1 mark)

AL13(I)_07

(a) The diagram below shows a set-up for investigating the effect on cell e.m.f. on the following system with changes in silver(I) ion concentration (from 10^{-4} to 10^{-1} mol dm^{-3}).



(i) Suggest suitable materials for use as electrodes R and S respectively.

(1 mark)

(ii) (I) State the function of the salt bridge.

(1 mark)

(II) Suggest why a freshly prepared salt bridge needs to be used when a new concentration of $Ag^+(aq)$ is used in the electrochemical cell.

(1 mark)

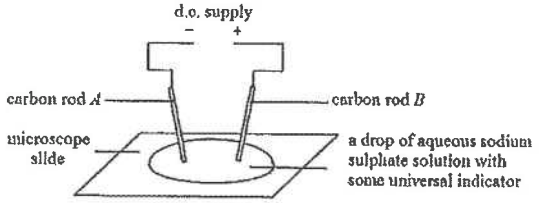
AL13(II)_02

(b) Purple $KMnO_4(aq)$ reacts with concentrated KOH(aq) to give green $K_2MnO_4(aq)$ and $O_2(g)$. Explain whether or not this reaction is a redox, and write the chemical equation for the reaction involved.

(2 marks)

DSE11SP_04

A student used the set-up shown below to conduct a microscale experiment on electrolysis.



(a) (i) The initial color of the drop shown above was green. State the color change of the liquid around carbon rod A after a current was passed through the circuit for some time. Explain your answer with the help of a half equation.

(3 marks)

(ii) A gas was liberated at carbon rod *B*. What was the gas? Explain its formation.

(2 marks)

(b) Some objects readily available in daily life contain carbon rods which can be used in this experiment. Suggest ONE such object.

(1 mark)

DSE11SP_09

There are four unlabelled reagent bottles each containing one of the white solids listed below:

ammonium chloride, ammonium nitrate, sodium hypochlorite and sodium sulphate

Suggest how you would carry out tests to distinguish the four solids from one another.

(6 marks + 1 mark)

DSE12PP_03

(a) Nitrogen reacts with magnesium to give magnesium nitride (Mg_3N_2).

(i) Draw the electron diagram of magnesium nitride, showing electrons in the outermost shells only.

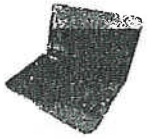
(1 mark)

(ii) Magnesium nitride reacts with water to give magnesium hydroxide and ammonia. Write the chemical equation for this reaction. Explain whether or not this reaction is a redox.

(2 marks)

DSE12PP_08

The photograph below shows a laptop computer which is powered by Direct Methanol Fuel Cell (DMFC).



The operation of DMFC is based on the following reaction under an acidic condition:

$$2CH_3OH(aq) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(l)$$

(a) Write half-equations for the anodic and cathodic reactions when DMFC is producing a current.

anodic reaction

cathodic reaction

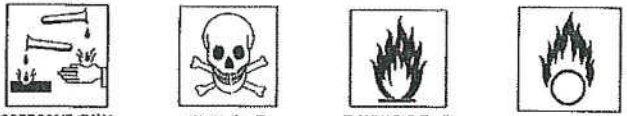
(2 marks)

(b) A concentrated aqueous methanol solution is used as the fuel in DMFC.

(i) Suggest why pure methanol is NOT used.

(1 mark)

(ii) Circle TWO of the following hazard warning labels that should be displayed on the container of a concentrated aqueous methanol solution.



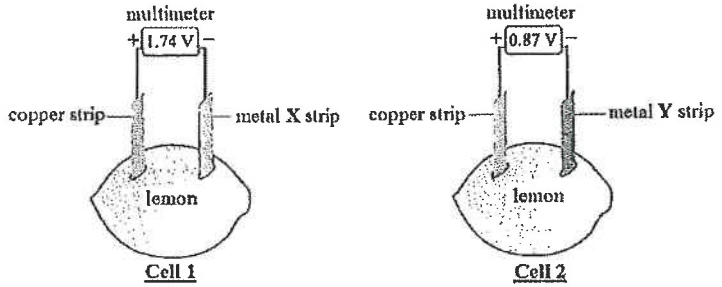
(1 mark)

(c) Would you expect DMFC to be widely used in powering laptop computers? Explain your answer.

(2 marks)

DSE12_03

Consider the information concerning the lemon cells shown in the diagrams below:



(a) What is the function of the lemons in these cells?

(1 mark)

(b) By completing the table below, arrange metal X, metal Y and copper in increasing order of reducing power.

Reducing power increasing →

(1 mark)

(c) For Cell 1, write the half equation for the change that occurs at:

(i) metal X strip (X is group II metal), and

(1 mark)

(ii) Copper strip.

(1 mark)

(d) For Cell 2, would the metal Y strip be the positive electrode if the copper strip is replaced with a silver strip? Explain your answer.

(1 mark)

DSE12_05

In order to prepare 50 dm^3 of 0.1 M $CuSO_4(aq)$, an inexperienced electroplating worker added the required exact amount of $CuSO_4 \cdot 5H_2O(s)$ to water in a plastic container. He then stirred the mixture with an iron rod until the $CuSO_4 \cdot 5H_2O(s)$ dissolved completely. Finally, he sent a sample of the solution to the Quality Control Laboratory for analysis, but found that the concentration of $CuSO_4(aq)$ was lower than 0.1 M.

(a) With the aid of a chemical equation, explain why the concentration of the $CuSO_4(aq)$ prepared was lower than 0.1 M.

(2 marks)

(b) The worker used the prepared $CuSO_4(aq)$ to coat a layer of copper on a metallic object by electrolysis. He uses the unreasonable high voltage, and found that some bubbles were formed on the object and the copper layer easily flaked off. [Similar to ASL05(I)_07d]

(i) Explain why copper can be coated on the metallic object by electrolysis.

(1 mark)

(ii) Suggest what the bubbles were, and explain why the copper layer easily flaked off.

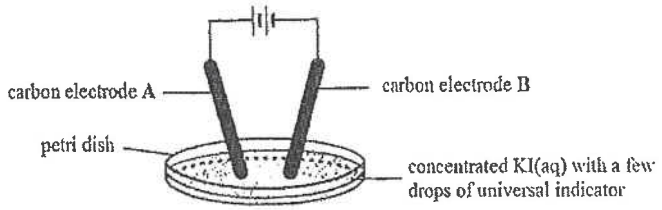
(2 marks)

(c) Draw a labelled diagram of the experimental set-up used in a laboratory for coating a layer of copper on a metallic object by electrolysis.

(3 marks)

DSE13_09 [Similar to CE02_09c, DSE11SP_04]

The diagram below shows the set-up used in an investigation on the electrolysis of concentrated potassium iodide solution:



(a) State and explain the expected observation around carbon electrode A during the electrolysis.

(2 marks)

(b) The solution near carbon electrode B gradually turned blue.

(i) Explain this observation.

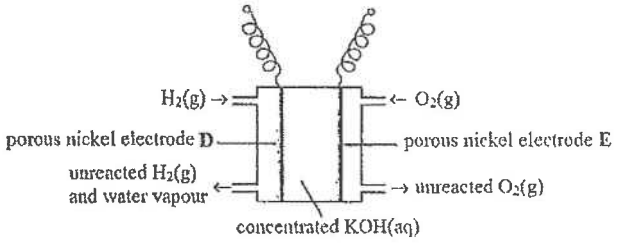
(2 marks)

(ii) Would there be any change in observation if carbon electrode B is replaced by a copper electrode in the investigation? Explain.

(1 mark)

DSE13_10 [Similar to AL08(I)_02]

The diagram below shows the structure of a hydrogen-oxygen fuel cell using concentrated potassium hydroxide solution as the electrolyte.



(a) An oxygen cylinder can be used to provided oxygen for the above fuel cell. From the hazard warning labels shown below, circle the label that should be displayed on the oxygen cylinder.

(1 mark)

(b) Write the half equation for the change occurring at each of the following electrodes when this fuel cell is producing a current.

Electrode D

Electrode E

(2 marks)

(c) Some people have the view that cars powered by hydrogen-oxygen fuel cells are more environmentally friendly than those powdered by petrol.

Comment on this view from each of the following aspects:

(i) Source of fuel

(1 mark)

(ii) The car emissions.

(1 mark)

DSE13_11

Safety airbags are important devices installed in vehicles. During a serious car crash, the chemicals in the airbag immediately react to release a large amount of gas. An airbag hence inflates instantly, protecting the passenger. The main chemicals in safety airbags are sodium azide (NaN_3) and potassium nitrate (KNO_3). The equations below show the reactions involved when an airbag is inflated.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

$$10Na(s) + 2KNO_3(s) \longrightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$$

(c) The main function of $NaN_3(s)$ is to produce $N_2(g)$ for inflating the airbags. Suggest why it is necessary to include $KNO_3(s)$ in the airbags.

(1 mark)

DSE14_05

Concentrated acids are common reagents found in laboratories.

(a) State a safety measure in handing concentrated acids in laboratories.

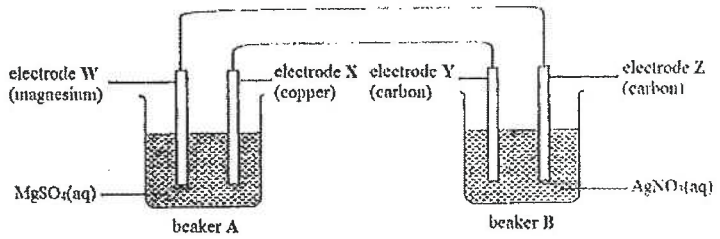
(1 mark)

(c) Explain how concentrated sulphuric acid, concentrated nitric acid and concentrated ethanoic acid can be distinguished by using copper granules.

(3 marks)

DSE14_08

The diagram below shows a set-up in which electrons are flowing through the electric wires. Moreover, one of the electrodes in beaker A is forming ions.



(a) State an expected observation at each of the following electrodes:

(i) Electrode W

(1 mark)

(ii) Electrode X

(1 mark)

(b) Write the half equation for the expected change at each of the following electrodes:

(i) Electrode Y

(1 mark)

(ii) Electrode Z

(1 mark)

(c) Complete the following table by filling in 'anode' or 'cathode' to describe the electrodes.

	Electrode W	Electrode Z
Anode / Cathode		

(1 mark)

(d) Predict, with reason, what would happen if the $MgSO_4(aq)$ in beaker A is replaced by ethanol.

(1 mark)

DSE14_09

Consider each of the experiments below and answer the questions that follow.

(b) Acidified potassium permanganate solution is added to sodium sulphite solution.

(i) State the expected color change.

(1 mark)

(ii) For the reaction leading to the color change,

(1) State the name of the type of reaction; and

(1 mark)

(2) Write the ionic equation for the reaction.

(1 mark)

DSE14_11

Vanadium is a transition metal, its chemical symbol is V. The formulae and the colors of three aqueous vanadium-containing ions are shown below:

Formula	$VO^{2+}(aq)$	$V^{3+}(aq)$	$V^{2+}(aq)$
Color	Blue	Green	violet

(a) Based on the given information, suggest TWO properties of vanadium to characterize it as a transition metal.

(1 mark)

(b) Vanadium also forms the ion $VO_2^+(aq)$. In the presence of acid, 1.0 mol of $VO_2^+(aq)$ ions and 1.0 mol of $SO_2(g)$ react completely to form $SO_4^{2-}(aq)$ ions and one of the above aqueous vanadium-containing ions.

(i) By considering the amount of electrons transferred, deduce the final color of the solution obtained.

(2 marks)

(ii) Write a chemical equation from the reaction in (i).

(1 mark)

DSE15_02

For each of the following experiments, state the expected observation, and write the chemical equation(s) for the reaction(s) involved.

(b) Adding sodium sulphite solution to acidified potassium dichromate solution until in excess.

(2 marks)

DSE15_04

Lead-acid accumulator is a secondary cell containing sulphuric acid. It is commonly used in starting up motor vehicle engines.

(a) What is meant by the term 'secondary cell'?

(1 mark)

(b) Suggest why a lead-acid accumulator is suitable for starting up motor vehicle engines.

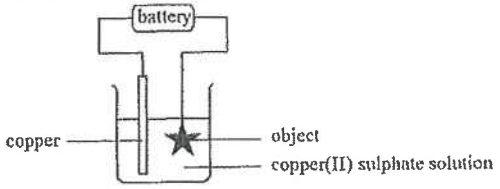
(1 mark)

(c) State one environmental impact that would be imposed from the disposal of lead-acid accumulators.

(1 mark)

DSE15_07 [Similar to ASL01(I)_06]

Refer to the set-up for electroplating an object shown in the diagram below:



(a) Explain why oily dirts on the object should be removed before electroplating.

(1 mark)

(b) Copper(II) sulphate is an electrolyte. What is meant by the term 'electrolyte'?

(1 mark)

(c) List ALL the ions existing in the solution

(1 mark)

(d) Explain why copper(II) ions are preferentially discharged during the electroplating process.

(1 mark)

(e) Write the half-equation of the change that occurs at the anode.

(1 mark)

(f) State the observable change, if any, in the solution during the electroplating process.

(1 mark)

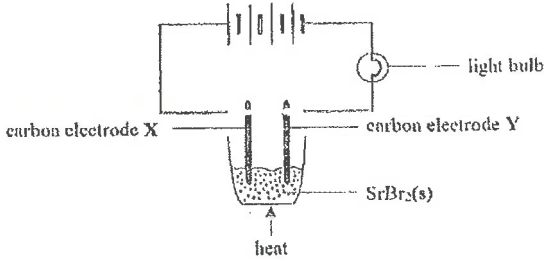
(g) It is known that 2.28×10^{22} electrons have passed through the external circuit during the electroplating process. Calculate the mass of copper that would theoretically be plated on the object. [Similar to ASL00(I)_05d]

(Relative atomic mass: Cu = 63.5; Avogadro's constant = 6.02×10^{23} mol^{-1})

(2 marks)

DSE16_08 [Similar to CE03_07a]

Consider the experimental set-up shown below:



(a) In the above experiment, the bulb lights up when the $SrBr_2(s)$ becomes molten.

(Atomic number of Sr = 38)

(i) State the observation at carbon electrode X.

(1 mark)

(ii) Write a half equation for the change that occurs at carbon electrode Y.

(1 mark)

(b) Explain why the experiment should be performed in a fume cupboard.

(1 mark)

(c) Zinc-carbon cells are used in the above experiment. The equation below shows the reaction that occurs in the zinc-carbon cells when the bulb lights up.

$$2MnO_2(s) + 2NH_4Cl(aq) + Zn(s) \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l) + ZnCl_2(aq)$$

(i) Deduce, in terms of change in oxidation number, the oxidizing agent in a zinc-carbon cell.

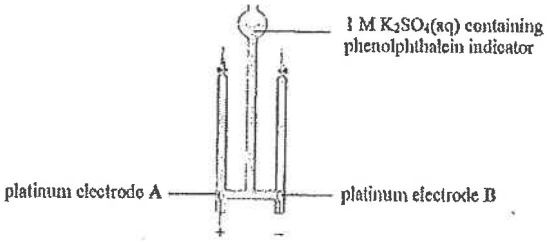
(2 marks)

(ii) Write a half equation for the change that occurs at the cathode in a zinc-carbon cell. [Same as AL01(I)_04a]

(1 mark)

DSE17_04

The diagram below shows a set-up for the electrolysis of a colorless solution of 1 M $K_2SO_4(aq)$ containing phenolphthalein indicator.



(a) State, with explanation, the expected observation around the following electrodes during the electrolysis:

(i) Electrode A

(ii) Electrode B

(3 marks)

(b) Write the equation of the overall reaction in the electrolysis.

(1 mark)

(c) Explain whether there are any changes in the expected observation around the following electrodes during the electrolysis if the 1 M $K_2SO_4(aq)$ is replaced with 1 M $H_2SO_4(aq)$.

(i) Electrode A

(ii) Electrode B

(3 marks)

DSE17_06

Concentrated sulphuric acid is a reagent commonly found in laboratories.

(a) Circle TWO hazard warning labels that should be displayed on a bottle of concentrated sulphuric acid:

(1 mark)

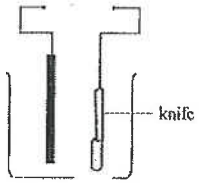
(c) With the help of a chemical equation, state the observation when hot concentrated sulphuric acid reacts with copper.

(2 marks)

DSE18_05

Electroplating and rust prevention are common applications of electrochemistry.

(a) The diagram below shows an incomplete set-up. Add suitable drawings and labels to the diagram for electroplating of silver onto the knife.



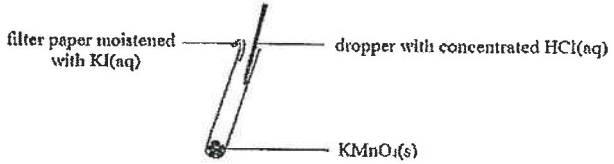
(2 marks)

(b) Suggest a method, besides painting or electroplating, that can prevent underground iron-made pipelines from rusting. Explain your answer.

(2 marks)

DSE18_08

Refer to the experimental set-up as shown below:



(a) HCl is a strong acid. What is meant by the term 'strong acid'?

(1 mark)

(b) When concentrated HCl(aq) is dropped into $KMnO_4(s)$, a yellowish green gas is formed.

(i) What is the yellowish green gas?

(1 mark)

(ii) Explain whether the reaction forming the yellowish green gas is a redox reaction.

(1 mark)

(c) With the aid of an ionic equation, state the expected observation when the yellowish green gas reaches the filter paper.

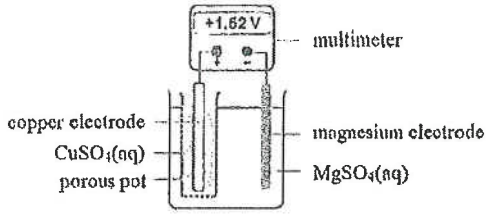
(2 marks)

(d) In consideration of laboratory safety, explain where the experiment should be performed.

(1 mark)

DSE19_07

Consider the chemical cell as shown below:



(a) (i) What is the function of the porous pot?

(1 mark)

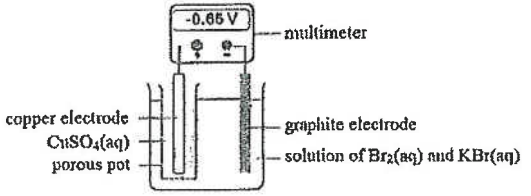
(ii) Deduce whether the electron flow through the external circuit from the magnesium electrode to the copper electrode.

(1 mark)

(iii) Write the hald equation for change that occurs at the cathode.

(1 mark)

Consider another chemical cell as shown below:



(b) (i) Write the half equation for the change that occurs at the graphite electrode.

(1 mark)

(ii) State the expected observation at the copper electrode.

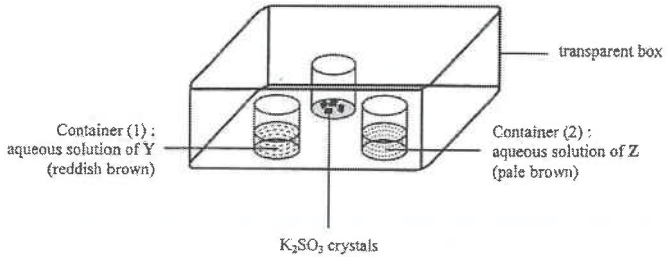
(1 mark)

(iii) Would the multimeter reading become more negative, less negative or remain unchanged if the solution of $Br_2(aq)$ and KBr(aq) is replaced by a solution of $I_2(aq)$ and KI(aq), while the other conditions remain unchanged? Explain your answer.

(1 mark)

DSE20_01cii

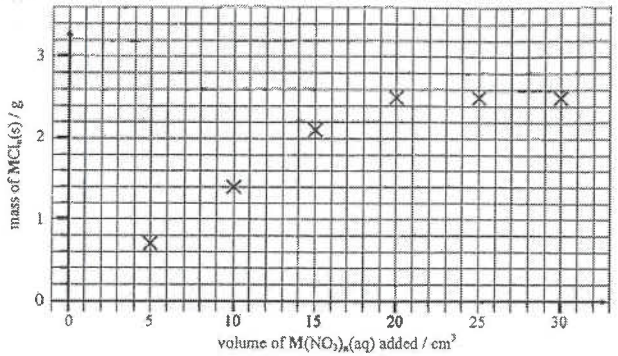
(c) An experiment for **Y** and **Z** is performed as shown in the set-up below. Dilute hydrochloric acid is added to the K_2SO_3 crystals, then the whole set-up is covered with a lid.



(ii) **State the expected observation in Container (1) and write an ionic equation for the reaction involved.**

DSE20_02

2. An experiment was performed to deduce the empirical formula of an insoluble chloride of a metal **M**. At room temperature, different volumes of a 0.50 mol dm^{-3} $M(NO_3)_n(aq)$ were added to six beakers each containing 50 cm^3 of 0.36 mol dm^{-3} HCl(aq). The $MCl_n(s)$ obtained in each beaker was filtered, washed, dried and weighed. The mass of $MCl_n(s)$ obtained and the corresponding volume of $M(NO_3)_n(aq)$ added were plotted on the graph below.



(a) Suggest why the masses of $MCl_n(s)$ for the last three points in the graph are the same.

(1 mark)

(b) (i) By **sketching** on the graph above, deduce the volume of the $M(NO_3)_n(aq)$ that can completely react with 50 cm^3 of 0.36 mol dm^{-3} HCl(aq).

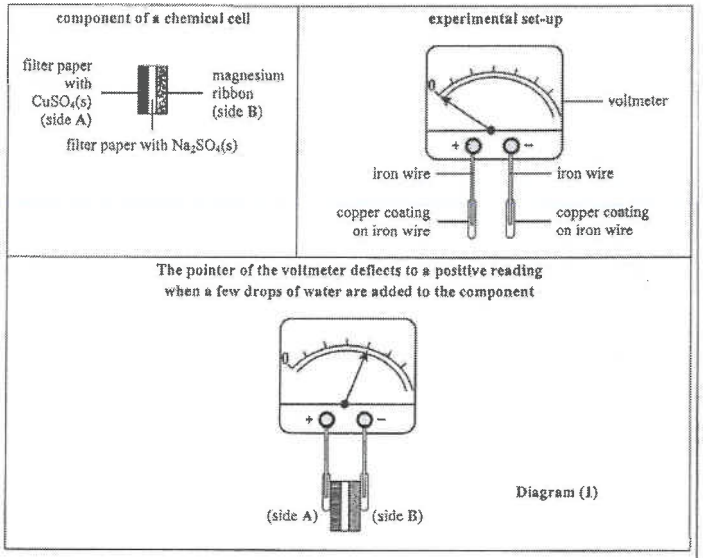
Volume of $M(NO_3)_n(aq)$ = _____ cm^3

(ii) Hence, calculate the number of moles of $M(NO_3)_n(aq)$ that can completely react with the HCl(aq).

2. (c) Determine, by calculation, the empirical formula of the chloride of **M**. Hence, deduce whether **M** would be silver or lead.

DSE20_06

6. The diagrams below show the component of a chemical cell, an experimental set-up and how the pointer of the voltmeter deflects when the set-up is connected to the component.



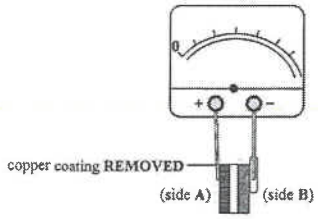
(a) Why does the pointer of the voltmeter deflect as shown when a few drops of water are added to the component ?

6. (b) Write the half equation for the change that occurs at each of the following electrodes when the pointer of the voltmeter deflects :

(i) anode

(ii) cathode

(c) Consider the following design modified from **Diagram (1)** by only removing the copper coating at side **A** :



Draw on **Diagram (2)** the expected position of the pointer of the voltmeter when water is added to the component.

(1 mark)

(d) In the design in part (c) above, a redox reaction occurs at side **A** when water is added to the component.

(i) Write a chemical equation for the reaction.

(ii) Name this type of reaction.

DSE21_02

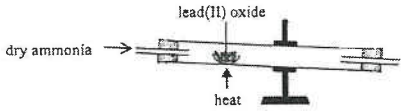
2. In the boxes (a) to (g) of the table below, fill in the information relating to the electrolysis of each electrolyte.

Electrolyte	Electrode	Observation at the electrode	Product at the electrode	Half equation OR Justification for the change occurred at the electrode
Molten $PbBr_2$	Graphite anode	(a) Observation:		
	Graphite cathode			(b) Half equation:
Very dilute $ZnCl_2$ solution	Platinum anode			(c) Half equation:
	Platinum cathode		(d) Product:	
Concentrated $CuSO_4$ solution	Copper anode		(e) Product:	
	Copper cathode	(f) Observation:		(g) Justification:

(7 marks)

DSE21_06(b),(c)

6. Lead can be obtained from lead(II) oxide using the experimental set-up shown below. Besides lead, nitrogen gas and steam are also formed.



(b) Write a chemical equation for the reaction. (1 mark)

(c) Explain which of the reagents is a reducing agent in the reaction. (1 mark)

DSE21_08

*8. You are provided with the following items :

lemon, multimeter, connecting wires, Zn strip, Cu strip, Ag strip

With the aid of a labelled diagram, suggest how you can perform an experiment to confirm (with explanation) the order of reducing power of metals as Zn > Cu > Ag.

(6 marks)

2022

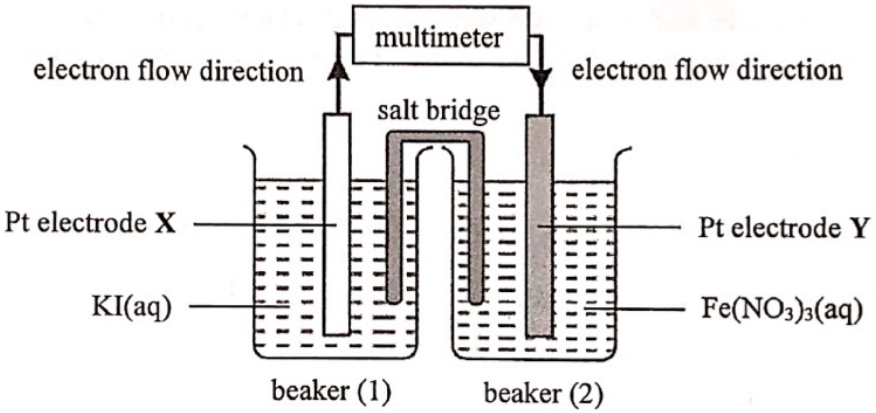
12. Consider the following chemical equation :

$$x\mathrm{NH_3(g)} + y\mathrm{O_2(g)} \rightarrow x\mathrm{NO(g)} + z\mathrm{H_2O(g)}$$

Which of the following combinations is correct ?

	x	y	z
A.	2	3	3
B.	2	3	6
C.	4	5	4
D.	4	5	6

13. Consider the following chemical cell :

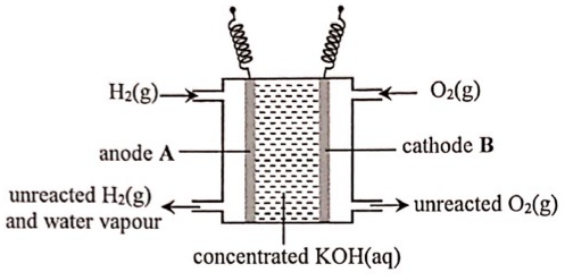


Which of the following statements is correct ?

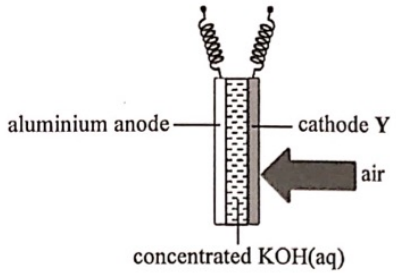
A. Electrode **X** is the cathode.
B. The solution in beaker (1) gradually turns brown.
C. The solution in beaker (2) gradually changes from pale green to yellow.
D. $Fe(NO_3)_3(aq)$ acts as a reducing agent.

2 (c) Explain whether the decomposition of $\mathbf{X_2O(s)}$ is a redox reaction.

5. The following hydrogen-oxygen fuel cell and aluminium-air cell are primary cells. Their simplified structures are shown below :



hydrogen-oxygen fuel cell



aluminium-air cell

(a) What is meant by the term 'primary cell' ?

(1 mark)

(b) For the above hydrogen-oxygen fuel cell,

(i) write the half equation for the change that occurs at anode **A**.

(ii) suggest one disadvantage of using this hydrogen-oxygen fuel cell.

(2 marks)

(c) In the above aluminium-air cell, oxygen in air reacts with water to form hydroxide ions at cathode **Y**.

(i) Write the half equation for the change that occurs at cathode **Y**.

(ii) The half equation for the change that occurs at the aluminium anode is as follows :

$$Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + 3e^-$$

Write the chemical equation for the overall reaction in the aluminium-air cell.

(iii) Suggest how aluminium can be obtained from aluminium oxide.

(3 marks)

Section C Analytical Chemistry

Answer **ALL** parts of the question.

3. (a) Answer the following short questions :

(i) Suggest a chemical test to show how $SO_2(g)$ and $CO_2(g)$ can be distinguished.

(2 marks)

(ii) Illustrate how $CH_3CH_2CHO(l)$ and $CH_3COCH_3(l)$ can be distinguished from their respective mass spectra.

(2 marks)

(iii) Which one of the following chemicals is the most suitable for drying ethyl butanoate ?

concentrated sulphuric acid, solid sodium hydroxide, anhydrous sodium sulphate

(1 mark)

Marking Scheme

MCQ

CE90_01	A	CE90_05	A	CE90_13	A	CE90_16	D
CE90_19	C	CE90_23	B	CE90_24	B	CE90_27	C
CE91_06	B	CE91_07	C	CE91_09	C	CE91_10	D
CE91_12	C	CE91_14	A	CE91_17	B	CE91_37	D
CE91_43	D	CE91_44	C	CE92_08	A	CE92_09	A
CE92_10	C	CE92_11	B	CE92_12	B	CE92_13	D
CE92_15	D	CE92_16	C	CE92_35	D	CE92_37	B
CE92_38	D	CE92_40	B	CE92_50	B	CE93_05	A
CE93_06	D	CE93_12	C	CE93_15	B	CE93_16	C
CE93_17	D	CE93_22	D	CE93_19	C	CE93_24	B
CE93_44	B	CE93_45	C	CE94_04	A	CE94_06	C
CE94_07	A	CE94_10	A	CE94_12	C	CE94_13	B
CE94_15	A	CE94_34	B	CE94_38	B	CE94_49	C
CE95_07	C	CE95_10	A	CE95_11	D	CE95_13	D
CE95_30	B	CE95_33	D	CE95_37	B	CE95_39	A
CE95_40	C	CE96_07	C	CE96_09	B	CE96_27	D
CE96_30	A	CE96_31	D	CE96_35	C	CE96_38	D
CE96_42	C	CE96_46	D	CE97_04	C	CE97_07	D
CE97_08	B	CE97_09	C	CE97_10	A	CE97_11	D
CE97_29	D	CE97_36	C	CE97_39	A	CE97_50	D
CE98_04	B	CE98_05	C	CE98_06	D	CE98_21	C
CE98_22	D	CE98_38	B	CE99_07	C	CE99_09	B
CE99_10	D	CE99_12	A	CE99_15	B	CE99_18	C
CE99_24	D	CE99_33	C	CE99_36	D	CE99_38	C
CE99_40	A	CE99_42	D	CE00_05	A	CE00_16	B
CE00_28	C	CE00_30	A	CE00_31	D	CE00_35	B
CE00_43	A	CE00_44	D	CE00_45	B	CE01_07	A
CE01_08	A	CE01_11	A	CE01_19	A	CE01_22	C
CE01_24	C	CE01_29	B	CE01_35	A	CE01_43	D
CE01_44	D	CE02_06	A	CE02_07	C	CE02_10	D
CE02_13	B	CE02_18	C	CE02_19	A	CE02_30	A
CE02_38	B	CE02_39	D	CE02_41	A	CE02_47	C
CE03_03	B (55%)	CE03_04	D (69%)	CE03_07	D (38%)	CE03_13	D (43%)
CE03_15	A (41%)	CE03_16	B (64%)	CE03_18	A (76%)	CE03_23	B (84%)
CE03_35	C	CE05SP_17	A	CE05SP_31	A	CE05SP_40	A
CE04_05	C (60%)	CE04_07	A (73%)	CE04_13	A (58%)	CE04_14	B (66%)
CE04_18	B (37%)	CE04_24	B (41%)	CE04_32	B (42%)	CE04_34	B (67%)
CE04_38	D (43%)	CE04_39	A (49%)	CE04_40	B (50%)	CE04_43	D (43%)
CE05_08	B (49%)	CE05_15	A (63%)	CE05_25	B (84%)	CE05_26	C (62%)
CE05_30	D (61%)	CE05_31	A (60%)	CE05_33	A (61%)	CE05_36	A (39%)
CE05_48	A (80%)	CE06_03	C (53%)	CE06_21	D (53%)	CE06_27	D (43%)

CE06_29	A (71%)	CE06_32	B (47%)	CE06_33	D (44%)	CE06_38	A (67%)
CE06_40	D (43%)	CE07_19	A (69%)	CE07_20	A (54%)	CE07_21	A (38%)
CE07_22	C (59%)	CE07_24	B (64%)	CE07_25	D (36%)	CE07_36	D (44%)
CE07_37	A (75%)	CE07_41	D (68%)	CE07_43	A (24%)	CE07_44	C (68%)
CE07_45	D (49%)	CE07_46	B (52%)	CE08_04	C (65%)	CE08_05	A (68%)
CE08_11	B (55%)	CE08_13	D (54%)	CE08_21	A (45%)	CE08_23	B (68%)
CE08_24	D (58%)	CE08_28	D (67%)	CE08_34	D (56%)	CE08_36	C (54%)
CE08_38	A (51%)	CE08_40	D (45%)	CE08_44	B (49%)	CE08_48	C (44%)
CE09_02	A (51%)	CE09_04	C (56%)	CE09_13	A (76%)	CE09_14	D (37%)
CE09_17	A (35%)	CE09_24	D (57%)	CE09_30	B (39%)	CE09_31	C (65%)
CE09_34	D (46%)	CE09_38	D (61%)	CE09_39	B (51%)	CE09_42	B (56%)
CE09_44	A (55%)	CE09_49	C (64%)	CE10_05	D (54%)	CE10_09	C (83%)
CE10_11	D (81%)	CE10_24	B (60%)	CE10_30	A (39%)	CE10_32	C (52%)
CE10_34	D (44%)	CE10_36	C (78%)	CE10_43	C (48%)	CE10_47	A
CE10_48	A (51%)	CE10_49	C (31%)	CE11_06	B (71%)	CE11_07	B (61%)
CE11_09	A (71%)	CE11_11	C (74%)	CE11_14	B (70%)	CE11_20	D (48%)
CE11_21	D (53%)	CE11_26	B (56%)	CE11_32	B (65%)	CE11_35	D (74%)
CE11_37	A (58%)	CE11_44	B (35%)	CE11_49	B (39%)	AL07(I)_03	B
ASL09(I)_03	C	ASL12(I)_03	A	ASL13(I)_03	D	DSE11SP_02	A
DSE11SP_12	B	DSE11SP_21	D	DSE11SP_23	A	DSE12PP_14	C
DSE12PP_22	A	DSE12PP_23	D	DSE12_06	B (74%)	DSE12_13	B (60%)
DSE12_18	C (77%)	DSE12_30	A (71%)	DSE13_16	C (65%)	DSE13_17	A (59%)
DSE13_06	B (51%)	DSE13_21	D (72%)	DSE13_22	D (49%)	DSE14_15	B (70%)
DSE14_11	C (61%)	DSE14_16	A (88%)	DSE14_20	A (63%)	DSE15_02	D (77%)
DSE15_06	A (72%)	DSE15_13	C (58%)	DSE15_16	D (38%)	DSE15_17	A (73%)
DSE16_11	A (84%)	DSE16_12	B (50%)	DSE16_13	C (51%)	DSE16_14	D (75%)
DSE16_15	B (36%)	DSE16_20	D (38%)	DSE16_23	C (77%)	DSE17_08	C (52%)
DSE17_04	B (76%)	DSE17_11	B (64%)	DSE17_15	B (83%)	DSE17_23	B (70%)
DSE18_12	B (79%)	DSE18_21	B (41%)	DES19_03	B	DES19_11	A
DES19_12	D	DES19_14	A	DES19_19	A		

DSE20_5 B
DSE20_9 A
DSE20_12 B
DSE20_14 C
DSE20_19 C

Structural Questions

CE90_02a(i)

(1) Oxidation: $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$

Reduction: $5e^- + 8H^+(aq) + MnO_4^-(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$

Overall: $2MnO_4^-(aq) + 16H^+(aq) + 10Cl^-(aq) \longrightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5Cl_2(g)$ [2]

OR, $2KMnO_4(aq) + 16HCl(aq) \longrightarrow 2KCl(aq) + 2MnCl_2(aq) + 8H_2O(l) + 5Cl_2(g)$

(2) $HCl \longrightarrow Cl_2$ (oxidation)

-1 0 [1]

$KMnO_4 \longrightarrow MnCl_2$ (reduction)

+7 +2 [1]

[The (+) and (-) sign for oxidation numbers is essential]

CE90_04a

(i) Electrode A. [1]

(ii) Hydrogen [1]

burns with a pop sound. [1]

(iii) At electrode A: $2H^+(aq) + 2e^- \longrightarrow H_2(g)$ [1]

At electrode B: $2Br^-(aq) \longrightarrow Br_2(aq) + 2e^-$ [1]

(v) Bromine [1]

Bromine is heavier (or denser) than the solution [1]

it sinks to the bottom [1]

(vi) (1) $OH^-(aq)$ and $Br^-(aq)$ [1]

OR, hydroxide ion and bromide ion

CE91_02c

(i) Tin metal [1]

(ii) The use of tin(II) is more economical because tin(II) gains two moles of electrons to become tin while tin(IV) gains four moles of electrons. [2]

(iii) Tin protects iron from rusting because tin prevents the contact of iron with water and air. [1]

(iv) No. Iron is more reactive than tin. [1]

Iron will lose electrons and corrode faster. [1]

CE92_05a

(i) B is the cathode because reduction occurs at B, $2H^+ + 2e^- \longrightarrow H_2$ [1]

(ii) Cathode (B) attracts Na^+ and H^+ ions. [1]

H^+ preferentially discharged because H is in a lower position than Na in the electrochemical series. [1]

Anode (A) attracts Cl^- and OH^- ions. [1]

Cl^- is preferentially discharged because the concentration of Cl^- is high.

Finally, as H^+ and Cl^- are preferentially discharged, [1]

Na^+ and OH^- are left. [1]

CE93_02a

(ii) To improve its appearance or to give it a shiny surface. [1]

(iii) To make the knob to conduct electricity. [1]

(iv) $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$ [1]

CE94_01e

(i) Sulphur dioxide [1]

SO_2 can turn acidified potassium permanganate solution from purple to colourless [1]

(ii) Any two: [2]

A brown solid is formed.

Metal X dissolves.

The blue solution fades.

CE94_07a

(i) (1) From Q to R, then S to P [1]

because reduction occurs at R ($Cu^{2+} + 2e^- \longrightarrow Cu$)

electrons must flow out from metal Q. [1]

(ii) (1) Colourless gas is formed at S. [1]

(2) The colour changes from blue to colourless. [1]

(iii) Set-up X is an electrochemical cell (to provide electricity). [1]

(iv) Q.

It is because electrons flow from Q to R. [1]

So Q loses electrons more readily than R. [1]

CE95_09b

(i) $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$ [1]

MnO_4^- is reduced because it receives electrons / the oxidation number of Mn changes from +7 to +2 / the oxidation number of Mn decreases. [1]

(ii) The solution turns (pale) brown / yellow. [1]

$2I^- \longrightarrow I_2 + 2e^-$ [1]

(iii) From KI solution to $KMnO_4$ solution / from right to left. [1]

(iv)

Oxidation:	$2I^-(aq) \longrightarrow I_2(g) + 2e^-$
Reduction:	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
Overall:	$2MnO_4^-(aq) + 16H^+(aq) + 10I^-(aq) \longrightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5I_2(g)$

[1]

OR, $2MnO_4^- + 16H^+ + 10I^- \longrightarrow 2Mn^{2+} + 8H_2O + 5I_2$

(v) (1) To allow migration (movement) of ions between the two beakers. [1]

(2) No. Sodium sulphite can be oxidized / react with permanganate ions. [1]

CE96_06a

(i) (1) (dirty) green precipitate / solid is formed [1]

$Fe^{2+}(aq) + OH^-(aq) \longrightarrow Fe(OH)_2(s)$ [1]

(2) No, because the reaction does not involve any change in oxidation number / there is no transfer of electron(s) [1]

(ii) (1) The purple solution is potassium permanganate / permanganate ions / manganese(VII) / $KMnO_4$ / $NaMnO_4$ / contains MnO_4^- ions [1]

(2) The solution changes colour from purple to yellow / brown.

Oxidation:	$Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$
Reduction:	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
Overall:	$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$

[2]

(iii) (1) Magnesium (Mg) / Zinc (Zn) / Aluminium (Al) [1]

(2) Any TWO of the following: [2]

Mg/ Zn/ Al/ metal dissolves.

Silvery (grey) powder deposit /

Colour of solution becomes paler (colourless)

Iron(II) sulphate acts as an oxidizing agent because the oxidation number of iron changes from +2 to 0 / decreases / Fe^{2+} ions accept electrons. [1]

CE96_06b

(i) A is 2M ammonia / 2M NH_3 [1]

Ammonia solution is alkaline. When ammonia ionizes in water to give OH^- which turns red litmus paper blue. $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ [1]

(ii) B is 2M nitric acid / 2M HNO_3 [1]

Oxidation:	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Reduction:	$3e^- + 4H^+(aq) + NO_3^-(aq) \longrightarrow NO(g) + 2H_2O(l)$
Overall:	$3Cu(s) + 8H^+(aq) + 2NO_3^-(aq) \longrightarrow 3Cu^{2+}(aq) + 2NO(g) + 4H_2O(l)$

[1]

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ [1]

Brown gas

(iii) (1) Add a piece of pH paper / a few drops of universal indicator to the reagent. [1]

(2) HCl will give a lower pH / a deeper red colour [1]

because HCl ionizes to a greater extent than CH_3COOH. HCl is a stronger acid / HCl has a higher concentration of H^+ [1]

OR (1) Add a piece of Mg ribbon / Zn granules / $CaCO_3(s)$ to the reagent.

(2) HCl will give gas bubbles at a faster rate

because HCl ionizes to a greater extent than CH_3COOH. HCl is a stronger acid / HCl has a higher concentration of H^+

OR (1) Measure the electrical conductivity of the solutions.

(2) HCl has a higher conductivity

because HCl ionizes to a greater extent than CH_3COOH. HCl is a stronger acid / HCl has a higher concentration of H^+

OR (1) Measure the pH of the solutions with a pH meter.

(2) HCl has a lower pH

because HCl ionizes to a greater extent than CH_3COOH. HCl is a stronger acid / HCl has a higher concentration of H^+

CE96_08b(iii)

(1) Copper (Cu) / nickel (Ni) [1]

Copper(II) / nickel(II) ions are bluish-green in colour. [1]

(2) Sulphur dioxide / SO_2 [1]

It can turn acidified (potassium) dichromate solution from orange to green. [1]

Oxidation:	$2H_2O(l) + SO_2(g) \longrightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$
Reduction:	$6e^- + 14H^+(aq) + Cr_2O_7^{2-}(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$
Overall:	$3SO_2(g) + 2H^+(aq) + Cr_2O_7^{2-}(aq) \longrightarrow 3SO_4^{2-}(aq) + 2Cr^{3+}(aq) + H_2O(l)$

OR, it can turn acidified (potassium) permanganate solution from purple to colourless.

Oxidation:	$2H_2O(l) + SO_2(g) \longrightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$
Reduction:	$5e^- + 8H^+(aq) + MnO_4^-(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
Overall:	$2H_2O(l) + 5SO_2(g) + 2MnO_4^-(aq) \longrightarrow 5SO_4^{2-}(aq) + 4H^+(aq) + 2Mn^{2+}(aq)$

OR, it can turn bromine water from brown to colourless.

Oxidation:	$2H_2O(l) + SO_2(g) \longrightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$
Reduction:	$2e^- + Br_2(aq) \longrightarrow 2Br^-(aq)$
Overall:	$2H_2O(l) + SO_2(g) + Br_2(aq) \longrightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2Br^-(aq)$

CE96_09b

(i) The solution contains mobile ions. [1]

(ii) A colourless gas (bubbles) is evolved. [1]

$4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$ [1]

(iii) Copper / Cu [1]

During the copper-plating process, the copper in the anode is oxidized to give Cu^{2+} ions. [1]

OR, $Cu \longrightarrow Cu^{2+} + 2e^-$ occurs at anode.

Concentration of Cu^{2+} ions in the electrolyte solution can be maintained. [1]

(iv) (1) To recover copper metal / To produce the loss of copper metal [1]

Cu^{2+} ions can cause water pollution / death of (harmful to) marine lives [1]

(2) 1 mole of Cu^{2+} ions react with 2 moles of NaOH [1]

OR, $Cu^{2+} + 2OH^- \longrightarrow Cu(OH)_2$

Concentration of Cu^{2+} ion

$$= \frac{3.5 \times 8}{20} \times \frac{1}{2} = 0.7\ M$$

[1]

CE97_04

Chemical knowledge

- Dissolve the nickel(II) sulphate crystals in the distilled water (in the beaker). [1]
- Connect the spoon and the nickel plate to the power supply with the spoon as the cathode and the nickel plate as the anode. [1]
- Immerse the spoon and the nickel plate in the nickel(II) sulphate solution. [1]

Observation (Any TWO of the following): [2]

- A layer of nickel (silvery / greyish metal) is deposited onto the spoon.
- The thickness of the nickel plate decreases.
- The colour of the nickel(II) sulphate solution remains unchanged.

Effective communication [3]

CE97_06a

(i) $Cr_2O_7^{2-}$ [1]

(ii) The sodium sulphate solution provides ions for the conduction of electricity / acts as an electrolyte to completes the circuit [1]

(iii) (1) The orange colour becomes paler / colourless / fades [1]

(2) Green / brown / purple colour was observed [1]

Explanation:

Under the influence of the electric field, cations in the deep blue solution are attracted to the negative pole (move to the left) and negative / $Cr_2O_7^{2-}$ ions are attracted to the positive pole (move to the right). [1]

OR, Under the influence of the electric field, the cations and anions are respectively attracted towards the negative and positive poles

The orange negative ions and the blue positive ions mix / meet at B to give the green colour. [1]

(iv) Reverse the polarity of the d.c. supply [1]

OR, connect the left hand electrode to the positive pole and the right hand electrode to the negative pole

Observation:

orange colour will appear at the left of A and blue colour will appear at the right of C. [1]

CE97_08a

(i) During electrolysis, both Cl^- and OH^- ions migrate towards the anode (positive electrode). [1]

Since a concentrated NaCl (brine) is used, the concentration of Cl^- ions is much higher than that of OH^-. [1]

Cl^- ions will be discharged at the anode to give chlorine. [1]

OR, $2Cl^- \longrightarrow Cl_2 + 2e^-$

(ii) (1) B / toxic [1]

(2) Chlorine can kill the bacteria / germs in water / sterilize water. [1]

CE97_08b

(ii) (1) Iron(II) sulphate (any iron(II) compound / sulphur dioxide / ethanol / potassium iodide / hydrogen sulphide) [1]

(2) Any one of the following:

For iron(II) sulphate (the iron(II) compound in (1))

Treat $Fe^{2+}(aq)$ with acidified potassium dichromate / in the presence of acid / H^+ ions. [1]

For SO_2

Bubble SO_2 into acidified potassium dichromate

(or place a piece of filter paper moistened with acidified potassium dichromate in SO_2 gas)

For ethanol

Heat/ reflux ethanol with acidified potassium dichromate

For KI

Treat KI(aq) with acidified potassium dichromate

For H_2S

Bubble $H_2S(g)$ into acidified potassium dichromate

(or place a piece of filter paper moistened with acidified potassium dichromate in H_2S gas)

(3) For Fe(II): Fe^{3+} / iron(III) ions [1]

For SO_2: $SO_4^{2-}(aq)$ / sulphate ions

For C_2H_5OH: CH_3COOH / ethanoic acid / CH_3CHO / ethanal

For KI: I_2 / iodine

For H_2S: S / sulphur

(iii) (1) $Cr^{2+} \longrightarrow Cr^{3+} + e^-$ [1]

(2) $O_2 + 4e^- + 4H^+ \longrightarrow 2H_2O$ [1]

(3) $O_2 + 4H^+ + 4Cr^{2+} \longrightarrow 4Cr^{3+} + 2H_2O$ [1]

(iv) making stainless steel [1]

chromium-plating [1]

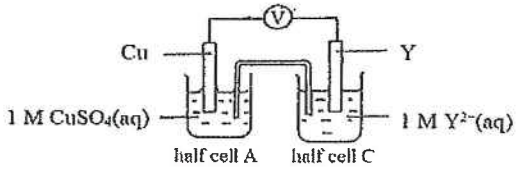
CE97_09b

(i) A solution containing the maximum amount of a solute (KNO_3) at a specified temperature. [1]

(ii) The strips of filter papers, after soaked with the saturated KNO_3 solution, is used as a salt bridge (to complete the circuit) [1]

(iii) (1) voltmeter / ammeter / multimeter / galvanometer [1]

(2) [2]



(1 mark for a correct diagram; 1 mark for labelling the half-cells and the voltmeter/ammeter/multimeter/galvanometer)

(iv) Reactivity: Cu < Y < X [1]

A more reactive metal loses electrons more readily than a less reactive metal. [1]

OR, electrons flow from a more reactive metal to a less reactive metal.

OR, electrons flow from X to Y and from Y to Cu.

(v) no observable change [1]

because Cu is less reactive than Y. [1]

CE98_02c

Brown colour of iodine fades / turns colourless [1]

Oxidation:	$H_2O(l) + SO_3^{2-}(g) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$
Reduction:	$2e^- + I_2(aq) \longrightarrow 2I^-(aq)$
Overall:	$H_2O(l) + SO_3^{2-}(g) + I_2(aq) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2I^-(aq)$

[1]

CE98_06b

(i) Alkaline-manganese cell. [1]

Silver oxide cell is not used because it is not of the right size. [1]

Zinc-carbon cell is not used because its voltage drops quite rapidly. [1]

(ii) No.

The shelf life of zinc-carbon cell is 1.5y and only 18 pieces can be consumed. 6 pieces will be wasted. [1]

The average price per cell used = \$49.9 / 18 = \$2.77

which is more expensive than the normal price of a zinc-carbon dry cell.

The price for 18 zinc-carbon cells = \$2.5 × 18 = \$45

which is cheaper than the price of the package. [1]

(iii) (1) **Electrode A** (zinc metal) because an oxidation occurs. [1]

(2)

Oxidation:	$Zn(s) + 2OH^-(aq) \longrightarrow ZnO(s) + H_2O(l) + 2e^-$
Reduction:	$Ag_2O(s) + H_2O(l) + 2e^- \longrightarrow 2Ag(s) + 2OH^-(aq)$
Overall:	$Zn(s) + Ag_2O(s) \longrightarrow ZnO(s) + 2Ag(s)$

[1]

CE98_09b

(i) Any TWO of the following: [2]

Sodium melts into a silvery ball / dashes around on the surface of water / floats on surface of water.

Sodium burns with a yellow flame.

Colourless gas evolved.

(ii) Open-ended question

Experiment II because sodium metal is highly reactive, it is dangerous to handle sodium metal. The reaction in experiment I is too violent and difficult to control. [1]

OR, Experiment I because a sodium hydroxide solution with high purity can be obtained.

(iii) (1) Na occupies a higher position than H in the electrochemical series / H^+ is more readily to receive electron than Na^+. [1]

(2) At anode: $2Cl^- \longrightarrow Cl_2 + 2e^-$

At cathode: $2H^+ + 2e^- \longrightarrow H_2$ [1]

Overall: $2Cl^- + 2H^+ \longrightarrow Cl_2 + H_2$

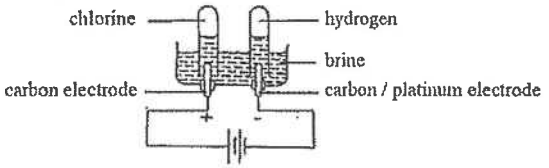
Equal number of moles of Cl_2 and H_2 will be liberated during electrolysis

Under the same temperature and pressure, equal no. of moles of gases occupy the same volume.

Theoretical volume of chlorine liberated = 50.0 cm^3 [1]

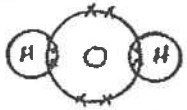
(3) After removal of Cl^- and H^+, only $Na^+(aq)$ and $OH^-(aq)$ ions remain in the solution. [1]

(iv) Labelled diagram of laboratory set-up [3]



(1 mark for labelling the two electrodes; 1 mark for showing the collection of gaseous products at the electrodes; 1 mark for labelling the correct products.)

CE99_06a

(i) 

[1]

(iii) (1) Provide mobile ions to increase the electrical conductivity of water. [1]

(2) Platinum / carbon (graphite) [1]

(3) $4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$ [1]

(4) H_2 : burn with a 'pop' sound [1]

O_2 : relights a glowing splint [1]

CE99_08a

(i) $Zn \longrightarrow Zn^{2+} + 2e^-$ [1]

(ii) (1) Acts as a conductor of electricity / cathode / positive pole / electrode [1]

(2) Acts as an oxidizing agent to remove hydrogen produced. [1]

(iii) Warm the paste with NaOH(aq) in order to change NH_4^+ ion to NH_3. [1]

Evolution of a gas (ammonia) [1]

which turns moist pH paper (red litmus) from red to blue. [1]

OR, Gives white fumes with HCl(g) indicate the presence of NH_4^+.

(iv) Open-ended question:

Yes, zinc-carbon cells will produce more (solid) wastes [1]

because zinc-carbon cells are not rechargeable. [1]

OR, No, cadmium / cadmium compounds are toxic and disposal of Ni-Cd cells can cause pollution problems.

(v) $Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$ [1]

$2e^- + NiO_2 + 2H_2O \longrightarrow Ni(OH)_2 + 2OH^-$ [1]

CE00_06a

(i) (1) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$ [1]

(2) manufacture of sulphuric acid / ammonium sulphate / fertilizers / bleach / food preservatives [1]

(ii) Dissolve ZnO in sulphuric acid. [1]

(iii) (1) Add zinc / magnesium / aluminium to displace ions of less reactive metals [1]

(2) Zn^{2+} ions will be preferentially discharged and ions of more reactive metals will remain in the solution [1]

(3) anode : $4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$ [1]

cathode : $Zn^{2+} + 2e^- \longrightarrow Zn$ [1]

(iv) making electrodes (anode) in zinc-carbon cell / galvanized iron / brass [1]

CE01_07c

(i) Gold has strong metallic bond between atoms. [1]

Diamond has a covalent network structure and strong covalent bonds exist between carbon atoms. [1]

(ii) 18-carat gold is stronger / not easily deformed [1]

(iii) (1) Copper / Cu [1]

because Cu^{2+} ions are blue / green [1]

Oxidation:	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Reduction:	$e^- + 2H^+(aq) + NO_3^-(aq) \longrightarrow NO_2(g) + H_2O(l)$
Overall:	$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \longrightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$ [1]

OR, $Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

Alternative answer:

Nickel / Ni

because Ni^{2+} ions are green

Oxidation:	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$
Reduction:	$e^- + 2H^+(aq) + NO_3^-(aq) \longrightarrow NO_2(g) + H_2O(l)$
Overall:	$Ni(s) + 4H^+(aq) + 2NO_3^-(aq) \longrightarrow Ni^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$

OR, $Ni + 4HNO_3 \longrightarrow Ni(NO_3)_2 + 2NO_2 + 2H_2O$

(iii) (2) Brown gas evolves / The piece of gold is partially dissolved. [1]

CE01_08a

(ii) (2) **Both** Br_2 and Cl_2 can react with $SO_3^{2-}(aq)$ [1]

Oxidation:	$H_2O(l) + SO_3^{2-}(aq) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$
Reduction:	$2e^- + Br_2(aq) \longrightarrow 2Br^-(aq)$
Overall:	$H_2O(l) + SO_3^{2-}(aq) + Br_2(aq) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2Br^-(aq)$ [1]

OR,

Oxidation:	$H_2O(l) + SO_3^{2-}(aq) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$
Reduction:	$2e^- + Cl_2(aq) \longrightarrow 2Cl^-(aq)$
Overall:	$H_2O(l) + SO_3^{2-}(aq) + Cl_2(aq) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq)$

Alternative answers:

Both Br_2 and Cl_2 can react with KI(aq)

Oxidation:	$2I^-(aq) \longrightarrow I_2(aq) + 2e^-$
Reduction:	$2e^- + Br_2(aq) \longrightarrow 2Br^-(aq)$
Overall:	$2I^-(aq) + Br_2(aq) \longrightarrow I_2(aq) + 2Br^-(aq)$

OR,

Oxidation:	$2I^-(aq) \longrightarrow I_2(aq) + 2e^-$
Reduction:	$2e^- + Cl_2(aq) \longrightarrow 2Cl^-(aq)$
Overall:	$2I^-(aq) + Cl_2(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$

CE01_09

(a) (i) oxygen [1]

(ii) relights a glowing splint [1]

(b) (i) use a solution of sodium chloride with a higher concentration / increasing the concentration of Cl^- ions in the electrolyte. [1]

(ii) At cathode : $2H^+(aq) + 2e^- \longrightarrow H_2(g)$

A anode: $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$ [1]

Equal no. of moles of H_2 and Cl_2 will be liberated during the electrolysis

Under the same temperature and pressure, equal no. of moles of all gases occupy the same volume. [1]

So, ratio of theoretical volumes of $H_2 : Cl_2 = 1 : 1$ [1]

(iii) Chlorine dissolves in water [1]

$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$ [1]

OR, Some of the chlorine produced reacts with the hydroxide ions formed during electrolysis.

$Cl_2 + 2OH^- \longrightarrow Cl^- + OCl^- + H_2O$

Volume of Cl_2 collected is smaller than the theoretical volume.

CE01_09c

(i) Copper(II) oxide / CuO [1]

(ii) Any TWO of the following: [2]

Effervescence / gas bubbles / misty fumes

Liquid in tube A turns blue / green

Copper wire dissolves.

Equation:

$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$ [1]

Oxidation:	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Reduction:	$2e^- + 4H^+(aq) + SO_4^{2-}(aq) \longrightarrow SO_2(g) + 2H_2O(l)$
Overall:	$Cu(s) + 4H^+(aq) + SO_4^{2-}(aq) \longrightarrow Cu^{2+}(aq) + SO_2(g) + 2H_2O(l)$

(iii) Blue litmus solution turns red [1]

because SO_2 dissolves in water to give an acidic solution [1]

(iv) To absorb excess SO_2 / prevent SO_2 to escape into air [1]

because SO_2 is toxic / harmful to the respiratory system [1]

CE02_02

(b) **The colour of the** potassium permanganate solution changes from purple to yellow. [1]

Oxidation:	$Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$
Reduction:	$5e^- + 8H^+(aq) + MnO_4^-(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
Overall:	$5Fe^{2+}(aq) + 8H^+(aq) + MnO_4^-(aq) \longrightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$ [1]

(c) The solution changes from colourless to brown / orange / yellow [1]

Oxidation:	$2Br^-(aq) \longrightarrow Br_2(aq) + 2e^-$
Reduction:	$2e^- + Cl_2(aq) \longrightarrow 2Cl^-(aq)$
Overall:	$2Br^-(aq) + Cl_2(aq) \longrightarrow Br_2(aq) + 2Cl^-(aq)$ [1]

CE02_03

(b) Manganese(IV) oxide [1]

It reacts with $H_2(g)$ which produced at the cathode / It acts as an oxidizing agent. [1]

CE02_04

Chemical knowledge

Position of ion in the electrochemical series [2]

If carbon / platinum / copper is used as the cathode, Cu^{2+} ions instead of H^+ ions will be discharged because Cu^{2+} occupies a lower position in the electrochemical series.

In the electrolysis of dilute $CuCl_2(aq)$ using carbon / platinum as anode, OH^- ions instead of Cl^- ions will be discharged because OH^- occupies a higher position in the electrochemical series.

Concentration of ion [2]

In the electrolysis of very dilute $CuCl_2(aq)$ using carbon / platinum as anode, OH^- ions will be discharged / O_2 is liberated at the anode. If concentrated $CuCl_2(aq)$ is used, Cl^- ions will be discharged / chlorine gas will be liberated instead.

Nature of electrode [2]

If carbon / platinum is used as the anode, Cl_2 / O_2 will be liberated at the anode

$4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e^-$

If copper is used as the anode, the anode will dissolve.

$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$

Effective communication [3]

CE02_06a

(iii) It contains mobile ions (Mg(l) and Cl(l)). [1]

CE02_09c

(i) (1) violet / purple / blue [1]

H^+ is discharged at carbon rod A (cathode)

$2H^+ + 2e^- \longrightarrow H_2$ [1]

OH^- concentration increases around carbon rod A / concentration of $OH^-(aq)$ is higher than that of $H^+(aq)$ [1]

(2) oxygen [1]

OH^- is discharged at carbon rod B (anode) [1]

$4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$

(ii) pencils / zinc-carbon cells [1]

(iii) Any TWO of the following: [2]

save chemicals / reduce the cost of chemicals (or laboratory equipment) used

reduce chance of chemicals hazards

reduce chemical wastes produced / environmental problems

shorten the time required for conducting an experiment

require less working space for carrying out an experiment

CE03_04

Chemical knowledge

<u>Similarities in chemical properties:</u>

- Sulphuric acid as an acid – H_2SO_4 ionizes in water to give $H_3O^+(aq)$ ions [1]

  Examples: reaction with alkali (base) to give salt and water only (neutralization) [1]

  $H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + H_2O$

  Reaction with carbonate (hydrogencarbonate) to give carbon dioxide, action on acid-base indicator, etc.

  $H_2SO_4 + NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$

<u>Differences in chemical properties:</u>

- The oxidizing power of concentrated H_2SO_4 is much stronger than that of dilute H_2SO_4 [1]

  Example: conc. H_2SO_4 can oxidize metal/non-metal/compounds. It is commonly reduced to SO_2. [1]

  e.g. $Cu + H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$

Oxidation:	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Reduction:	$2e^- + 4H^+(aq) + SO_4^{2-}(aq) \longrightarrow SO_2(g) + 2H_2O(l)$
Overall:	$Cu(s) + 4H^+(aq) + SO_4^{2-}(aq) \longrightarrow Cu^{2+}(aq) + SO_2(g) + 2H_2O(l)$

- Conc. H_2SO_4 can act as a dehydrating agent but dilute H_2SO_4 cannot. [1]

  Examples: conc. H_2SO_4 can dehydrate $CuSO_4.5H_2O$/sugar [1]

  e.g. $CuSO_4.5H_2O(s) \xrightarrow{\text{conc. } H_2SO_4} CuSO_4(s) + 5H_2O(l)$

  blue white

  e.g. $C_{12}H_{22}O_{11} \xrightarrow{\text{conc. } H_2SO_4} 12C + 11H_2O$

- Conc. H_2SO_4 is a non-volatile acid but dil. H_2SO_4 is not.

  Examples: conc. H_2SO_4 is used in the preparation of hydrochloric acid and nitric acid.

  e.g. $H_2SO_4 + NaCl \longrightarrow NaHSO_4 + HCl$

  $H_2SO_4 + NaNO_3 \longrightarrow NaHSO_4 + HNO_3$

Effective communication [3]

CE03_06c

(i) Yes

Oxidation number of Cu decreases from +2 to 0 [1]

Oxidation number of N increases from –3 to 0 [1]

(ii) $3CuO + 2NH_3 \longrightarrow 3Cu + 3H_2O + N_2$ [1]

CE03_07a

(i) Brown / orange / red fumes evolved [1]

$2Br^- \longrightarrow Br_2 + 2e^-$ [1]

(ii) Bromine / lead(II) bromide / lead is toxic [1]

(Accept bromine vapour is corrosive.)

(iii) The light bulb gradually goes out / becomes dim. [1]
At lower temperatures, movement of ions slows down. Therefore, a smaller current flows through the external circuit. [1]
When molten lead(II) bromide becomes solid, there is no translational motion of ions / ions are no longer mobile. Thus no current flow through the external circuit. [1]

CE04_02c

Heat the acids with copper metal [1]
Only $HNO_3(aq)$ gives gas bubbles / brown fumes / a blue solution. [1]
OR, Add the acids to Zn(s) / Fe(s) / Mg(s)
$HNO_3(aq)$ gives a colourless gas which subsequently turns brown; $H_2SO_4(aq)$ gives a colourless gas only.
OR, Treat the acids with $BaCl_2(aq)$ / $Pb(NO_3)_2(aq)$ / $SrCl_2(aq)$ / $CaCl_2(aq)$.
Only $H_2SO_4(aq)$ gives a white precipitate.

CE04_06a

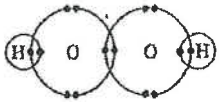
(i) platinum (Pt) / carbon (C) / graphite [1]
(ii) cathode: $2H^+ + 2e^- \longrightarrow H_2$ [1]
anode: $2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$ / $4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$ [1]
(iii) to increase electrical conductivity / to provide mobile ions [1]
(iv) Yes
volume of hydrogen collected : volume of oxygen collected = 2 : 1
∴ In water, hydrogen and oxygen combine in mole ratio of 2 : 1 [1]
As the atomicity of hydrogen and oxygen are both 2, [1]
∴ Formula of water is H_2O

CE03_09a

(i) From A to B
Sodium has a higher tendency to donate electrons than sulphur. [1]
At electrode A:
$Na \longrightarrow Na^+ + e^-$ [1]
At electrode B:
$S + 2e^- \longrightarrow S^{2-}$ [1]
(ii) To separate sodium from sulphur so as to prevent them from direct reaction. [1]
To allow the passage of ions between the two compartments to balance the charges. [1]
(iii) To keep sodium and sulphur in molten state / to keep mobility of particles inside the cell [1]
(iv) Sodium-sulphur cells can store up electricity produced in power station. [1]
When there is a surplus of electricity generated, the cell is charged up. [1]
When the consumption of electricity is greater than its production, the electricity that has been stored up in the cell will be used.

CE04_06b

(i) −1 [1]
(ii) [1]



(iii) (1) $H_2O_2(aq) + 2e^- + 2H^+(aq) \longrightarrow 2H_2O(l)$ [1]
(2) colour changes from pale green to yellow / brown [1]

Oxidation:	$Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$
Reduction:	$H_2O_2(aq) + 2e^- + 2H^+(aq) \longrightarrow 2H_2O(l)$
Overall:	$H_2O_2(aq) + 2Fe^{2+}(aq) + 2H^+(aq) \longrightarrow 2Fe^{3+}(aq) + 2H_2O(l)$ [1]

CE04_07c

(i) The mass of the beaker and its contents increases. / The volume of liquid in the beaker increases. [1]
Conc. H_2SO_4 absorbs water from the atmosphere / has a high affinity for water / is hygroscopic. [1]

CE05_04

(a) Chromium-containing substances are harmful to marine life / toxic / poisonous. [1]
(b) (i) $SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e^-$ [1]
(ii) $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$ [1]
(iii) $Cr_2O_7^{2-} + 8H^+ + 3SO_3^{2-} \longrightarrow 2Cr^{3+} + 4H_2O + 3SO_4^{2-}$ [1]
(c) $NaOH$ / Na_2CO_3 / NH_3 / $Ca(OH)_2$ [1]

CE05_07

Chemical knowledge [6]
Insert two of the metal strips into the lemon to form a chemical cell.
Measure the voltage of the cell using the multimeter.
Complete the electric circuit.
Control variables in the experiment such as:
– the size of the strips
– the separation / position between strips should be the same in each trial
– the temperature
The highest voltage can be obtained using a magnesium strip and a copper strip. (It is because among the three metals, Mg occupies the highest position in the electrochemical series and Cu the lowest position).
Adjust the distance / position between the two metal strips until the maximum output voltage is obtained.
Effective communication [3]

CE05_09

(a) (i) hydrogen [1]

(ii) manufacture of NH_3 / manufacture of CH_3OH / manufacture of hydrochloric acid / hardening of vegetable oils. [1]

(b) (i) Chlorine

(ii) At very low concentrations, O_2 will be formed / $OH^-(aq)$ discharged. [1]

Position of OH^- in ECS is higher than that of Cl^-. / OH^- is a stronger reducing agent than Cl^-. / OH^- loses electron more readily than Cl^-. [1]

(c) Zn is a reducing agent / Zn loses electrons [1]

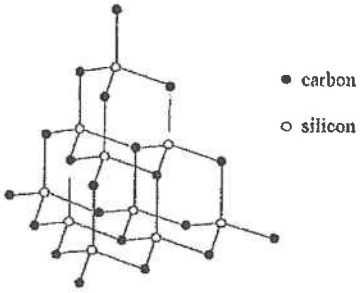
MnO_2 is an oxidizing agent / MnO_2 gains electrons [1]

When the cell is connected to an external circuit, electrons will flow through the external circuit. [1]

CE06_05

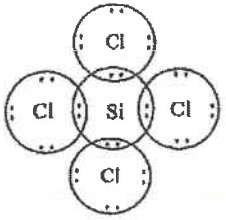
(a) covalent crystal [1]

(b) [1]



(c) (i) Oxidized. The oxidation number of Si increases from 0 to +4. [1]

(ii) [1]



(iii) Both H_2 and HCl are gases. They can easily be removed from the solid silicon produced. [1]

(d) mole of Si obtained = moles of $SiO_2 = \frac{950}{28.1 + 16 \times 2} = 15.8$ [1]

mass of Si = $15.8 \times 28.1 = 444$ g [1]

CE06_07

(a) (i) Heat the copper metal in air. [1]

Reddish brown copper changes into black copper(II) oxide. [1]

(ii) neutralization [1]

(b) $3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$ [2]

(c) Open-ended question

Method 1 [2]

- Less reactants / nitric acid is used. (For the production of 1 mol of $Cu(NO_3)_2$, 2 mol of HNO_3 is required in method 1, while 2.67 mol in method 2)
- Method 2 gives toxic product (NO) but Method 1 does not.

OR, Method 2

- The conversion involve only one step.
- In method 1, copper and oxygen do not easily undergo complete reaction / react slowly.

CE06_08

Chemical knowledge

Similarity in Chemical properties [4]

Both Cl_2 and Br_2 can oxidize SO_3^{2-} to SO_4^{2-}

$X_2 + SO_3^{2-} + H_2O \longrightarrow 2X^-(aq) + SO_4^{2-} + 2H^+$

Both Cl_2 and Br_2 can undergo addition with alkenes

$X_2 + CH_2{=}CH_2 \longrightarrow CH_2XCH_2X$

Both Cl_2 and Br_2 can undergo substitution with alkanes

$X_2 + CH_4 \longrightarrow CH_3Cl + HX$

Both Cl_2 and Br_2 can react with metals (e.g. Na) to give ionic halides

$X_2 + 2Na \longrightarrow 2NaX$

Both Cl_2 and Br_2 can react with Fe^{2+} to give Fe^{3+}

$X_2 + 2Fe^{2+} \longrightarrow 2X^- + 2Fe^{3+}$

Both Cl_2 and Br_2 can react with I^- to give I_2

$X_2 + 2I^- \longrightarrow 2X^- + I_2$

Both Cl_2 and Br_2 can undergo disproportionation in alkalis

$X_2(g) + 2OH^-(aq) \longrightarrow X^-(aq) + OX^-(aq) + H_2O(l)$

Trend in reactivity [2]

Chlorine is more reactive than bromine.

The addition $Cl_2(g)$ to KBr(aq) gives a brown solution. But the addition of $Br_2(aq)$ to KCl(aq) gives no observable change.

Effective communication [3]

CE06_10

(a) (i) zinc-carbon cells / pencil lead [1]

(ii) cans for soft drinks [1]

(b) (i) $Al + 4OH^- \longrightarrow Al(OH)_4^- + 3e^-$ [1]

(ii) $OCl^- + H_2O + 2e^- \longrightarrow Cl^- + 2OH^-$ [1]

(c) (i) Any TWO of the following: [2]

- the volume of bleach used / the depth of immersion of the carbon rod
- the distance between the carbon rod and the aluminium can
- temperature
- a carbon rod / aluminium can of the same size should be used

(ii) The electrical conductivity of the electrolyte increases with the concentration of NaOCl in the bleach. [1]

∴ The current produced by the cell increases.

CE07_04

(a) Both vinegar and wine contain molecules. [1]

Only vinegar (ethanoic acid) can ionize in water / contains (mobile) ions for conducting electricity. [1]

(b) (i) $Fe \longrightarrow Fe^{2+} + 2e^-$ [1]

(ii) $2H^+ + 2e^- \longrightarrow H_2$ [1]

(c) Iron reacts directly with vinegar / $H^+(aq)$ giving out hydrogen gas. [1]

CE07_09

Chemical knowledge [6]

<u>Corrosive property</u>

- safety glasses / goggles / rubber gloves / protective clothings / avoid contact with skin or eyes / wash with plenty of water if contacted with skin
- because acid of high concentration is corrosive

<u>Dilution process</u>

- add slowly small amount of rust remover into a large amount of water with stirring
- because large amount of heat given out in dilution of the rust remover (acid of high concentration) / avoid rust remover (acid) splashing out

<u>Other potential dangers</u>

- use plastic container instead of metal / do not use to clean marble / do not mix with chlorine bleach or caustic soda / do not put in warm place
- because will damage metal container / damage marble / toxic gas evolves if mix with chlorine bleach / large amount of heat releases if mix with caustic soda / acidic gas evolves if put in warm place

Effective communication [3]

CE07_11

(a) Species undergo oxidation is sulphide ion, O.N. of S changes from –2 to +4. [1]

Species undergo reduction are copper(I) ion and oxygen, O.N. of Cu changes from +1 to 0 and O.N. of O changes from 0 to –2. [1]

(b) The impure copper anode (+ve electrode) becomes copper(II) ions / $Cu \rightarrow Cu^{2+} + 2e^-$ [1]

Copper(II) ions in the solution discharge on the pure copper cathode (-ve electrode) / $Cu^{2+} + 2e^- \rightarrow Cu$ [1]

(c) Silver and gold [1]

They are less reactive than copper (less readily to dissolve as ions when compared with copper) [1]

(d) Not correct. Concentration of copper(II) ions drops gradually.

At anode, iron/zinc dissolve as ions because they become ions more readily than copper. [1]

However at cathode, copper(II) ions are always preferentially discharged. [1]

(e)
- SO_2 available as resource for contact process
- The cost of transportation of SO_2 is minimized
- Prevent air pollution induced by SO_2

[Any 2 points above. 1 mark for each point.] [2]

CE08_05

(a) Electrons flow from magnesium strip to zinc strip / from right to left because Mg is more reactive / easier to be oxidized / easier to lose electrons than Zn. [1]

(b) (i) Magnesium strip: oxidation / losing of electrons occurs at it. [1]

(ii) $Mg \longrightarrow Mg^{2+} + 2e^-$ [1]

(c) Interchange copper strip and zinc strip in Potato A. [1]

(d) Fresh potatoes contain water so that ions move more easily / ions are more mobile / more mobile ions. [1]

(e) The multimeter reading drops to zero / near zero. [1]

CE08_06

(a)

Chlorine should NOT be dried by calcium oxide because they will react.	Dry by concentrated sulphuric acid / silica gel / anhydrous calcium chloride
Chlorine should NOT be collected by upward delivery / downward displacement of air because it is denser than air	Chlorine should be collected by downward delivery / upward displacement of air / gas syringe.

[2] [2]

(b) The preparation should be carried out in a fume cupboard / well-ventilated area. [1]

(c) (i) $Cl^- + OCl^- + 2H^+ \longrightarrow Cl_2 + H_2O$ [1]

(ii) OCl^- / NaOCl / NaClO [1]

[wrong species = 0 mark for whole part (ii)]

The O.N. of Cl in OCl^- changes from +1 to 0. [1]

CE09_06

(a) chars / turns black / turns brown / swells up / steam / white fumes [1]

$C_6H_{12}O_6 \longrightarrow 6C + 6H_2O$ [1]

(b) (i) copper dissolves / blue solution / colourless gas / choking smell [1]

$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$ [1]

OR, $Cu + 2H^+ + H_2SO_4 \longrightarrow Cu^{2+} + SO_2 + 2H_2O$

OR, $Cu + 4H^+ + SO_4^{2-} \longrightarrow Cu^{2+} + SO_2 + 2H_2O$

(ii) Let the test tube cool down. [1]

Put the whole test tube in a tank of water with mouth of the tube point downward and then clean it. [1]

CE09_13

Chemical knowledge

A description of electroplating of iron: [6]

a. The protective layer plated on iron can be a metal such as nickel / chromium / copper / silver.

b. Electrolyte used is an aqueous salt solution of the metal. Example: nickel(II) sulphate (solution)

c. The metal (e.g. Ni) should be made anode (positive electrode / connected to positive pole of power supply).

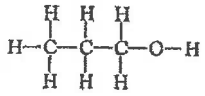
d. The iron object should be made cathode (negative electrode / connected to negative pole of power supply).

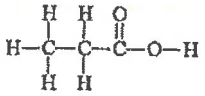
e. The metal (e.g. Ni) (anode) is oxidized / loses electrons to form ions.
(Accept half equation: $Ni \longrightarrow Ni^{2+} + 2e^-$)

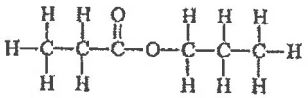
f. The metal ions (e.g. Ni^{2+}) are reduced/gain electrons on iron (cathode) surface to form metal (e.g. Ni)
(Accept half equation: $Ni^{2+} + 2e^- \longrightarrow Ni$)

Effective communication [3]

CE10_03

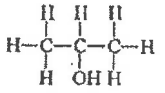
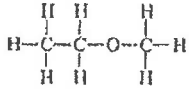
(a) A:  [1]

B:  [1]

C:  [1]

(b) from orange to green [1]

(c) fractional distillation / using separating funnel [1]

(d)  OR  [1]

CE10_05

(a) Emulsify / Dissolve the oil in the coating. [1]

(b) (i) Oxidation / redox [1]

(ii) Toxic / Poisonous chlorine gas is evolved. [1]

(iii) Molarity of sodium hypochlorite $= 0.5 \div (1 + 49)$ [1]

$= 0.01$ (mol dm^{-3}) [1]

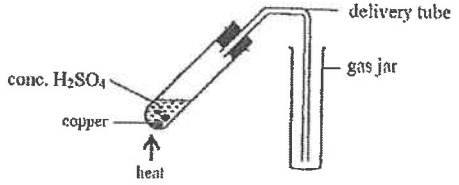
CE10_07

(a) bleaching [1]

OR, food preservation

(b) Immerse in water. / Rinse with water. [1]

Sulphur dioxide is soluble in water. [1]

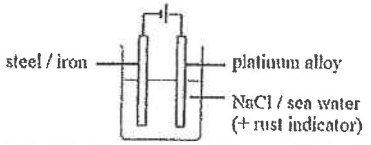
(c) 

[3]

CE10_09

Chemical knowledge [6]

(a) Set-up:



(b) Control experiment (steel / iron not connected to negative terminal)

(c) Observation:

Rust indicator does not turn blue (but turns blue in the control experiment).

OR, After some time there is no rusting (but rusting occurs in the control experiment).

(d) Principle:

Electrons flow to steel / iron, and thus steel / iron cannot be oxidized to iron(II) ions.

Effective communication [3]

CE10_11

(a) It should be zinc powder because zinc undergoes oxidation / releases electrons in the reaction. [1]

(b) providing medium for ions transfer [1]

(c) Mercury is toxic / poisonous. [1]

(d) No, Mg occupies a higher position in the electrochemical series than Zn. [1]
OR, Mg is a stronger reducing agent than Zn.
OR, Mg loses electrons more readily than Zn. Mg is more reactive than Zn.
OR, MgO is more stable than ZnO.

(e) Decrease. The difference in position of electrochemical series / reactivity series between Cu and Hg is smaller than that between Zn and Hg. [1]

(f) (i) $2Cl^- \longrightarrow Cl_2 + 2e^-$ [1]

(ii) $2H_2O + 2e^- \longrightarrow 2OH^- + H_2$ [1]
OR, $2H^+ + 2e^- \longrightarrow H_2$

(iii) Unreacted Na^+ ions in the anodic compartment can pass through the membrane to the cathodic compartment. [1]
OH^- ions are formed in the reduction of H_2O at the cathode. [1]
OR, As H^+ ions are discharged at the cathode, OH^- ions remain.

CE11_04

(a) Electrons flow from chromium rod to iron rod in the external circuit. [1]
Because iron(II) ions accept electrons making the ion colour fade out. [1]
$Fe^{2+} + 2e^- \longrightarrow Fe$

(b) $Cr \longrightarrow Cr^{3+} + 3e^-$ [1]

(c) (i) By sacrificial protection. / Chromium reacts with oxygen or water more readily than iron. / Chromium is oxidized more readily than iron. [1]

(ii) Electroplating [1]
Chromium covered on the object can prevent iron from contacting with oxygen and water. [1]

CE11_05

(a) (i) +4 [1]

(ii) Sodium hydrogensulphite ($NaHSO_3$) can react with oxygen in air, [1]
thus it can prevent the ethanol from oxidation to form ethanoic acid. [1]

(iii) $0.1 \times (23.0 + 1.0 + 32.1 + 16.0 \times 3) = 10.41$ g [1]

(b) (i) $2NaHSO_3 + Zn \longrightarrow Na_2S_2O_4 + Zn(OH)_2$ [1]

(ii) Reducing agent. [1]

CE11_10a

(i) Colourless bubbles / gas evolve. [1]
Because hydrogen ions are preferentially discharged. / $2H^+ + 2e^- \longrightarrow H_2$ [1]

(ii) At the beginning, colourless bubbles / gas evolve. [1]
After some time, a greenish-yellow gas / pale green gas / a gas with choking smell evolve. [1]
Because the hydroxide ion is higher than chloride ion in the electrochemical series, thus hydroxide ions are preferentially discharged at the beginning. After some time, the concentration of chloride ions is much higher than that of hydroxide ions, thus chloride ions are preferentially discharged. [1]

(iii) The resulting solution is alkaline.
Because $H^+(aq)$ ions are eventually discharged, but $OH^-(aq)$ ions are not discharged. [1]
OR, The resulting solution is sodium hydroxide.
OR, The concentration of $OH^-(aq)$ ions after electrolysis is higher than that of $H^+(aq)$ ions.

CE11_10b

(i) Anode. It is because the conversion of ethanol to ethanoic acid is an oxidation. [1]

(ii) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$ [1]

(iii) Higher concentration of ethanol produced larger current. [1]

AL95(II)_03

(a) At anode: [1]
$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
At cathode:
$2MnO_2(s) + 2NH_4^+(aq) + 2e^- \longrightarrow Mn_2O_3(s) + 2NH_3(g) + H_2O(l)$ [1]
OR $2MnO_2(s) + NH_4^+(aq) + 2e^- \longrightarrow Mn_2O_3(s) + OH^-(aq) + NH_3(g)$
Overall equation
$Zn(s) + 2MnO_2(s) + 2NH_4^+(aq) \longrightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2NH_3(g) + H_2O(l)$ [1]
OR $Zn(s) + 2MnO_2(s) + NH_4^+(aq) \longrightarrow Zn^{2+}(aq) + Mn_2O_3(s) + NH_3(g) + OH^-(aq)$

(b) (i) If a current is drawn for some time, $NH_3(g)$ will accumulate at the cathode, [½]
and increase the internal resistance, leading to a drop in electrode potential. [1]

(ii) If the cell is allowed to stand for some time, $NH_4^+(aq)$ which is an acid will react with Zn. [½]
$Zn(s) + 2NH_4^+(aq) \longrightarrow Zn^{2+}(aq) + 2NH_3(aq) + H_2(g)$
With decrease in $[NH_4^+(aq)]$, the electrode potential will also drop. [½]

ASL99(I)_07 (modified)

(a) $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$ [1]

(b) (i) To increase the electrical conductivity of the electrolyte. [1]

(ii) Boric acid is added to the electrolytic bath to maintain a slightly acidic environment. [1]

(c) Mole of electron formed $= \frac{4.50 \times 10^{21}}{6.02 \times 10^{23}} = 7.46 \times 10^{-3}$ [1]

Mass of Ni(s)formd $= \frac{7.46 \times 10^{-3} \times 58.7}{2} = 0.219\ g$ [1]

Thickness of nickel $= \frac{0.219}{8.90 \times 20} = 1.23 \times 10^{-3} cm$ [1]

(d) By precipitation of $Ni^{2+}(aq)$ with NaOH(aq). [1]

ASL00(I)_02

(a) Bottle C [1]

Mixing reagent A and B does not have an observable change, which implies that there is no redox reaction between A and B. As both $I^-(aq)$ and $Br^-(aq)$ are reducing agent, [½]
and they do not react with each other. Hence, A or B can be a NaI or KBr. [½]

Mixtures turn to brown when A or B mix with C, where $I_2(aq)$ and $Br_2(aq)$ are brown.

$Cl_2(aq) + 2I^-(aq) \longrightarrow 2Cl^-(aq) + I_2(aq)$ [½]

$Cl_2(aq) + 2Br^-(aq) \longrightarrow 2Cl^-(aq) + Br_2(aq)$ [½]

(b) Add hexane into the mixture of A, C and B, C respectively. [1]

If the hexane layer turns from colorless to violet, the reagent contains NaI(aq). [½]

If the hexane layer turns from colorless to orange, the reagent contains KBr(aq). [½]

(c) Perform the experiment in the fumehood. [1]

ASL00(I)_03

(a) Because $Cr^{3+}(aq)$ is toxic, [1]

(b) Mole of $Cr_2O_7^{2-}(aq) = 1.0 \times 10^5 \times 1.2 \times 10^{-4} = 12$ [1]

Mole of $FeSO_4 \cdot 7H_2O$ required $= 12 \times 6 = 72$

Mass of $FeSO_4 \cdot 7H_2O$ required $= 72 \times (55.8 + 32.1 + 16 \times 4 + 7 \times 18)$ [1]

$= 20000\ g = 20\ kg$ [1]

(c) NaOH / sodim hydroxide [1]

(d) Chromium(III) hydroxide and iron(III) hydroxide [1]

ASL00(I)_05

(a) The nickel plating provides the smoothness / higher corrosion resistance. [1]

(b) Sivery shiny surface for decoration. [1]

Higher reactive than iron to provide sacrificial protection. [1]

(c) To provide acidic environment to convert water insoluble CrO_3 to water soluble CrO_4^{2-}. [1]

(d) (i) $CrO_4^{2-}(aq) + 8H^+(aq) + 6e^- \longrightarrow Cr(s) + 4H_2O(l)$ [1]

Mole of electron $= \frac{4.50 \times 10^{23}}{6.02 \times 10^{23}} = 0.748$ [½]

Mole of Cr(s) formed $= \frac{0.748}{6} = 0.125$ [½]

Thickness of chromium $= \frac{0.125 \times 52}{7.2 \times 3 \times 10^3} = 3.00 \times 10^{-4}\ cm$ [1]

(ii) H_2 gas bubbles formed will hinder the deposition of chromium metal layer. [1]

ASL00(II)_10 (modified)

(a) 2,8,14, 2 [1]

(b) Iron exists as giant metallic structure which the cations lattice soaked in the sea of [1]
delocalized electrons. These delocalized electrons have a translational motion [1]
along the electric field.

(c) (i) Iron(III) chloride / $FeCl_3$ [1]

(ii) Cl_2 can dissolve in water to give HCl(aq), and loss its oxidizing properties. [1]

(d) $Fe^{3+}(aq) + Fe(s) \longrightarrow 2Fe^{2+}(aq)$ [1]

(e) (i) A reddish brown $Fe(OH)_3$ solid forms [1]

(ii) A dirty green $Fe(OH)_2$ solid forms [1]

ASL00(II)_11

Add few drops of acidified $KMnO_4(aq)$ into two solutions respectively. [1]

Only $Na_2SO_3(aq)$ can decolorize the purple color of $KMnO_4(aq)$, while $Na_2SO_4(aq)$ cannot. [1]

$2MnO_4^-(aq) + 5SO_3^{2-}(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 3H_2O(l)$ [1]

AL01(I)_04

(a) Anode: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$ [1]

Cathode: $2MnO_2(s) + 2NH_4^+(aq) + 2e^- \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$ [1]

(b) No. of mole of $MnO_2 = 25.0 \div (54.94 + 16.00 \times 2) = 0.2876$ [1]

Mass of Zn(s) consumed $= 0.5 \times 0.2876 \times 65.38 = 9.40\ g$ [1]

ASL01(I)_06

(a) (i) Remove oil and grease [1]

(ii) Remove metal oxides [1]

(b) (i) To provide an even discharge of nickel to nickel cations for more even distribution of cations. [1]

(ii) $Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$

(c) Part of electron is used to discharge another metal cation impurities present in the anode. [1]

(d) Discharge of strong acid or strong alkali as sewage can cause pollution. [1]

Neutralize acidic or alkaline sewage before discharge. [1]

OR, sewage contains high concentration of toxic metal cations.

Precipitate these toxic metal cations by NaOH before discharge

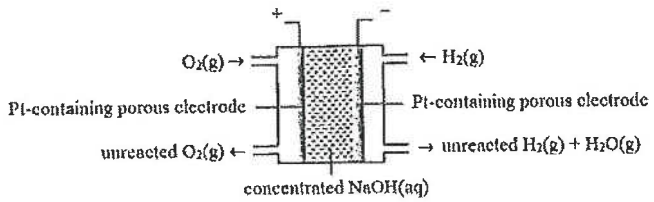
AL01(I)_07

Warm with concentrated HNO_3 / concentrated H_2SO_4 [1]

S is oxidized by HNO_3 / H_2SO_4 to SO_2 [1]

AL02(II)_03

(a)



[2]

(b) Half equation for cathodic reaction:

$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$ [½]

Half equation for anodic reaction:

$H_2(g) + 2OH^-(aq) \longrightarrow 2H_2O(l) + 2e^-$ [½]

Overall reaction:

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

The enthalpy change of the reaction is liberated in the form of electrical energy. [1]

(c) Any one of the following: [1]

Fuel cells are more efficient than batteries in the conversion of chemical energy into electrical energy.

Fuel cells cause less environmental problems.

ASL02(II)_11

(a) (i) Sodium hypochlorite / sodium hypochlorite(I) [1]

(ii) $OCl^-(aq) + 2H^+(aq) + Cl^-(aq) \longrightarrow Cl_2(aq) + H_2O(l)$ [1]

(b) (i) Solution turns from green (Fe^{2+}) to orange (Fe^{3+}) [1]

$Cl_2(aq) + 2Fe^{2+}(aq) \longrightarrow 2Fe^{3+}(aq) + 2Cl^-(aq)$ [1]

(ii) Solution turns from colorless to orange (Br_2) [1]

$Cl_2(aq) + 2Br^-(aq) \longrightarrow Br_2(aq) + 2Cl^-(aq)$ [1]

ASL02(II)_12

(a) (i) To form a wetting agent / emulsion with sodium hydroxide to prevent spraying of alkaline solution. [1]

(ii) To remove oil and grease on the article to be electroplated. [1]

(b) To neutralize the alkaline residue and remove the oxides on the metal article. [1]

(c) To remove oxides on the metal article. [1]

To provide acidic condition for dissolving rhodium salt. [1]

(d) Mole of electron used for electroplating $= \dfrac{2.40 \times 10^{21} \times 80\%}{6.02 \times 10^{23}} = 3.19 \times 10^{-3}$ [½]

Mole of Rh formed $= \dfrac{0.17}{102.9} = 1.65 \times 10^{-3}$ [½]

Oxidation state of Rb $= \dfrac{3.19 \times 10^{-3}}{1.65 \times 10^{-3}} = 1.93$

∴ Oxidation state of Rb = +2 [1]

(c) Other cations, such as H^+, in the electrolyte may also be discharged on cathode. [1]

$2H^+(aq) + 2e^- \longrightarrow H_2(g)$

ASL03(I)_03

(a) (i) Oxidizing power: $I_2 < Br_2 < Cl_2$ [1]

(ii) Using displacemen reactions:

$Cl_2(g)$ can displace Br_2 from KBr(aq) and can displace I_2 from KI(aq). [1]

$Br_2(aq)$ can displace I_2 from KI(aq), but cannot displace Cl_2 from KCl(aq). [1]

∴ oxidizing power: $Cl_2 > Br_2 > I_2$

(b) A redox reaction in which a species is simultaneously oxidized and reduced. [1]

$H_2O_2 \longrightarrow H_2O + O_2$ [1]

$Cl_2 + 2OH^- \longrightarrow ClO^- + Cl^- + H_2O$

AL03(II)_04 (modified)

(a) It forms strong dative bond with Fe(II) in haemoglobin and inhibits Fe(II) from forming complex with O_2. Thus the oxygen carrying capacity of haemoglobin is decreased. [1] [1]

(b) When there is an increase (decrease) in indoor CO level, the electrochemical reaction will proceed at faster (slower) rate. [1]

A larger (smaller) current will flow through the CO detector. [1]

(c) Incomplete combustion of fossil fuels / leakage of town gas. [1]

ASL04(I)_02

False.

F, the most electronegative element, can exhibit only one O.S. of −1. [1]

AL04(II)_05

(a) Treating $Cl_2(g)$ with dilute NaOH(aq) at room temperature.

$Cl_2 + 2OH^- \longrightarrow Cl^- + OCl^- + H_2O$

(b) Formula mass of NaOCl = 23.0 + 16.0 + 35.5 = 74.5 [1]

$[NaOCl]$ in diluted bleach $= \dfrac{60}{74.5} \times 10 \times \dfrac{1}{100} = 8.05 \times 10^{-3}$ mol dm^{-3} [1]

(c) HSO_4^- hydrolyzes in water to give H^+ and SO_4^{2-} [½]

$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$

OCl^- reacts with H_3O^+ to give $Cl_2(g)$ which is toxic [½]

$Cl^- + OCl^- + 2H^+ \rightleftharpoons H_2O + Cl_2$ [1]

AL05(I)_07b

(i) $Na_2SO_3(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$ [1]

(ii) KOH(aq) should not used as $SO_2(g)$ reacts vigorously with KOH(aq). An empty conical flask (as a trap) should be used instead. [1]
It is not necessary to include the flask containing KOH(aq) in the set-up. [1]
$SO_2(g)$ should not be collected over water as it is very soluble. Collect the $SO_2(g)$ produced by downward delivery / upward displacement of air / using a syringe. [1]

(iii) Treat $SO_2(g)$ with $Cr_2O_7^{2-}/H^+(aq)$. [1]
The solution changes from orange to green. [1]
OR, Treat $SO_2(g)$ with $MnO_4^-/H^+(aq)$.
The solution changes from purple to colorless.

ASL05(I)_07

(a) (i) To make the knobs a conductor of electricity for the nickel-plating process. [1]

(ii) To make it more appealing [1]

(b) $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$ [1]

(c) (i) At low pH, $H^+(aq)$ instead of $Ni^{2+}(aq)$ will be discharged at the cathod. [1]
The current efficiency will decrease.
At high pH, $Ni^{2+}(aq)$ will be precipitated as $Ni(OH)_2(s)$ [1]
∴ It is necessary to maintain the pH in a range of about 4 to 6.

(ii) H_3BO_3 is a weak acid. The ionization of H_3BO_3 can replenish the $H^+(aq)$ ions lost by discharge at the cathode and maintains the pH of the electrolytic bath. [1]

(d) A high current density can result in a loose spongy metal deposit which may peel off from the knobs. [1]

AL05(II)_02

(a) $2MnO_4^-(aq) + 10Cl^-(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 5Cl_2(g) + 8H_2O(l)$ [1]
$Cl_2(aq) + 2Fe^{2+}(aq) \longrightarrow 2Cl^-(aq) + 2Fe^{3+}(aq)$ [1]
$2MnO_4^-(aq) + 5SO_2(g) + 2H_2O(l) \longrightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 4H^+(aq)$ [1]
OR $2MnO_4^-(aq) + 5SO_3^{2-}(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 3H_2O(l)$

(b) (i) The reaction
$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \longrightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$ is feasible. [1]
As revealed in the given experimental results, oxidizing power is in the order: [1]
$MnO_4^-(aq) > Cl_2(g) > Fe^{3+}(aq)$
Acidified $KMnO_4(aq)$ can oxidize $Fe^{2+}(aq)$

(ii) Cannot be predicted from the given information [1]
The experimental results only reveal the following:
Oxidizing power: $MnO_4^-(aq) > SO_4^{2-}(aq)$, and $MnO_4^-(aq) > Fe^{3+}(aq)$ [1]
No comparsion of oxidizng power between $SO_4^{2-}(aq)$ and $Fe^{3+}(aq)$ can be obtained.

AL05(II)_04

(a) $3Cu(s) + 8HNO_3(aq) \longrightarrow 3Cu(NO_3)_2(aq) + 4H_2O(l) + 2NO(g)$ [1]

(b) (i) Colorless gas bubble (NO) are formed / The liquid level in the dropper becomes lower (owing to the gas pressure). [1]
The liquid turns blue owing to the formation of $Cu^{2+}(aq)$ ions. [1]
When all liquid has been driven out of the dropper, a brown gas is formed. [1]
This is due to the formation of $NO_2(g)$.
$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

(ii) Any ONE of the following: [1]

- The product of the reaction between Cu and HNO_3 (NO) readily reacts with O_2 to give NO_2. The formation of colorless NO(g) cannot be seen if a test tube is used.
- Less toxic gas $NO_2(g)$ is released to the atmosphere.

AL06(I)_03

(a) $S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2H_2O(l) + 6NO_2(g)$ [1]

(b) $4Mn^{2+}(aq) + O_2(g) + 8OH^-(aq) + 2H_2O(l) \longrightarrow 4Mn(OH)_3(s)$ [1]

(c) $3MnO_4^{2-}(aq) + 2H_2O(l) \longrightarrow 2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq)$ [1]

ASL06(I)_03b

(i) Hydrogen iodide vapor is formed initially. [1]
Concentrated sulphuric acid oxidizes hydrogen iodide to iodine [1]
Iodine vapor is violet in color. [1]

(ii) Metal chloride is usually more volatile than the sulphate. [1]

AL06(II)_04

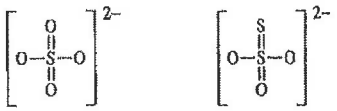
(a) Cathodic reaction:
$PbO_2(s) + 2e^- + 4H^+(aq) + SO_4^{2-}(aq) \rightleftharpoons PbSO_4(s) + 2H_2O(l)$ [1]
Anodic reaction:
$Pb(s) + SO_4^{2-}(aq) \rightleftharpoons PbSO_4(s) + 2e^-$ [1]

(b) There is no loss of materials from the cell during the charging and recharging process. [1]

(c) (i) During the charging process, $H_2SO_4(aq)$ is produced. The density of the battery acid increases. [½]
During the discharging process, $H_2SO_4(aq)$ is consumed. The density of the battery acid decreases. [½]

(ii) If the battery is charged with a high voltage, the $PbO_2(s)$ formed will not adhere strongly to the lead plate. The life of the battery will become shortened. [1]

AL07(I)_02



[2]

In SO_4^{2-}, O.S. of S = +6 [1]

In $S_2O_3^{2-}$, O.S. of central s atom = +4; O.S. of the other S atom = 0 [1]

AL08(I)_01

Step 1: $2NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6HCl(g)$ [1]

$NH_3(g)$ acts as **reducing agent.** [½]

Step 2: $NH_3(g) + HCl((g) \longrightarrow NH_4Cl(s)$ [1]

$NH_3(g)$ acts as **base.** [½]

AL08(I)_02

(a) The principle of the fuel cell is based on the conversion of chemical energy released in the reaction [½]

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ to electrical energy. [½]

In the $H_2(g)$ compartment, $H_2(g)$ is oxidized to $H_2O(l)$:

$H_2(g) + 2OH^-(aq) \longrightarrow 2H_2O(l) + 2e^-$ (the negative electrode) [½]

In the $O_2(g)$ compartment, $O_2(g)$ is reduced to $OH^-(aq)$:

$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$ (the positive electrode) [½]

The concentrated NaOH(aq) acts as an electrolyte and **provides $OH^-(aq)$ ions for the anodic reaction.** [½]

The porous electrodes allow the flow of $H_2(g)$ and $OH^-(aq)$ in and out of the compartments. [½]

The electrolytic reactions are catalyzed by the Pt in the electrodes.

(b) Any ONE of the followings: [1]

- $H_2 - O_2$ fuel cells have high efficiency of energy conversion.
- $H_2 - O_2$ fuel cells can operate continuously if the flow of $H_2(g)$ and $O_2(g)$ can be maintained.
- Water formation which can be drunk.

AL08(I)_02

0.5 M KI(aq):

Some $I^-(aq)$ ions have undergone air oxidation to give $I_2(s)$, which dissolve in $I^-(aq)$ to give brown $I_3^-(aq)$. [1]

$4I^-(aq) + O_2(g) + 4H^+(aq) \longrightarrow 2I_2(s) + 2H_2O(l)$ [½]

$I_2(s) + I^-(aq) \longrightarrow I_3^-(aq)$ [½]

(Accept equations showing other oxidizing agent, e.g. O_3)

14 M $HNO_3(aq)$:

$HNO_3(aq)$ undergoes **photodecomposition** to give $NO_2(g)$, which is brown both in gaseous state and in aqueous solution. [1]

$4HNO_3(aq) \longrightarrow 4NO_2(g) + 2H_2O(l) + O_2(g)$ [1]

0.02 M $KMnO_4(aq)$:

$MnO_4^-(aq)$ undergoes **slow decomposition** and the decomposition is catalyzed by sunlight. [1]

Brown $MnO_2(s)$ is formed.

$4MnO_4^-(aq) + 4H^+(aq) \longrightarrow 4MnO_2(s) + 3O_2(g) + 2H_2O(l)$ [1]

ASL08(I)_02

0.5 M KI(aq):

Some $I^-(aq)$ ions have undergone air oxidation to give $I_2(s)$, which dissolve in $I^-(aq)$ to give brown $I_3^-(aq)$. [1]

$4I^-(aq) + O_2(g) + 4H^+(aq) \longrightarrow 2I_2(s) + 2H_2O(l)$ [½]

$I_2(s) + I^-(aq) \longrightarrow I_3^-(aq)$ [½]

(Accept equations showing other oxidizing agent, e.g. O_3)

14 M $HNO_3(aq)$:

$HNO_3(aq)$ undergoes **photodecomposition** to give $NO_2(g)$, which is brown both in gaseous state and in aqueous solution. [1]

$4HNO_3(aq) \longrightarrow 4NO_2(g) + 2H_2O(l) + O_2(g)$ [1]

2M NaOH(aq)

NaOH(aq) reacts with $CO_2(g)$ in air to give $NaHCO_3(aq)$ which undergoes dehydration to give $Na_2CO_3(s)$. [1]

$NaOH(aq) + CO_2(g) \longrightarrow NaHCO_3(aq)$ [½]

$2NaHCO_3(aq) \longrightarrow Na_2CO_3(s) + H_2O(l)$ [½]

AL09(I)_02

(a) $:N{\equiv}C{-}C{\equiv}N:$ [1]

(b) $(CN)_2$ exists as simple molecules. Its relative molecular mass is smaller than that of Cl_2. [1]

$(CN)_2$ is a gas.

(c) $(CN)_2(g) + 2NaOH(aq) \longrightarrow NaOCN(aq) + NaCN(aq) + H_2O(l)$ [1]

AL09(I)_07d

Oxidizing [1]

AL09(II)_03

$Fe^{2+}(aq)$ is readily oxidized by $O_2(g)$ in air to $Fe^{3+}(aq)$. [1]

$Fe^{3+}(aq)$ undergoes hydrolysis to give brown $Fe(OH)_3(s)$. [1]

AL10(I)_03

Adding $H_2SO_4(aq)$ to $K_2CrO_4(aq)$: the yellow $CrO_4^{2-}(aq)$ solution turns orange $Cr_2O_7^{2-}(aq)$. [½]

$2CrO_4^{2-}(aq) + 2H^+(aq) \longrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$ [1]

Adding $FeSO_4(aq)$ to the orange solution: it turns green $Cr^{3+}(aq)$. [½]

$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ [1]

AL10(I)_07b

HBr and HI and reducing agents. They react with concentrated H_2SO_4 to give the corresponding halogens (Br_2 or I_2). In such cases, the non-oxidizing and non-volatile acid H_3PO_4 should be used. [1] [1]

Concentrated H_2SO_4 can only be used to prepare HCl and HF.

AL12(I)_02

(b) (ii) +4 [1]

(iii) $2VO_2^+(aq) + 3Zn(s) + 8H^+(aq) \longrightarrow 2V^{2+}(aq) + 3Zn^{2+}(aq) + 4H_2O(l)$ [1]

AL12(II)_07

(a) When the cell is producing a current, $Cd^{2+}(aq)$ ions will be formed at the anode. [1]

$NO_3^-(aq)$ ions in the salt bridge will migrate to the anode compartment to neutralize the surplus $Cd^{2+}(aq)$ ions. [1]

(Accept explanations based on reduction of $Ni^{2+}(aq)$ ions at cathode.)

(b) (i) Anode reaction:

$Cd(s) + 2OH^-(aq) \longrightarrow Cd(OH)_2(s) + 2e^-$ [1]

Cathodic reaction:

$NiO(OH)_2(s) + H_2O(l) + e^- \longrightarrow Ni(OH)_2(s) + OH^-(aq)$ [1]

(ii) In the overall reaction, all species involved are either in solid state or in liquid state. As solid and liquids have constant concentration, depleting or formation of the reactant or product will have very little effect on the cell e.m.f. [1]

(c) Any ONE of the followings: [1]

- Li-ion batteries have higher current / energy density
- As compared with NiCd batteries of the same dimensions, Li-ion batteries are lighter.
- Li-ion batteries pose less harm to the environment when they are disposed of.
- Li-ion batteries have litte memory effect.

AL13(I)_07

(a) (i) R: Cu(s) [½]

S: Ag(s) [½]

(ii) (I) To complete the circuit by allowing movement of ions between the two half-cells but prevent mixing of the two solutions. [1]

(II) Some $Ag^+(aq)$ ions may have migrated to the salt bridge so that the concentration will be affected. [1]

AL13(II)_02

(b) Yes, the oxidation state of Mn changes from +7 to +6 / the oxidation state of O changes from 0 to −2. [1]

$4MnO_4^-(aq) + 4OH^-(aq) \longrightarrow 4MnO_4^{2-}(aq) + 2H_2O(l) + O_2(g)$ [1]

DSE11SP_04

(a) (i) Purple / blue [1]

H^+ is prefentially discharged at carbon rod A (cathode)

$2H^+(aq) + 2e^- \longrightarrow H_2(g)$ [1]

$\therefore$ OH^- concentration increase around carbon rod A / concentration of $OH^-(aq)$ is higher than that of $H^+(aq)$. [1]

(ii) oxygen [1]

$OH^-(aq)$ is more preferentially discharged at carbon rod B (anode) than $SO_4^{2-}(aq)$. [1]

$4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e^-$

(b) Pencil / zinc-carbon cells [1]

DSE11SP_09

3 sets of tests needed each of which carries 2 marks: [6]

- Suitable test matches the intention to distinguish certain compounds
- Correct observation / result

Effective communication [1]

Conduct flame test using the samples.

Only two sodium compounds (NaOCl and Na_2SO_4) give a golden yellow flame.

Heat samples with NaOH(aq).

Only the two ammonium compounds (NH_4Cl and NH_4NO_3) give an alkaline gas / ammonia.

Add HCl(aq)

Only NaOCl(aq) gives greenish yellow gas / chlorine.

Touch with moist litmus paper / color flower petal.

Only NaOCl gives bleaching effect.

Added acidified $BaCl_2(aq)$ to aqueous solution of the two sodium compounds.

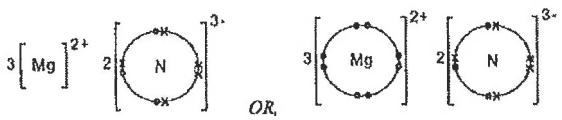
Only $Na_2SO_4(aq)$ gives a white precipitate.

Add acidified $AgNO_3(aq)$ to aqueous solutions of the two ammonium compounds.

Only $NH_4Cl(aq)$ gives a white precipitate.

DSE12PP_03

(a) (i)



OR,

[1]

(ii) $Mg_3N_2 + 6H_2O \longrightarrow 3Mg(OH)_2 + 2NH_3$ [1]

No. There is no change in oxidation number of any atom. [1]

DSE12PP_08

(a) Anode : $CH_3OH(aq) + H_2O(l) \longrightarrow CO_2(g) + 6H^+(aq) + 6e^-$ [1]

Cathode : $O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$ [1]

(b) (i) Methanol does not conduct electricity. It is not suitable to be used as the reaction medium for the electrochemical reaction. [1]

OR, H_2O is involved in the half-equations.

OR, Acid is involved in the electrochemical reaction.

(ii) Toxic and flammable [1]

(c) Accept both 'Yes' and 'No' answers. Marks will be awarded only to the explanation. [2]

For 'No' answer,

- Electrical sockets can be found in most places. DMFC laptop computers will only be used in places where electic sockets are not available.
- The cost for the manufacture of methanol is higher than that for the generation of electricity in most places.

For 'Yes' answers,

- The use of DMFC laptop computers will become prevalent when stringent environmental laws are enforced as the disposal of DMFCs causes less harm to the environment than other rechargeable cells / methanol is a greener fuel than hydrocarbons.
- DMFC laptop computers will be commonly be used in the field work where electric sockets are not available.

Accept other reasonable answers.

DSE12_03

(a) Provide H^+ / ions / electrolyte for the chemical cell. [1]

(b) Copper, Metal Y, Metal X / Cu, Y, X [1]

(c) (i) $X \longrightarrow X^{2+} + 2e^-$ [1]

(ii) $2H^+ + 2e^- \longrightarrow H_2$ [1]

(d) No, the metal Y strip would be the negative electrode. It is because silver is lower than copper in the electrochemical series / silver is less reactive than copper. So silver should be lower than Y in the electrochemical series / less reactive than Y. [1]

DSE12_05

(a) Displacement reaction occurred when the iron rod is dipped into the copper(II) sulphate solution. / Some copper(II) ions (Cu^{2+}) are reduced and deposited onto the surface of the iron rod as copper metal. [1]

$Cu^{2+}(aq) + Fe(s) \longrightarrow Cu(s) + Fe^{2+}(aq)$ [1]

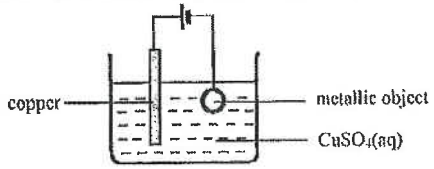
$CuSO_4(aq) + Fe(s) \longrightarrow Cu(s) + FeSO_4(aq)$

(b) (i) Copper is lower than hydrogen in the electrochemical series / Cu^{2+} is discharged preferentially than H^+ when a current is applied. [1]

(ii) Hydrogen gas / H_2 [1]

The hydrogen gas bubbles hinder the deposition of copper on the surface of the metallic object, hence causing the copper metal deposited easily flaked off. [1]

(c)



[3]

DSE13_09

(a) Brown color / yellow color is observed. [1]

Due to the high concentration of KI in the solution, I^- ions are preferentially discharged to give I_2 / discharged instead of OH^- to give I_2 which dissolves in KI(aq) to give brown I_3^- ions. [1]

(Note – minimum requirement: concentration effect + preferentially discharge of I^- / high concentration of KI + discharge of I^-)

(b) (i) H^+ is discharged / reduced to H_2 at electrode B. [1]

$2H^+(aq) + 2e^- \longrightarrow H_2(g)$

Depletion of H^+ ions makes $[OH^-(aq)] >> [H^+(aq)]$ / The amount of OH^- ions increases at electrode B as H^+ is being consumed. [1]

∴ Universal indicator turns blue under alkaline conditions.

(ii) Accept both 'yes' and 'no' answers. Award 1 mark for a reasonable explanation. [1]

'No': B is the negative electrode. Copper will not lose electrons to give Cu^{2+} at the negative electrode / Copper (Cu) cannot undergo reduction at the negative electrode / Copper will not take part in chemical changes and will act only as the electrode.

'Yes': Copper and carbon have different electrical conductivity. Therefore the solution near electrode B turns blue more quickly / The current in the external circuit changes.

DSE13_10

(a)  [1]

(b) Electrode D: $H_2(g) + 2OH^-(aq) \longrightarrow 2H_2O(l) + 2e^-$ [1]
Electrode E: $O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$ [1]

(c) (i) Accept both 'agree' and 'disagree' answers. Award 1 mark for a sound argument. [1]

Agree: The hydrogen can be obtained from renewable source (with one proper example) (E.g. electrolysis of water using the electricity generated from hydropower / reforming of CH_4 obtained from animal manure.)

Disagree: The hydrogen gas used is produced from fossil fuel such as steam reforming of nature gas.
Disagree: (Electrical) energy is consumed in the production of hydrogen (from water).
(NOT Accept the answer is yes, because the hydrogen can be obtained from the electrolysis of water, and so the fuel cells do not consume fossil fuel.)

(ii) Agree: Only water is produced from the hydrogen-oxygen fuel cells [1]
OR, No CO_2 / SO_2 / NO_x / CO / unburnt hydrocarbon in the exhaust.

DSE13_11

(c) KNO_3 is added to react with sodium which is (highly) reactive / corrosive / flammable / strongly reducing. [1]

DSE14_05

(a) Wearing protective gloves or plastic gloves or gown or safety googles or any suitable PPE / adding concentrated acids into water when diluting the concentrated acids / use a fume cupboard. [1]
Not accepted : maintain a good ventilation.

(c) Concentrated sulphuric acid reacts with copper to liberate a colorless gas / irritating gas / gas with characteristic smell / black solid (copper(II) oxide). [1]
Concentrated nitric acid reacts with copper to liberate a brown gas / bluish-green or blue solution. [1]
When concentrated ethanoic acid is added to copper granules, no observable changes occur / no reaction. [1]
Not accepted: exothermic / bluish-green or blue solution in concentrated sulphuric acid.

DSE14_08

(a) (i) The electrode dissolves / becomes smaller / becomes thinner gradually. [1]
(ii) (Colorless) bubbles / gas are given out. [1]

(b) (i) $4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e^-$ [1]
(ii) $Ag^+(aq) + e^- \longrightarrow Ag(s)$ [1]

(c) Electrode W Electrode Z [1]
Anode Cathode

(d) Electrons would not flow through the electric wires / no observable changes on all electrodes / no reaction occurs because ethanol is not an electrolyte / cannot conduct electricity. [1]

DSE14_09

(b) (i) Purple acidified potassium permanganate solution is decolorized / turns into colorless / turns into pale pink. [1]

(ii) (1) Redox / reduction (of acidified potassium permanganate) / oxidation-reduction [1]

(2) $2MnO_4^-(aq) + 5SO_3^{2-}(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 3H_2O(l)$ [1]
(State symbols are not required)

DSE14_11

(a) Vanadium exhibits variable oxidation numbers and its ions in aqueous solution carry colors. [1]

(b) (i) 1 (mol of) $VO_2^+(aq)$ ions gains 2 (mol of) electrons from 1 (mol) of $SO_2(g)$ to become 1 (mol of) $V^{3+}(aq)$. [1]
$V^{3+}(aq)$ is green in color. [1]

(ii) $SO_2(g) + VO_2^+(aq) \longrightarrow SO_4^{2-}(aq) + V^{3+}(aq)$ [1]

DSE15_02

(b) The solution changes from orange to green. (NOT accept "colorless gas bubbles / $SO_2(g)$") [1]
[1]
$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) + 8H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 4H_2O(l)$

DSE15_04

(a) A cell that can be recharged after use. [1]

(b) It can provide a high current / voltage / power to start up the engine. [1]
NOT accept "energy", "electrical energy".

(c) Lead / lead compounds are toxic / harmful. [1]
OR, Sulphuric acid is corrosive / irritant.
NOT accept answers like "lead compounds are pollutants / heavy metal"
NOT accept answers like 'acid cause harm the environment".

DSE15_07

(a) Oily dirts hinders the conduction of electricity / hinders the plating of copper on the object. [1]

OR, The copper surface will easily flake off / the electroplated surface will not be smooth.

(b) Electrolyte is a compound that conducts electricity when melted or dissolved in water. [1]

OR, Electrolyte is a substance that consist of mobile ions when melted or dissolved in water.

OR, Electrolyte is a substance that undergoes decomposition when electricity is passing through it.

(c) Cu^{2+}, SO_4^{2-}, H^+, OH^- [1]

(d) Copper(II) ion has higher oxidizing power than hydrogen ion. [1]

OR, Copper(II) ion undergoes reduction more readily than hydrogen ion.

OR, Copper(II) ion is lower than hydrogen the electrochemical series.

(e) $Cu \longrightarrow Cu^{2+} + 2e^-$ [1]

(f) No observable change [1]

(g) Mole of electrons involved $= \frac{2.20 \times 10^{22}}{6.02 \times 10^{23}} = 0.0379$ [1]

Mass of copper formed $= \frac{0.0379}{2} \times 63.5 = 1.20\ g$ (accept 1.20 – 1.21) [1]

DSE16_08

(a) (i) Reddish brown gas observed. (*NOT accept reddish brown liquid.*) [1]

(ii) $Sr^{2+} + 2e^- \longrightarrow Sr$ [1]

(b) Bromine gas formed is toxic / poisonous. / Bromine is toxic. / A toxic gas is formed. [1]

Do not accept answers like "irritant", "harmful".

(c) (i) Oxidation number of Mn decreases / changes from +4 to +3. [1]

Therefore $MnO_2(s)$ is the oxidizing agent. [1]

(ii) $2MnO_2(s) + 2NH_4^+(aq) + 2e^- \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$ [1]

OR, $2NH_4^+(aq) + 2e^- \longrightarrow 2NH_3(aq) + H_2(g)$

DSE17_04

(a) (i) A: $OH^-(aq)$ ions are (preferentially) discharged to give a (colorless) gas (oxygen). [1]

(Accept oxygen is not mentioned. Not accept incorrect gas is mentioned.)

(Not accept: $OH^-(aq)$ ions are preferentially discharged to give oxygen.)

(ii) $H^+(aq)$ ions are (preferentially) discharged to give a (colorless) gas (hydrogen). [1]

(Accept hydrogen is not mentioned. Not accept incorrect gas is mentioned.)

(Not accept: $H^+(aq)$ ions are preferentially discharged to give hydrogen.)

The solution turns pink as $[OH^-(aq)] > [H^+(aq)]$ (when H^+ ions are consumed). [1]

(Accept only mentioned concentration of OH^- / amount of OH^- / no. of mole of OH^- increases / accumulate more OH^-, without mentioning H^+.)

(b) $2H_2O \longrightarrow 2H_2 + O_2$ [1]

(State symbols not required. Incorrect answer if wrong state symbols were given.)

(c) (i) A: No change. $OH^-(aq)$ ions are (still preferentially) discharged to give a colorless gas (oxygen). [1]

(ii) No change. $H^+(aq)$ ion, the only cations, discharged to give a colorless gas (hydrogen). [1]

(Accept: A faster rate of colorless gas bubble formation will be observed with increased concentration of H^+ in the solution.)

No color change in the solution / The solution will not turn into pink as it is still acidic, despite the decrease in $[H^+(aq)]$ / as $H^+(aq)$ is in excess. [1]

(Accept: The solution close to the surface of the electrode will turn pink due to the discharge of H^+, but the overall color change will become much less obvious / the solution remains colorless due to the presence of excess H^+ in the solution.)

DSE17_06

(a) Oxidizing and corrosive [1]

(c) Copper dissolves / The solution turns blue / A colorless / choking gas (bubbles) evolves. [1]

$Cu + H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$ [1]

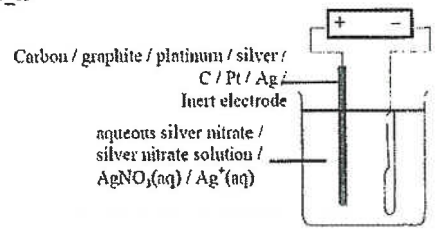
OR The liquid turns black / A black solid / precipitate is formed.

$Cu + H_2SO_4 \longrightarrow CuO + H_2O + SO_2$

State symbols not required.

DSE18_05

(a) [3]



All 3 labels correct: 2 marks, Any 1 label correct: 1 mark

(Accept drawing of battery with correct poles / only + and – signs at the correct positions / electron flow in the correct direction in the external circuit.

(b) Connect zinc / magnesium blocks (through connecting wires to the surface of the pipelines / scarification protection. [1]

Zinc / magnesium can release electrons more readily than iron. [1]

OR, Zinc and magnesium are more reactive than iron. / Zinc and magnesium has greater reducing power than iron. / Zinc and magnesium is higher than iron in the ECS.

OR, Connect the negative electrode of a D.C. source (through connecting wires)

to the surface of the pipelines (and the positive electrode to a platinum electrode) / Cathodic protection
The electrons provided by the D.C. source prevent iron from releasing electrons.
(Do not accept wrapping with plastics / alloying / use stainless steel pipelines)

DSE18_08

(a) An acid which can (almost) completely ionize / dissociate to H^+ ions in water. [1]

(b) (i) Chlorine / $Cl_2(g)$ [1]

(ii) Any ONE of the followings: [1]
It is a redox reaction:
- O.N. of Cl changes from -1 to 0 /
- O.N. of Mn changes from +7 to +2
- Cl^- transfer electrons to MnO_4^-
- O.N. of Mn and Cl change at the same time
- MnO_4^- is reduced and Cl^- is oxidized.

(c) The filter paper turns yellowish brown [1]
(Do not accept yellow / orange)
$2I^- + Cl_2 \longrightarrow 2Cl^- + I_2$ [1]

(d) The experiment should be performed in a fume cupboard as chlorine gas is toxic / toxic gas is released. [1]
(Do not accept well-ventilated benches, etc.)

DSE19_07

(a) (i) Separate the $CuSO_4(aq)$ and $MgSO_4(aq)$ / allow ions to pass through / to complete the circuit. [1]

(ii) Yes, the multimeter reading is positive showing electrons flow from Mg to Cu through the external circuit because
Mg loses electrons more readily than Cu. [1]
OR
- Mg is more reactive than Cu.
- Mg is a stronger reducing agent than Cu.
- Mg is higher than Cu in the reactivity series or ECS.
- Mg is the negative electrode and Cu is the positive electrode.

(iii) $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ (Ignore state symbols) [1]

(b) (i) $Br_2(aq) + 2e^- \longrightarrow 2Br^-(aq)$ (Ignore state symbols) [1]

(ii) The size of the electrode decreases. [1]
OR
- The mass of the electrode decreases.
- The electrode dissolves.
- Colour around the electrode deepens.
- Colour around the electrode becomes darker blue.

(Do NOT accept "the colour around the electrode turns blue".)

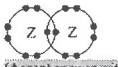
(iii) Less negative [1]

Iodine gains electrons less readily than bromine. [1]
OR
- Iodine is less reactive than bromine.
- Iodine is a weaker oxidising agent than bromine.
- Iodine is higher than bromine in the ECS.

(Accept "iodine is a weaker oxidising agent".)

DSE20_01

1. (a) 2, 8, 18, 7 1

(b) 

1
(Accept answer with correct inner shell electrons)
(Not accept answer with incorrect inner shell electrons, if inner shell electrons are drawn)

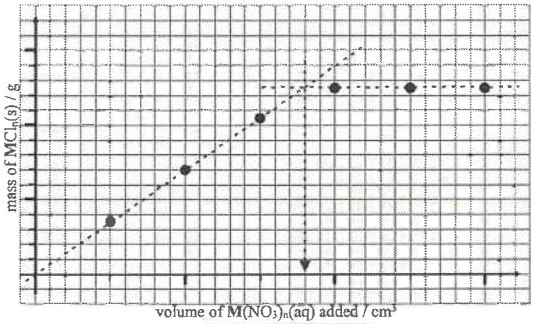
(c) (i) $K_2SO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + SO_2(g)$ / 2
$K_2SO_3(s) + 2H^+(aq) \rightarrow 2K^+(aq) + H_2O(l) + SO_2(g)$
Correct states (1 mark)
Balanced equation (1 mark)
(No mark if the chemical species shown in the equation are incorrect)

(ii) (Reddish brown / brown) changes to colourless. / The solution changes to colourless. 1
(Not accept incorrect initial colour. Not accept pale brown)
$Br_2 + SO_2 + 2H_2O \rightarrow 2Br^- + SO_4^{2-} + 4H^+$ 1
(State symbols not required) (Ignore incorrect state symbols)
OR $Y_2 + SO_2 + 2H_2O \rightarrow 2Y^- + SO_4^{2-} + 4H^+$

(iii) Y and Z have the same number of electrons / seven electrons in the outermost shells, hence similar chemical properties (leading to similar observation). 1
(Not accept "Same chemical properties")

DSE20_02

2. (a) It is because for the last three points in the graph, the amount of $M(NO_3)_n$ / M^{n+} added is in excess. / 1
It is because for the last three points in the graph, all HCl / Cl^- has been used up.
(Not accept only "The reaction is completed" is written)

(b) (i) 1


volume of $M(NO_3)_n(aq)$ = 18 cm^3 (Accept 17.5 – 18.5 cm^3) 1
(Accept max. 1 decimal place)
(No mark if the answer is correct, but the answer was obtained with a wrong way.)

(ii) 18 / 1000 x 0.5 = 0.009 mol (Accept 0.00875 – 0.00925 mol) 1
(Accept answer with no unit) (Not accept answer with incorrect unit)

(c) no. of mole of Cl^-: 50 / 1000 x 0.36 = 0.018 mol 1
Ratio of metal ions : chloride ions = 0.009 : 0.018 = 1 : 2. The empirical formula of the metal chloride is MCl_2. 1
M would be lead because the ratio of Ag to Cl in its empirical formula is 1:1 while now is 1:2 applicable to Pb to Cl. 1

6. (a) • To provide an aqueous medium / dissolve $CuSO_4(s)$ and $Na_2SO_4(s)$ so as to produce mobile ions. 1
• Magnesium is higher than copper in the electrochemical series / ECS and release electrons. The electrons pass from the negative pole of the voltmeter to the positive pole, producing to a positive reading. 1

• Magnesium is more reactive than copper.
• Magnesium is a stronger reducing agent than copper.
• Magnesium losses electrons more readily than copper.
• Magnesium occupies a higher position than copper in the ECS.
• Electrons flow from side B to side A.
• Current flows from side A to side B.

(b) (i) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ (Ignore state symbols) (Electron with a negative charge symbol) (Not accept: Mg^{+2}) 1

(ii) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (Ignore state symbols) 1

(c) The position of the pointer is higher than 0 and lower than the reading in Diagram (1). 1
(Candidates have to draw the pointer in Diagram (2))

(d) (i) $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$ (Ignore state symbols) 1
/ $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$ (Ignore state symbols)

(ii) † (Metal) Displacement (reaction) 1

SECTION 8 Chemical Reactions and Energy

Multiple-Choice Questions

ASL10(I)_08

Which of the following process is endothermic?

A. Freezing of water
B. Condensation of steam
C. Reaction of $H^+(aq)$ with $OH^-(aq)$ to give $H_2O(l)$
D. Electrolysis of water

DSE11SP_10

Which of the following reactions is endothermic?

A. $Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$
B. $CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$
C. $2C_4H_{10}(g) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(l)$
D. $C_9H_{20}(l) \longrightarrow C_2H_6(g) + C_3H_6(g) + C_4H_8(g)$

DSE11SP_13

Standard enthalpy changes of several reactions, as denoted by x, y and z respectively, are listed in the table below.

Reaction	Standard enthalpy change / kJ mol^{-1}
$C(s) + O_2(g) \longrightarrow CO_2(g)$	x
$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g)$	y
$C(s) + 2H_2(g) \longrightarrow CH_4(g)$	z

For the reaction $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$, which of the following is a reasonable estimate of its standard enthalpy change?

A. $x + y - z$
B. $-x - y + z$
C. $x + 2y - z$
D. $-x - 2y - z$

DSE11SP_19

In an experiment, 10.0 g of KCl(s) was added to 100 cm^3 of water. The mixture was then stirred until all the KCl(s) dissolved. The temperature of the mixture was found to drop by 5.5°C. What is the molar enthalpy change, in kJmol^{-1}, of the dissolving process of KCl(s) under the conditions of the experiment?

(Specific heat capacity of the mixture = 4.2 J g^{-1} K^{-1}; Density of water = 1.0 g cm^{-3};
Relative atomic masses: K = 39.1, Cl = 35.5)

A. +2.31
B. +2.54
C. +17.23
D. +18.96

DSE12PP_05

Which of the following processes is endothermic?

A. $H_2O(l) \longrightarrow H_2O(s)$

B. $CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4 \cdot 5H_2O(s)$

C. $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$

D. $Ca(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$

DSE12PP_12

Consider the standard enthalpy changes of the following reactions:

$I_2(s) + Cl_2(g) \longrightarrow 2ICl(s)$ $\quad \Delta H = +14$ kJ mol^{-1}

$ICl(s) + Cl_2(g) \longrightarrow ICl_3(s)$ $\quad \Delta H = -88$ kJ mol^{-1}

What is the standard enthalpy change of formation of $ICl_3(s)$:

A. -81 kJ mol^{-1} B. -74 kJ mol^{-1}

C. $+74$ kJ mol^{-1} D. $+81$ kJ mol^{-1}

DSE12_07

The standard enthalpy change of combustion of some substances are shown below:

Substance	Standard enthalpy change of combustion at 298 K / kJ mol^{-1}
$H_2(g)$	-286
C(graphite)	-394
$CH_3CH_2OH(l)$	-1371

The standard enthalpy change of formation at 298 K of $CH_3CH_2OH(l)$ is

A. -275 kJ mol^{-1} B. $+275$ kJ mol^{-1}

C. $+691$ kJ mol^{-1} D. -3017 kJ mol^{-1}

DSE13_15

For which of the following reactions must its enthalpy change be determined by INDIRECT method?

A. $Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$

B. $2C(s) + O_2(g) \longrightarrow 2CO(g)$

C. $CH_3CH_2OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

D. $MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$

DSE13_18

Under standard conditions, complete combustion of 0.050 mol of propane (C_3H_8) gives 111 kJ of heat. Which of the following is the standard enthalpy change of formation of propane?

(Standard enthalpy change of formation of $H_2O(l) = -286$ kJ mol^{-1};

Standard enthalpy change of formation of $CO_2(g) = -394$ kJ mol^{-1})

A. -106 kJ mol^{-1} B. $+106$ kJ mol^{-1}

C. -569 kJ mol^{-1} D. $+569$ kJ mol^{-1}

DSE14_09

The enthalpy changes of three reactions under certain conditions are shown below:

Reaction	Enthalpy change
$B_2H_6(g) + 3O_2(g) \longrightarrow B_2O_3(s) + 3H_2O(l)$	-2170 kJ mol^{-1}
$B(s) + \frac{3}{4} O_2(g) \longrightarrow \frac{1}{2} B_2O_3(s)$	-635 kJ mol^{-1}
$H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l)$	-286kJ mol^{-1}

Which of the following is the enthalpy change of formation of $B_2H_6(g)$ under the same conditions?

A. $+42$ kJ mol^{-1} B. $+614$ kJ mol^{-1}

C. $+677$ kJ mol^{-1} D. $+1249$ kJ mol^{-1}

DSE15_12

Consider the following reactions:

(1) $CO_2(g) + CaO(s) \longrightarrow CaCO_3(s)$ $\quad \Delta H_1$

(2) $NH_3(g) + HBr(g) \longrightarrow NH_4Br(s)$ $\quad \Delta H_2$

(3) $HF(aq) + NaOH(aq) \longrightarrow NaF(aq) + H_2O(l)$ $\quad \Delta H_3$

(4) $NaHCO_3(aq) + HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$ $\quad \Delta H_4$

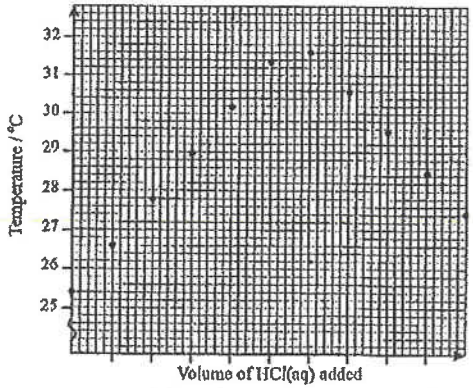
Which of the following represents enthalpy change of neutralization?

A. ΔH_1 B. ΔH_2

C. ΔH_3 D. ΔH_4

DSE14_12

In an experiment, standard HCl(aq) was added from a burette to a known volume of NaOH(aq) placed in an expanded polystyrene cup. The graph below shows the temperatures of the mixture in the cup during the process:



What is the greatest temperature rise of the mixture in the cup as estimated from the graph above?

A. 2.0 °C B. 4.6 °C

C. 6.2 °C D. 6.6 °C

DSE15_18

Which of the following combinations is / are correct?

Chemical reaction	Enthalpy change of reaction
(1) $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$	Positive
(2) $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$	Positive
(3) $2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$	Negative

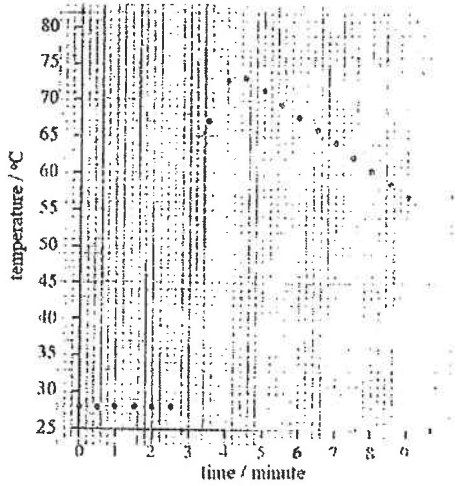
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE16_24

1st statement	2nd statement
The standard enthalpy change of formation of a compound must be negative value.	Under standard conditions, a compound must be energetically more stable than its constituent elemnets.

DSE17_07

In an experiment for studying the enthalpy change of a reaction, the variation of the temperature of the content in the reaction container with time was plotted in a graph as shown below:
The reaction starts at the third minute. Which of the following combinations is correct?



	The greatest temperature rise of the content	Enthalpy change of the reaction
A.	51 °C	negative
B.	45 °C	negative
C.	51 °C	positive
D.	45 °C	positive

DSE18_18

Consider the following information:

$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g) \quad \Delta H^\circ = +x \text{ kJ mol}^{-1}$

Which of the following statements is/are correct?

(1) The standard enthalpy change of formation of $H_2O(l)$ is $-0.5x$ kJ mol^{-1}
(2) The standard enthalpy change of formation of $H_2O(l)$ is $+0.5x$ kJ mol^{-1}
(3) The standard enthalpy change of combustion of $H_2(g)$ is $-x$ kJ mol^{-1}

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE18_22

Which of the following processes are endothermic?

(1) Melting of wax
(2) Cracking of heavy oil
(3) Adding zinc powder to $CuSO_4(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE19_09

It is given that:
Standard enthalpy change of formation of water = -286 kJ mol^{-1}
Standard enthalpy change of combustion of propane = -2222 kJ mol^{-1}
Standard enthalpy change of formation of carbon dioxide = -394 kJ mol^{-1}

What is the standard enthalpy change of formation of propane?

A. -52 kJ mol^{-1}
B. -104 kJ mol^{-1}
C. $+52$ kJ mol^{-1}
D. $+104$ kJ mol^{-1}

DSE19_22

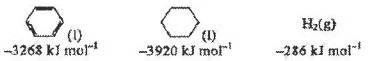
Which of the following are exothermic?

(1) Thermal decomposition of mercury(II) oxide solid
(2) Dilution of concentrated sulphuric acid with water
(3) Reaction of magnesium ribbon with dilute hydrochloric acid

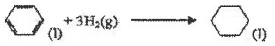
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE2020:

10. Refer to the standard enthalpy changes of combustion below :



What is the standard enthalpy change of the following reaction ?



A. −206 kJ mol^{-1}
B. −652 kJ mol^{-1}
C. +206 kJ mol^{-1}
D. +652 kJ mol^{-1}

13. The enthalpy changes for some conversions are shown below :

$$W \xrightarrow{\Delta H = -150\ kJ\ mol^{-1}} X \xrightarrow{\Delta H = +100\ kJ\ mol^{-1}} Y \xrightarrow{\Delta H = +60\ kJ\ mol^{-1}} Z$$

Which of the following combinations is correct ?

	W ⟶ Z	Z ⟶ X
A.	exothermic	endothermic
B.	exothermic	exothermic
C.	endothermic	exothermic
D.	endothermic	endothermic

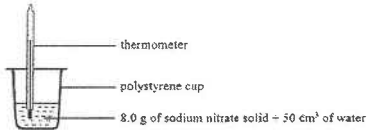
21. Which of the following statements are correct ?

(1) The standard enthalpy change of formation of $NH_3(g)$ can be determined directly from experiment.
(2) The standard enthalpy change of combustion of $H_2NNH_2(l)$ is negative.
(3) The standard enthalpy change of formation of $N_2(g)$ is zero.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE2021:

14. Based on the experimental set-up in the diagram below, after 8.0 g of sodium nitrate solid is completely dissolved in 50 cm^3 of water, the temperature drops by 6 °C.



Which of the following would give a drop of temperature by 3 °C under the same experimental conditions ?

A. After 2.0 g of sodium nitrate solid is completely dissolved in 25 cm^3 of water.
B. After 4.0 g of sodium nitrate solid is completely dissolved in 100 cm^3 of water.
C. After 16.0 g of sodium nitrate solid is completely dissolved in 100 cm^3 of water.
D. After 24.0 g of sodium nitrate solid is completely dissolved in 75 cm^3 of water.

15. When 7.89 g of carbon monoxide gas burns completely, 80 kJ of heat is released. Under those experimental conditions, the enthalpy change of formation of carbon dioxide gas is −394 kJ mol^{-1}. What is the enthalpy change of formation of carbon monoxide gas under the same experimental conditions ?

(Relative atomic masses : C = 12.0, O = 16.0)

A. −678 kJ mol^{-1}
B. −474 kJ mol^{-1}
C. −314 kJ mol^{-1}
D. −110 kJ mol^{-1}

Structural Questions

AL98(II)_02c

Both $H_2(g)$ and $CH_3OH(l)$ are possible fuels for powering rockets. Their combustion reactions are show below.

$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g)$$

$$CH_3OH(l) + 1\frac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

(i) For each of the above reactions, calculate the enthalpy change at 298 K per kg of the fuel-oxygen mixture in the mole ratio as indicated in the stoichiometric equation.

(3 marks)

(ii) The effectiveness of a fuel can be estimated by dividing the enthalpy change per kg of the fuel-oxygen mixture in its combustion reaction by the average molar mass of the product(s) in g.

Deduce which of the above two fuels is more effective in powering rockets.

Note: You are provided with the following data at 298 K:

Compound	Molar mass / g	ΔH°_f / kJ mol^{-1}
$CO_2(g)$	44	−394
$H_2O(g)$	18	−242
$CH_3OH(l)$	32	−239

(3 marks)

AL99(I)_07b

In an experiment to determine the enthalpy change of neutralization, a polystyrene foam cup was used as a calorimeter. When a solution of an acid was poured into a solution of an alkali in the calorimeter, the temperature rise was recorded by a thermometer which also served as a stirrer.

State THREE sources of error in the result obtained in such an experiment.

(2 marks)

ASL99(I)_02

Consider the standard enthalpy changes of combustion, $\Delta H^\circ_{c,298}$ of the alkanols listed in the table below:

Alkanol	$\Delta H^\circ_{c,298}$ / kJ mol^{-1}
$CH_3OH(l)$	−726
$CH_3CH_2OH(l)$	−1367
$CH_3(CH_2)_2OH(l)$	−2017
$CH_3(CH_2)_3OH(l)$	x

(a) Explain why the combustion of $CH_3OH(l)$ is exothermic.

(1 mark)

(b) Estimate the value of x. Show how you arrive at your answer.

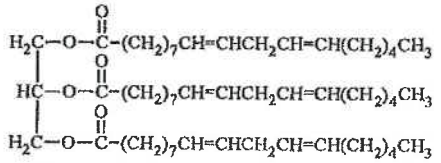
(2 marks)

(c) At 298 K, the standard enthalpy changes of formation of $CO_2(g)$ and $H_2O(l)$ are –393 and –286 kJ mol^{-1} respectively. Calculate the standard enthalpy change of formation of $CH_3OH(l)$ at 298K.

(3 marks)

ASL99(II)_13 [Similar to DSE18_06b]

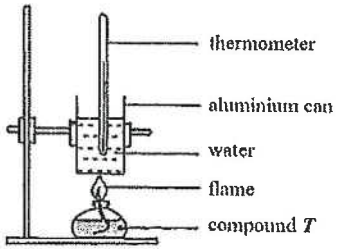
Compound T is the main chemical constituent of a cooking oil. T has the following structural formula:



(a) State all functional groups in T.

(2 marks)

(b) The enthalpy change of combustion of T can be determined using the set-up shown below:



When 2.30 g of T was burnt, the temperature of water of mass 250 g in the aluminium can was found to increase by 20.5°C.

(i) Calculate the enthalpy change of combustion of T, in kJ mol^{-1}, under the conditions of the experiment.
(Specific heat capacity of water = 4.18 J g^{-1} K^{-1}; relative molecular mass of T = 878)

(3 marks)

(ii) Suggest TWO main sources of error in the experiment.

(2 marks)

ASL00(II)_08

(a) The standard enthalpy changes of combustion of cyclohexa-1,3-diene (C_6H_8), cyclohexane (C_6H_{12}) and hydrogen are as follows:

$\Delta H^\circ_{c,298}$ [$C_6H_8(l)$] = –3584 kJ mol^{-1}
$\Delta H^\circ_{c,298}$ [$C_6H_{12}(l)$] = –3924 kJ mol^{-1}
$\Delta H^\circ_{c,298}$ [$H_2(g)$] = –286 kJ mol^{-1}

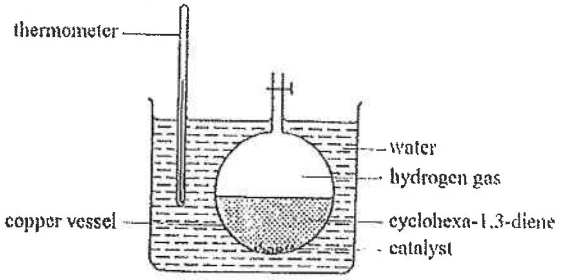
(i) With the help of a chemical equation, state the meaning of the standard enthalpy change of combustion of cyclohexane.

(3 marks)

(ii) Write a chemical equation to represent the complete hydrogenation of cyclohexa-1,3-diene. Hence, calculate the standard enthalpy change of hydrogenation of cyclohexa-1,3-diene.

(3 marks)

(b) In an experiment to determine the enthalpy change of hydrogenation of cyclohexa-1,3-diene, 0.10 mol of cyclohexa-1,3-diene was treated with excess hydrogen gas in the presence of a catalyst in a copper vessel. The vessel was immersed in 300.0 g of water. The diagram below shows the experimental set-up:



(i) Name a catalyst suitable for the hydrogenation.

(1 mark)

(ii) It is necessary to shake the vessel vigorously during the experiment. Explain.

(1 mark)

(iii) Suggest TWO reasons why a copper vessel was used instead of a glass vessel.

(2 marks)

(iv) At the end of the experiment, the temperature of the water increased by 16.5°C.

(I) Calculate the enthalpy change of hydrogenation of cyclohexa-1,3-diene, in kJ mol^{-1}, under the conditions of the experiment.
(specific heat capacity of the water is 4.2 J g^{-1} K^{-1})

(3 marks)

(II) State TWO assumptions in your calculation.

(2 marks)

ASL01(II)_09 [Similar to DSE15_08]

(a) The table below lists the standard enthalpy changes of formation of three compounds:

Compound	$\Delta H^\circ_{f,298}$ / kJ mol^{-1}
$C_6H_{12}O_6(s)$ (glucose)	−1274
$CO_2(g)$	−394
$H_2O(l)$	−286

(i) Calculate the standard enthalpy change of combustion of glucose.

(3 marks)

(ii) Calculate the theoretical amount of energy released when 10.0 g of glucose undergoes complete combustion.

(2 marks)

(b) The thermochemical equation for the combustion of tripalmitin ($C_{51}H_{98}O_6$) is given below:

$$C_{51}H_{98}O_6(s) + \frac{145}{2}O_2(g) \longrightarrow 51CO_2(g) + 49H_2O(l) \quad \Delta H^\circ_{c,298} = -31400 \text{ kJ mol}^{-1}$$

Calculate the theoretical amount of energy released when 10.0 g of tripalmitin undergoes complete combustion.

(2 marks)

(c) With reference to your answers in (a) and (b), suggest why plants store their energy mainly in the form of carbohydrates, whereas animals store their energy mainly in the form of fats (tripalmitin).

(2 marks)

ASL02(II)_08 [Similar to DSE17_07]

(a) In an experiment to determine the enthalpy change of combustion of ethanol, a calorimeter containing 200.0 g of water was used. Burning 0.185 g of ethanol caused the temperature of the water in the calorimeter to rise by 6.0 °C.

(i) Draw a labelled diagram of the set-up used in the experiment.

(2 marks)

(ii) Assuming that the heat capacity of the calorimeter is negligible, calculate the enthalpy change of combustion of ethanol, in kJ mol^{-1}, under the conditions of the experiment. (specific heat capacity of the mixture is 4.2 J g^{-1} K^{-1})

(3 marks)

(iii) State TWO other assumptions made in your calculation.

(2 marks)

(b) (i) Do you agree with the following statement? Explain your answer.
'The standard enthalpy change of formation of ethanol can be determined directly by experiment.'

(1 mark)

(ii) The table below lists the standard enthalpy changes of combustion of three substances.

Substance	$\Delta H^\circ_{c,298}$ / kJ mol^{-1}
C(graphite)	−394
$H_2(g)$	−286
$C_2H_5OH(l)$	−1368

Calculate the standard enthalpy change of formation of ethanol, $\Delta H^\circ_{f,298}[C_2H_5OH(l)]$.

(3 marks)

(c) The table below lists the standard enthalpy changes of neutralization of three acids with NaOH(aq).

Acid	$\Delta H^\circ_{neutralization,298}$ / kJ mol^{-1}
HCl(aq)	−57.3
$HNO_3(aq)$	−57.3
$CH_3CO_2H(aq)$	−55.2

Account for the following statements:

(i) The standard enthalpy change of neutralization of HCl(aq) with NaOH(aq) is the same as that of $HNO_3(aq)$ with NaOH(aq).

(2 marks)

(ii) The standard enthalpy change of neutralization of HCl(aq) with NaOH(aq) is more negative than that of $CH_3CO_2H(aq)$ with NaOH(aq).

(2 marks)

ASL03(II)_09 [Same as DSE19_08]

In a thermometric titration experiment, 25.0 cm^3 of 2.0 M sodium hydroxide solutions was placed in a polystyrene foam cup and was titrated against hydrochloric acid. The experimental results are listed in the table below:

Volume of HCl(aq) added / cm^3	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0
Temperature of mixture / °C	25.8	30.0	34.4	38.8	39.8	38.2	36.6	35.0

(a) Plot a graph to show the variation of the temperature of the mixture with the volume of HCl(aq) added.

(3 marks)

(b) (i) From your graph, determine the maximum temperature that could be attained by the mixture.

(1 mark)

(ii) Calculate the molarity of the HCl(aq) used.

(2 marks)

(c) Using your result in (b), calculate the enthalpy change of neutralization of NaOH(aq) with HCl(aq) under the conditions of the experiment.
(You may assume that the density of the mixture is 1.0 g cm^{-3}, the specific heat capacity of the mixture is 4.2 J g^{-1} K^{-1} and that the heat capcity of the polystyrene cup is negligible.)

(3 marks)

ASL04(II)_10

In an experiment to determine the enthalpy change of hydration of $CuSO_4(s)$ indirectly, 0.025 mol of $CuSO_4(s)$ and 0.025 mol of $CuSO_4 \cdot 5H_2O(s)$ were dissolved separately in 50.0 cm^3 of deionized water in a polystyrene cup. The maximum change in temperature of each mixture was determined. The table below lists the results obtained:

The form of copper(II) sulphate(VI) used	Maximum change in temperature / °C
$CuSO_4(s)$	+7.7
$CuSO_4 \cdot 5H_2O(s)$	−1.7

(a) Calculate, under the condition of the experiment, the molar enthalpy change of solution of each of the following compounds.

(1) $CuSO_4(s)$

(2) $CuSO_4 \cdot 5H_2O(s)$

(You may assume that the copper(II) sulphate(VI) solution formed has a specific heat capacity of 4.2 J g^{-1} K^{-1} and a density of 1.0 g cm^{-3}, and that the heat capcity of the polystyrene cup is negligible.)

(4 marks)

(b) From your results in (a), calculate the molar enthalpy change of hydration of $CuSO_4(s)$.

(2 marks)

(c) Suggest why the enthalpy change of hydration of $CuSO_4(s)$ cannot be determined directly.

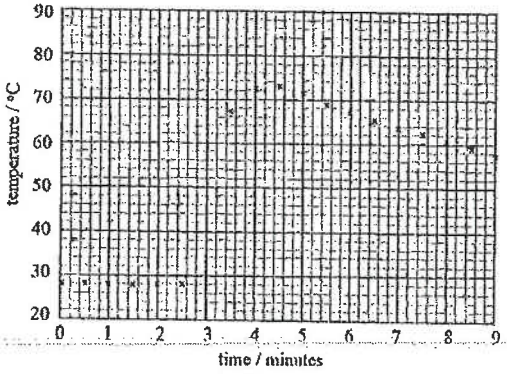
(1 mark)

ASL05(I)_04

An experiment was carried out to determine the enthalpy change of the following reaction:

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Cu(s) + Zn^{2+}(aq)$$

25.0 cm^3 of 1.00 M $CuSO_4(aq)$ was transferred to a polystyrene cup with negligible heat capacity, and the temperature of the solution was recorded every half minute for 2½ minutes. At precisely 3.0 minutes, 4.0 g of zinc powder was added to the cup. The mixture was stirred and its temperature was recorded for an additional 6 minutes. The graph below shows the plot of temperature against time.



(a) Show, by calculation, that $CuSO_4$ is the limiting reactant.

(2 marks)

(b) Find, from the graph, the maximum temperature rise of the mixture. (You should show your working on the graph.)

(2 marks)

(c) Assuming that the specific heat capacity and the density of the mixture are 4.2 J g^{-1} K^{-1} and 1.0 g cm^{-3} respectively, calculate the enthalpy change of this reaction, in kJ mol^{-1}.

(3 marks)

AL05(II)_05

Most of the petroleum stock located on Earth is likely to be used up in 50 to 100 years if petroleum consumption is maintained at the current rate. With a view to cutting down petroleum consumption, some countries have adopted an alternative fuel for motor vehicles – gasoline which contains ethanol.

(a) Based on the standard enthalpy changes of formation given below, calculate the standard enthalpy changes for the complete combustion of octane and ethanol respectively.

Compound	ΔH°_f / kJ mol^{-1}
$C_8H_{18}(l)$	−250
$C_2H_5OH(l)$	−278
$CO_2(g)$	−394
$H_2O(l)$	−286

(4 marks)

(b) Assuming that gasoline contains only octane, compare the enthalpy change of combustion values, in kJ g^{-1}, of gasoline and an alternative fuel containing gasoline and 10% ethanol by mass.

(4 marks)

(c) Besides cutting down petroleum consumption, suggest one additional advantage of using the alternative fuel over using gasoline.

(1 mark)

AL06(I)_02

Given:

$$C(diamond) \longrightarrow C(graphite) \quad \Delta H^\circ = -2 \text{ kJ mol}^{-1}$$

Explain why the conversion of diamond into graphite will not occur spontaneously under normal condition.

(1 mark)

ASL06(I)_06

When 10.0 cm^3 of ethyl ethanoate was mixed with 8.0 cm^3 of trichloromethane, the temperature of the mixture increased by 9.5 °C.

(a) With the help of a diagram, showing the structures of the molecules, explain why the above mixing process is exothermic.

(2 marks)

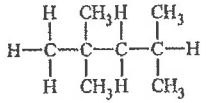
(b) Based on the data given below, estimate by calculation the enthalpy change, in kJ mol^{-1}, for the above mixing process.

Compound	Molar mass	Density	Specific heat capacity
Ethyl ethanoate	88.0 g mol^{-1}	0.90 g cm^{-3}	1.92 J g^{-1} K^{-1}
Trichloromethane	119.5 g mol^{-1}	1.49 g cm^{-3}	0.97 J g^{-1} K^{-1}

(3 marks)

ASL06(II)_11

Compound *X* has the following structure:



Complete combustion of 1.0 g of *X* liberates 44.5 kJ at 298 K under atmospheric pressure.

(a) Give the systematic name of *X*.

(1 mark)

(b) Calculate the standard enthalpy change of combustion of *X* at 298 K.

(3 marks)

(c) Calculate the standard enthalpy change of formation of *X* at 298 K.

(3 marks)

Standard enthalpy change of formation of $CO_2(g)$ and $H_2O(l)$ at 298 K are –393.5 kJ mol^{-1} and –285.8 kJ mol^{-1} respectively.

AL08(II)_01

The table below lists the **standard enthalpy change of formation of four compounds.**

Compound	$\Delta H^\circ_{f,298}$ / kJ mol^{-1}
$H_2O(l)$	–286
$HCl(g)$	–92
$SiO_2(s)$	–910
$SiCl_4(l)$	–640

(a) State the meaning of the term 'standard enthalpy change of formation of a compound'.

(1 mark)

(b) $SiCl_4(l)$ undergoes hydrolysis to give $SiO_2(s)$

(i) Write the chemical equation for the hydrolysis.

(1 mark)

(ii) Using the above data, calculate the standard enthalpy change for the hydrolysis. State ONE assumption made in your calculation.

(3 marks)

ASL09(II)_01

Hydrolysis of protein gives a variety of amino acids, and alanine ($CH_3CH(NH_2)CO_2H$) is one of the amino acids commonly obtained.

(a) In the human body, alaine undergoes biological oxidation to give cabon dioxide, water and urea ($CO(NH_2)_2$). Write the chemical equation for this reaction.

(1 mark)

(b) When nitrogen-containing organic compounds are burnt in calorimetric experiments, the nitrogen they contained is transformed to nitrogen molecules.

Write the chemical equation for the combustion of each of the following compounds in a calorimetric experiment:

(i) Alaine

(1 mark)

(ii) Urea

(1 mark)

(c) Using the equations that you have given in (a) and (b), as well as the standard enthalpy change of combustion given in the table below:

Compound	$\Delta H^\circ_{c,298}$ / kJ mol^{-1}
Alanine	–1577
Urea	–632

Calculation the energy, in kJ, that can be obtained from te biological oxidation of 1.00 g of alanine at 298 K.

(4 marks)

ASL10(II)_07 [Similar to DSE14_06]

The table below lists the **standard enthalpy change of formation of four compounds.**

Compound	$\Delta H_f^\circ{}_{298}$ / kJ mol^{-1}
$H_2O(l)$	–286
$H_2O_2(l)$	–188
$NH_3(g)$	–46
$N_2H_4(l)$	+51

(a) What is the meaning of the term 'standard enthalpy change of formation'?

(1 mark)

(b) Hydrazine (N_2H_4) is a colorless liquid commonly used as a rocket fuel. It can be synthesized in a chemical process in which ammonia is oxidized by hydrogen peroxide to give hydrazine and water.

For the oxidation of ammonia to hydrazine,

(i) Write its chemical equation, and

(1 mark)

(ii) calculate its standard enthalpy change using the above thermochemical data.

(2 marks)

(c) A student found the following information in a Material Safety Data Sheet (MSDS):

'Hydrazine is extremely explosive in the presence of oxidizing materials'

The student accounted for the phenomenon by the positive standard enthalpy change of formation of hydrazine. Is the student's explanation correct? Elaborate your answer.

(2 marks)

AL10(II)_02

A flight of space shuttle requires the use of three propellants:

A solid propellant, which is a mixture of powder Al(s) and $NH_4ClO_4(s)$, is used to power the rockets carrying the shuttle. Upon ignition, the solid propellant reacts to give $Al_2O_3(s)$, $AlCl_3(s)$, NO(g) and $H_2O(g)$. This reaction provides energy for launching the rockets and the shuttle up to the upper atmosphere.

After the shuttle separates from the rockets, the shuttle is propelled into its designed orbit by a **cryogenic propellant**, which is a mixture of $H_2(l)$ and $O_2(l)$.

When the shuttle is in its orbit, a **hypergolic propellant**, of which the fuel is $CH_3NHNH_2(l)$ and oxidant is $N_2O_4(l)$, will provide energy for manoeuvring the shuttle. The fuel and oxidant react upon mixing, without ignition, to give $CO_2(g)$, $H_2O(g)$ and $N_2(g)$.

(a) Write the chemical equation for the reaction of

(i) Al(s) with $NH_4ClO_4(s)$, and

(1 mark)

(ii) $CH_3NHNH_2(l)$ with $N_2O_4(l)$.

(1 mark)

(b) Given the following standard enthalpy change of formation, calculate the standard enthalpy change, at 298 K, of reaction (I) and that of reaction (II).

Compound	$\Delta H_f^\circ{}_{298}$ / kJ mol^{-1}
$Al_2O_3(s)$	−1676
$AlCl_3(s)$	−704
$CH_3NHNH_2(l)$	+53
$CO_2(g)$	−394
$H_2O(g)$	−242
$NH_4ClO_4(s)$	−295
NO(g)	+90
$N_2O_4(l)$	−20

(4 marks)

(c) Suggest an advantage of using the solid propellant in powering the rockets.

(1 mark)

(d) The cryogenic propellant is also used to produce electricity for use in the shuttle. Briefly describe the electrochemical process involved.

(2 marks)

(e) State an advantage of using the hypergolic propellant in manoeuvring the shuttle.

(1 mark)

AL11(II)_03 [Similar to DSE16_07]

The enthalpy change of formation ΔH_f of ZnO(s) can be determined indirectly from the enthalpy change of formation of $H_2O(l)$ and the enthalpy changes of reactions (1) and (2) below.

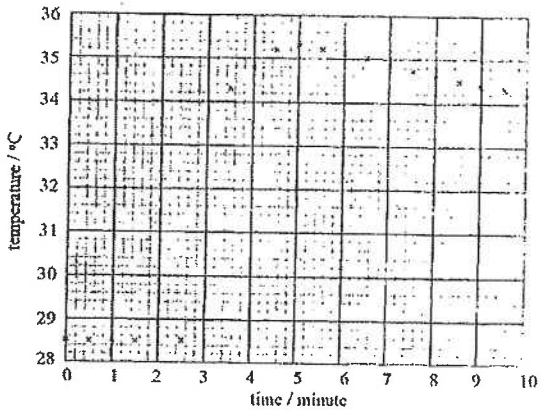
$$ZnO(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2O(l) \quad (1)$$
$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g) \quad (2)$$

An experiment as outlined below was carried out to determine the enthalpy change of reaction (1):

25.0 cm^3 of 1.10 mol dm^{-3} HCl(aq) was placed in an expanded polystytrene cup. The temperature of the acid in the cup was measured with a thermometer at half-minute intervals.

Right at the third minute, 0.75 g of ZnO(s) was added to the cup. The mixture in the cup was then stirred with the thermometer and its temperature was measured for an additional 7 minutes.

The recordings of temperature are shown in the graph below:



(a) (i) Deduce the greatest temperature change of the reaction mixture. (Show your working on the graph.)

(2 marks)

(ii) Calculate the molar enthalpy change of reaction (1) under the conditions of the experiment. (Assume that that heat capacity of the expanded polystyrene cup is negligible, and that the specific heat capacity and density of the solutions are 4.2 J g^{-1} K^{-1} and 1.0 g cm^{-3} respectively.)

(4 marks)

(b) Given that under the same conditions, the molar change of reaction (2) is –49 kJ, and the molar enthalpy change of formation of $H_2O(l)$ is –286 kJ, calculate ΔH_f of ZnO(s).

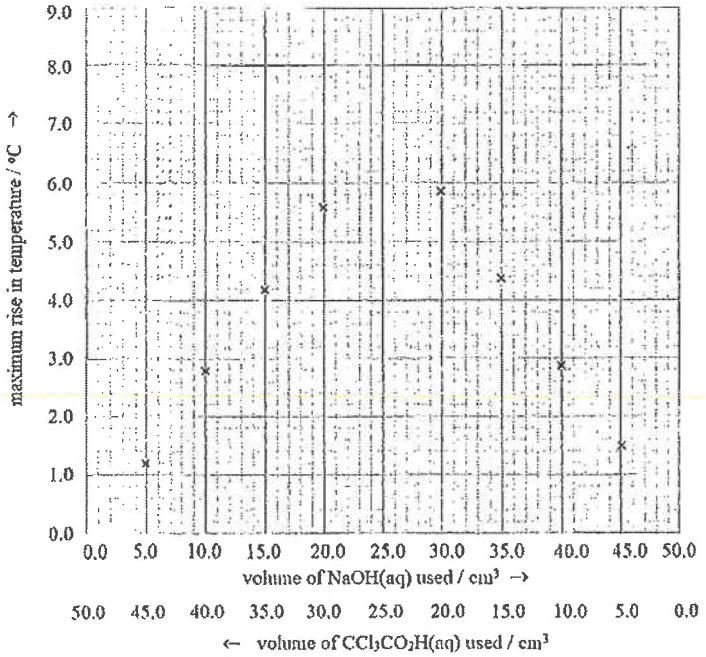
(3 marks)

AL13(II)_09 (modified) [Similar to DSE19_08]

An experiment was carried out to determine the enthalpy change of neutralization of $CCl_3CO_2H(aq)$ with NaOH(aq):

$$Cl_3CO_2H(aq) + NaOH(aq) \longrightarrow CCl_3CO_2Na(aq) + H_2O(l)$$

A sample of 1.50 mol dm^{-3} $CCl_3CO_2H(aq)$ and 1.02 mol dm^{-3} NaOH(aq) were mixed in different volume ratios to give mixture of 50.0 cm^3 in an expanded polystyrene cup. Each mixture was stirred and the highest temperature reached was recorded. The graph below shows the maxminum rise in temperature for each of the reaction mixture.



(a) Assume that the density and specific heat capacity of all reaction mixtures are 1.0 g cm^{-3} and 4.2 J g^{-1} K^{-1} respectively, and the heat capacity of the expanded polystyrene cup is negligible. Calculate the enthalpy change of neutralization, in kJ mol^{-1}, of $CCl_3CO_2H(aq)$ with NaOH(aq).

(5 marks)

(b) Under the same experimental conditions, the enthalpy change of neutralization of $CH_3CO_2H(aq)$ with NaOH(aq) was found to be –52 kJ mol^{-1}. Explain why the two acids, $CCl_3CO_2H(aq)$, have different enthalpy changes of neutralization with NaOH(aq).

(2 marks)

DSE11SP_05

In an experiment to determine the enthalpy change of combustion of ethanol, a calorimeter containing 200.0 g of water was used. Burning 0.185 g of ethanol caused the temperature of the water in the calorimeter to rise by 6.0 °C.

(a) Draw a labelled diagram of the set-up used in the experiment.

(2 marks)

(b) Assuming that the heat capacity of the calorimeter is negligible, calculate the enthalpy change of combustion of ethanol, in kJ mol^{-1}, under the conditions of the experiment. (Specific heat capacity of water = 4.2 J g^{-1} K^{-1})

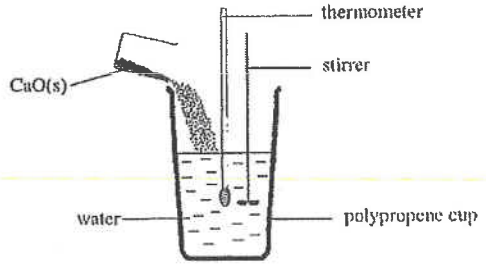
(3 marks)

(c) State ONE other assumption made in your calculation.

(1 mark)

DSE12PP_07

(a) A student carried out an experiment to determine the enthalpy change of the reaction of calcium oxide with water. The set-up used is shown in the diagram below:



The experimental results are as follows:

Mass of CaO(s) used	= 3.0 g
Volume of water in the cup	= 50.0 cm^3
Initial temperature of water in the cup	= 28.2 °C
Highest temperature attained by the $Ca(OH)_2(aq)$ formed	= 46.7 °C

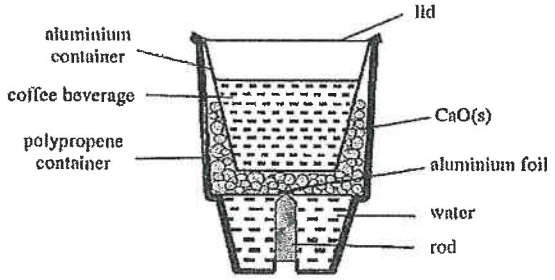
(i) Calculate the enthalpy change, in kJ mol^{-1}, of the reaction of calcium oxide with water under the conditions of the experiment.
(Assume: density of water is 1.0 g cm^{-3} and specific heat capacity of the $Ca(OH)_2(aq)$ formed is 4.2 J g^{-1} K^{-1}; the polypropene cup, thermometer and stirrer used all have negligible heat capacity.)

(4 marks)

(ii) According to the literature, ΔH^{θ} for this reaction is –82.2 mol^{-1}. Suggest ONE reasonable explanation for the discrepancy between the literature value and the value obtained in (i).

(1 mark)

(b) The diagram below shows the design of a can of self-heating coffee beverage. When the bottom of the can is pushed, the rod will pierce the aluminum foil and cause mixing of the water and calcium oxide. The coffee beverage in the can will then be heated up.



(i) With reference to the properties of the materials involved, explain why
(I) a polypropene container is used to contain the calcium oxide, and

(II) an aluminium container is used to contain the coffee beverage.

(3 marks)

(ii) Suggest ONE reasonable explanation for using calcium oxide in this type of self-heating beverage can.

(1 mark)

DSE12_08

Potassium hydrogencarbonate ($KHCO_3$) can be used to bake bread. Upon heating, $KHCO_3$ decomposes into K_2CO_3, H_2O and CO_2.

(a) Explain the purpose of using $KHCO_3$ in bread baking.

(1 mark)

(b) Write the chemical equation for the decomposition of $KHCO_3$ upon heating.

(1 mark)

(c) The enthalpy change of decomposition of $KHCO_3(s)$ can be determined indirectly from the enthalpy change of the following two reactions:

$KHCO_3(s) + HCl(aq) \longrightarrow KCl(aq) + H_2O(l) + CO_2(g)$ Reaction (1)

$K_2CO_3(s) + 2HCl(aq) \longrightarrow 2KCl(aq) + H_2O(l) + CO_2(g)$ Reaction (2)

In an experiment to determine the enthalpy change of Reaction (1), 3.39 g of $KHCO_3(s)$ was added to excess HCl(aq) in an expanded polystyrene cup. The experimental data obtained are shown below:

Initial temperature of the reacting solution:	25.8 °C
Final temperature of the reacting solution:	20.2 °C
Mass of the resulting solution:	27.5 g
Specific heat capacity of the contents:	4.3 J g^{-1} K^{-1}
Molar mass of $KHCO_3$:	100.1 g

(i) Assuming that the heat capacity of the cup used is negligible, calculate the enthalpy change of Reaction (1) from the above data.

(2 marks)

(ii) In another experiment performed under the same conditions, the enthalpy change of Reaction (2) was found to be –49.1 kJ mol^{-1}. Calculate the enthalpy change of decomposition of $KHCO_3(s)$ under the experimental condition.

(2 marks)

(d) According to the literature, the standard enthalpy change of formation of $K_2CO_3(s)$, $KHCO_3(s)$, $CO_2(g)$ and $H_2O(l)$ are as follows:

Compound	$\Delta H^{\theta}_{f,298}$ / kJ mol^{-1}
$K_2CO_3(s)$	–1146
$KHCO_3(s)$	–959
$CO_2(g)$	–394
$H_2O(l)$	–286

(i) Using the given information, calculate the standard enthalpy change of decomposition of $KHCO_3(s)$.

(1 mark)

(ii) Suggest why the answers obtained form (c)(ii) and d(i) are different.

(1 mark)

DSE14_06 [Similar to ASL10(II)_07]

Petrol is a commonly used motor car fuel. It can be obtained from petroleum by fractional distillation

(a) (iii) Octane (C_8H_{18}) is a component of petrol. Using octane as an example, state the meaning of the term 'standard enthalpy change of combustion' with the aid of a chemical equation.

(2 marks)

(b) Motor cars powered by petrol emit air pollutants such as nitrogen monoxide and carbon monoxide. Installing a certain device in motor cars can convert these two oxides to less harmful substances.

(i) Name this device.

(1 mark)

(ii) The equation for the reaction involved in the conversion is shown below:

$$2CO(g) + 2NO(g) \longrightarrow 2CO_2(g) + N_2(g)$$

The standard enthalpy changes of formation of NO(g), CO(g) and $CO_2(g)$ are as follows:

Compound	ΔH°_f / kJ mol^{-1}
NO(g)	+90.3
CO(g)	−110.5
$CO_2(g)$	−394.0

Calculate the standard enthalpy change of the above reaction.

(3 marks)

DSE15_08 [Similar to ASL01(II)_09]

Natural gas is an important energy source for electricity generation. It contains mainly methane (CH_4).

(a) Write the general formula of the molecules in the homologous series that methane belongs to.

(1 mark)

(b) The combustion of methane is an exothermic reaction. Its chemical equation is shown below:

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

(i) Complete the table below by stating all the covalent bond(s) that are broken and formed during the combustion of methane.

Covalent bond(s) broken	
Covalent bond(s) formed	

(2 marks)

(ii) Suggest why the combustion is exothermic in terms of the breaking and forming of covalent bonds.

(1 mark)

(iii) Calculate the standard enthalpy change of combustion of methane.
(Standard enthalpy changes of formation:
$CH_4(g) = -74.8$ kJ mol^{-1}; $CO_2(g) = -393.5$ kJ mol^{-1}; $H_2O(l) = -285.9$ kJ mol^{-1})

(2 marks)

(c) Some regions tend to generate electricity more by natural gas but less by coal. Give TWO reasons from environmental protection consideration.

(2 marks)

DSE16_07 [Similar to AL11_03]

The enthalpy change of formation of $MgCO_3(s)$ can be obtained using an indirect method. Firstly, the enthalpy change for the reaction of $MgCO_3(s)$ with $H_2SO_4(aq)$, and that of Mg(s) with $H_2SO_4(aq)$ are respectively determined experimentally. After that, the enthalpy change of formation of $MgCO_3(s)$ can be obtained through calculation with given enthalpy changes of formation of $CO_2(g)$ and $H_2O(l)$.

(a) According to definition, under which condition could that 'heat change' of a reaction be regarded as the 'enthalpy change'?

(1 mark)

(b) Explain why, instead of a direct method, an indirect method is used to obtain the enthalpy change of formation of $MgCO_3(s)$.

(1 mark)

(c) In order to determine experimentally the enthalpy change for the reaction of $MgCO_3(s)$ with $H_2SO_4(aq)$, an accurate mass of $MgCO_3(s)$ was firstly allowed to react with excess $H_2SO_4(aq)$ in a polystyrene foam cup. The maximum rise in temperature of the mixture was then found. After calculation, the enthalpy change for the reaction can be obtained.

(i) Suggest one possible error for the above experimental procedure.

(1 mark)

(ii) Explain whether the enthalpy change for the reaction of $CaCO_3(s)$ with $H_2SO_4(aq)$ can be obtained using a similar experimental procedure.

(1 mark)

(d) Using the information given below, calculate the standard enthalpy change of formation of $MgCO_3(s)$.

	ΔH° / kJ mol^{-1}
Standard enthalpy change for the reaction of $MgCO_3(s)$ with $H_2SO_4(aq)$	−50
Standard enthalpy change for the reaction of Mg(s) with $H_2SO_4(aq)$	−467
Standard enthalpy change of formation of $CO_2(g)$	−394
Standard enthalpy change of formation of $H_2O(l)$	−286

(3 marks)

DSE17_07 [Similar to ASL02(II)_08]

Ethyne is a gaseous hydrocarbon with molecular formula C_2H_2.

(a) Suggest why the enthalpy change of formation of $C_2H_2(g)$ CANNOT be determined directly by experiment.

(1 mark)

(b) Hess's law can be used to find enthalpy changes which CANNOT be determined directly by experiment. State Hess's law.

(1 mark)

(c) Based on the enthalpy changes of combustion ΔH_c of $C_2H_2(g)$, C(graphite) and $H_2(g)$ to construct an enthalpy change cycle and applying Hess's law can give the enthalpy change of formation of $C_2H_2(g)$.

(i) Draw, with labels, this enthalpy change cycle.

(2 marks)

(ii) The standard enthalpy change of combustion $\Delta H°_c$ of $C_2H_2(g)$, C(graphite) and $H_2(g)$ are given below:

	$\Delta H°_c$ / kJ mol^{-1}
$C_2H_2(g)$	−1300
C(graphite)	−394
$H_2(g)$	−286

(1) State the standard conditions for 'standard enthalpy change'.

(1 mark)

(2) Calculate the standard enthalpy change of formation of $C_2H_2(g)$.

(2 marks)

DSE18_06 [Similar to ASL99(II)_13, ASL09(II)_01]

Energy exists in various forms.

(a) Glucose ($C_6H_{12}O_6$) is one important energy source for living things.

(i) Write a chemical equation for the conversion of carbon dioxide gas and liquid water to solid glucose and oxygen gas.

(1 mark)

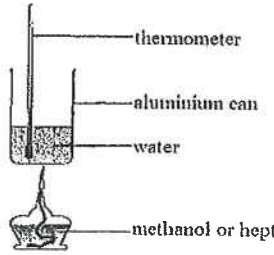
(ii) The following standard enthalpy changes of formation are given:
$CO_2(g) = -394$ kJ mol^{-1}, $H_2O(l) = -286$ kJ mol^{-1}, $C_6H_{12}O_6(s) = -1274$ kJ mol^{-1}
Calculate the standard enthalpy change of the conversion in (i) above.

(2 marks)

(iii) Green plants can convert carbon dioxide and water to glucose and oxygen. State the transformation of energy in this conversion.

(1 mark)

(b) Burning heptane (C_7H_{16}) releases energy. The enthalpy change of combustion of heptane was determined using the set-up shown below:



Step (I): The aluminum can with a fixed mas of water was heated by burning methanol. The temperature of water increased by 18.5 °C after 1.58 g of methanol was burnt.

Step (II): The aluminium can with the same mass of water in Step (I) was heated by burning heptane. The temperature of water increased by 25.8 °C after 1.02 g of heptane was burnt.

(i) Given that, under the conditions of experiment, the enthalpy change of combustion of methanol is −715 kJ mol^{-1}, calculate the enthalpy change of combustion of heptane, in kJ mol^{-1}, under the same conditions.
(Relative molecular masses: methanol = 32.0, heptane = 100.0)

(3 marks)

(ii) Besides the heat loss, suggest another source of error in the experiment.

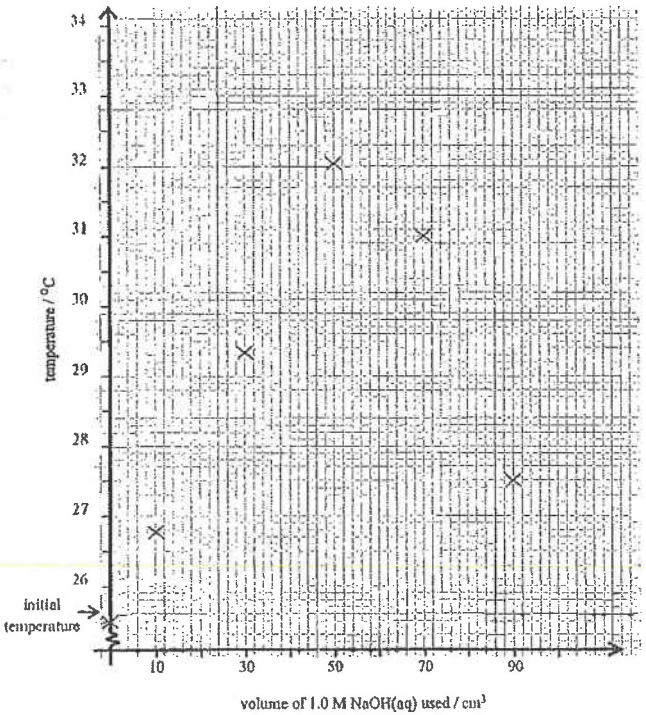
(1 mark)

DSE19_08 [Same as ASL03(II)_09, similar to AL13(II)_09]

Several trials of an experiment were performed for determining the enthalpy change of neutralization for a reaction, for each trial, a total volume of 100.0 cm^3 of a solution was obtained from mixing specified volumes of a HCl(aq) and 1.0 M NaOH(aq) as shown below in an expanded polystyrene cup. The HCl(aq) and NaOH(aq) were kept at the same initial temperature before mixing.

Trial	1	2	3	4	5
Volume of the HCl(aq) used / cm^3	90	70	50	30	10
Volume of the 1.0 M NaOH(aq) used / cm^3	10	30	50	70	90

For each trial, he mixture was stirred and its mazimum temperature reached was recorded. A graph of the maximum temperature reached for each trial is shown below:



(a) It is estimated from the graph that 58.0 cm^3 of NaOH(aq)(and 42.0 cm^3 of HCl(aq)) is required for obtaining the possible maximum temperature reached in the experiment. Show how this estimation can be done in the above graph.

(1 mark)

(b) (i) Calculate the number of moles of NaOH(aq) reacted with HCl(aq) in (a). Hence, find the concentration of the HCl(aq).

(2 marks)

(ii) Given that the initial temperature of the mixture for each trial is 25.5°C, calculate the enthalpy change of neutralisation of the reaction, in kJ mol^{-1}.

(Density of the mixture = 1.00 g cm^{-3};
specific heat capacity of the mixture = 4.18 J g^{-1} K^{-1};
heat capacity of the expanded polystyrene cup : negligible)

(2 marks)

(c) The one determined above is not the standard enthalpy change of neutralisation. What, then, is meant by the term 'standard enthalpy change of neutralisation' ?

(1 mark)

DSE20_05bii,iii

5. The molecular formula of an organic compound W is $C_4H_6O_4$. It is soluble in water.

(a) When a piece of magnesium ribbon is placed into an aqueous solution of W, hydrogen gas evolves. According to this observation, suggest a functional group that W may contain.

(1 mark)

(b) It is known that one mole of W can completely react with two moles of NaOH.

(i) Draw TWO possible structures of W.

(ii) Consider the following thermochemical equation of a neutralisation reaction in standard conditions :

$C_4H_6O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_4H_4O_4(aq) + 2H_2O(l)$ $\quad \Delta H^{\ominus} = y$ kJ mol^{-1}

State the meaning of the term 'standard enthalpy change of neutralisation', and deduce the standard enthalpy change of neutralisation for this reaction in terms of y.

(iii) The standard enthalpy change of neutralisation between HCl(aq) and NaOH(aq) is –57.3 kJ mol^{-1}. Explain whether the enthalpy change deduced in (ii) above should be more negative than, less negative than or equal to –57.3 kJ mol^{-1}.

DSE20_07c

7. An experiment is performed to study the following reaction :

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow BaCl_2(s) + 10H_2O(l) + 2NH_3(g)$

(a) When the two solid reactants are mixed and stirred in a conical flask, ammonia gas with a characteristic pungent smell is formed. Explain how ammonia gas can be tested.

(2 marks)

(b) $Ba(OH)_2 \cdot 8H_2O(s)$ is an alkali. What is meant by the term 'alkali' ?

(1 mark)

(c) The standard enthalpy change of formation of $Ba(OH)_2 \cdot 8H_2O(s)$ is -3345 kJ mol^{-1}.

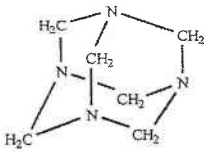
(i) Write a thermochemical equation for the standard enthalpy change of formation of $Ba(OH)_2 \cdot 8H_2O(s)$.

(ii) Calculate the standard enthalpy change of the reaction between $Ba(OH)_2 \cdot 8H_2O(s)$ and $NH_4Cl(s)$.
(Standard enthalpy changes of formation :
$NH_3(g) = -46$ kJ mol^{-1}, $H_2O(l) = -286$ kJ mol^{-1}, $NH_4Cl(s) = -314$ kJ mol^{-1},
$BaCl_2(s) = -859$ kJ mol^{-1})

(iii) Hence, explain whether the temperature of the mixture would increase, decrease or remain unchanged during the reaction.

DSE21_05

5. Hexamine ($C_6H_{12}N_4$) is the main component of a portable solid fuel. It is a solid under room conditions and its structure is shown below :



(a) Suggest why the combustion of hexamine is exothermic in terms of the breaking and forming of covalent bonds.

(b) It is given that :

Compound	Standard enthalpy change of formation / kJ mol^{-1}
$C_6H_{12}N_4(s)$	+123
$CO_2(g)$	−394
$H_2O(l)$	−286
$NO_2(g)$	+33

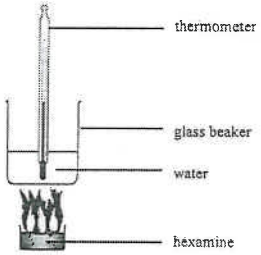
(i) Write a thermochemical equation for the standard enthalpy change of formation of hexamine.

(ii) Hexamine combusts as shown by the equation below :

$$C_6H_{12}N_4(s) + 13O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) + 4NO_2(g)$$

Calculate the standard enthalpy change of combustion of hexamine.

5. (c) The following diagram shows an experimental set-up for determining the enthalpy change of combustion of hexamine under certain experimental conditions.



The data obtained are shown below :

Mass of hexamine combusted :	2.40 g
Mass of water :	600.0 g
Initial temperature of water :	23.5 °C
Final temperature of water :	47.5 °C
Molar mass of hexamine :	140.0 g
Specific heat capacity of water :	4.20 J g^{-1} K^{-1}

Assuming that the heat capacity of the glass beaker is negligible, calculate the enthalpy change of combustion of hexamine under these experimental conditions.

14. The enthalpy changes of formation of some substances under certain conditions are shown below :

Substance	Enthalpy change of formation / kJ mol^{-1}
$H_2O(l)$	−286
$Na_2O(s)$	−414
$NaOH(s)$	−425

What is the enthalpy change of the following reaction under the same conditions ?

$$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(s)$$

A. +275 kJ mol^{-1}
B. −150 kJ mol^{-1}
C. −722 kJ mol^{-1}
D. −1125 kJ mol^{-1}

21. Which of the following statements are correct ?

(1) The standard enthalpy change of formation of graphite is zero.
(2) The standard enthalpy change of combustion of carbon monoxide is a negative value.
(3) The standard enthalpy change of formation of carbon monoxide is equal to the standard enthalpy change of combustion of graphite.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

7. (b) (ii) It is given that the enthalpy change of neutralisation is the enthalpy change when solutions of an acid and an alkali react together to produce one mole of water.

In the experiment, HCl(aq) is in excess. Calculate the enthalpy change of neutralisation between $Ca(OH)_2(s)$ and HCl(aq), in kJ mol^{-1}, under the experimental conditions.

(Volume of the reaction mixture = 100.0 cm^3;
density of the reaction mixture = 1.00 g cm^{-3};
specific heat capacity of the reaction mixture = 4.2 J g^{-1} K^{-1};
heat capacity of the expanded polystyrene cup : negligible)
(Relative atomic masses : H = 1.0, O = 16.0, Cl = 35.5, Ca = 40.1)

(5 marks)

(c) Standard enthalpy changes of neutralisation ΔH_n° for two reactions are given below :

	ΔH_n° / kJ mol^{-1}
Reaction between $Ca(OH)_2(s)$ and HCl(aq)	−58.6
Reaction between CaO(s) and HCl(aq)	−186.0

Calculate the standard enthalpy change of the following reaction.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$

Marking Scheme

MCQ

ASL10(I)_08	D	DSE11SP_10	D	DSE11SP_13	C	DSE11SP_19	D
DSE12PP_05	C	DSE12PP_12	A	DSE12_07	A (56%)	DSE13_15	B (46%)
DSE13_18	A (58%)	DSE14_09	A (76%)	DSE15_12	C (66%)	DSE14_12	D (48%)
DSE15_18	C (68%)	DSE16_24	D (58%)	DSE17_07	A (45%)	DSE18_18	A (66%)
DSE18_22	A (72%)	DSE19_09	B	DSE19_22	C		

DSE20_10 A
DSE20_13 C
DSE20_21 C

Structural Questions

AL98(II)_02c

(i) (1) $\Delta H = \dfrac{-242 \times 1000}{18} = -1.34 \times 10^4 \text{ kJ kg}^{-1}$ [1]

(2) $\Delta H^\circ_c[CH_3OH(l)] = \Delta H^\circ_f[CO_2(g)] + 2\Delta H^\circ_f[H_2O(l)] - \Delta H^\circ_f[CH_3OH(l)]$
$= -394 + 2(-242) - (-239) = -639 \text{ kJ mol}^{-1}$ [1]

$\Delta H = \dfrac{-639 \times 1000}{(32 + 1.5 \times 32)} = -8.0 \times 10^3 \text{ kJ kg}^{-1}$ [1]

(ii) Effectiveness of fuel

$(1): \dfrac{-1.34 \times 10^4}{18} = -744$ [1]

$(2): \dfrac{-8 \times 10^3}{\frac{1}{3}(44 + 2 \times 18)} = -300$ [1]

Based on the above data, $H_2(g)$ is more effective fuel. [1]

AL99(I)_07b

Any THREE of the following: [3]

- Heat loss to the surrounding
- The specific heat capacity of the reaction mixture equals to that of water
- The heat absorbed by the polystyrene foam cup / the thermometer is negligible
- The density of the solution is the same as that of water

ASL99(I)_02

(a) As the energy released in forming bonds in products (C=O and O–H) larger than [1]
energy absorbed for breaking bonds in reactants (C–C, C–H, O–H and O=O) [1]

(b) The average enthalpy change for breaking 1 C=C and 2 C–H bonds

$= \dfrac{(1367 - 726) + (2017 - 1367)}{2} = 645.5 \text{ kJ mol}^{-1}$ [1]

Value of $x = -2017 + 645.5 = -2662.5 \text{ kJ mol}^{-1}$ [1]

(c) $CH_3OH(l) + {}^3/_2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$ [1]

$\Delta H^\circ_{c,298}[CH_3OH(l)] = \sum\Delta H^\circ_f[\text{product}] - \sum\Delta H^\circ_f[\text{reactant}]$
$-726 = (-393) + 2(-286) - \Delta H^\circ_{f,298}[CH_3OH(l)]$ [1]
$\Delta H^\circ_{f,298}[CH_3OH(l)] = -239 \text{ kJ mol}^{-1}$ [1]

ASL99(II)_13

(a) Ester group [1]

C=C [1]

(b) (i) Energy released $= 250 \times 4.18 \times 20.5 = 21422.56\ J = 21.4\ kJ$ [1]

Mole of compond T burnt $= \frac{2.30}{878} = 2.62 \times 10^{-3}$ [1]

Enthalpy change of combustion $= \frac{-21.4}{2.62 \times 10^{-3}} = -8178\ kJ\ mol^{-1}$ [1]

(ii) Any TWO of the following [2]

Incomplete combustion of compound T

Heat lost to the surrounding

Heat absorbed by the aluminium can is non-neligible

ASL00(II)_08

(a) (i) An enthalpy change when 1 mol of cyclohexane is burnt completely in excess oxygen gas under the standard conditions. [1]

$C_6H_{12}(s) + 9O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$ [1]

(ii) $C_6H_6(l) + 2H_2(g) \longrightarrow C_6H_{12}(l)$ [1]

$\Delta H^\circ_{rxn} = \sum \Delta H^\circ_c[reactant] - \sum \Delta H^\circ_c[product]$

$= (-3584) + 2(-286) - (-3924)$ [1]

$= -232\ kJ\ mol^{-1}$ [1]

(b) (i) Platinum / nickel [1]

(ii) To ensure that hydrogen gas well contact with cyclohexa-1,3-diene and catalyst for reaction. [1]

(iii) Copper is a better heat conductor than glass. [1]

Copper has a higher strength to withstand the high pressure built up by the hydrogen gas. [1]

(iv) (I) Energy released $= 300 \times 4.2 \times 16.5 = 20790\ J = 20.79\ kJ$ [1]

Enthalpy change of hydrogenation $= \frac{-20.79}{0.10} = -207.9\ kJ\ mol^{-1}$ [2]

(II) Any TWO of the following: [2]

No heat lost to the surrounding

Hydrogenation of cyclohexa-1,3-diene is completed.

There is no evaporation of cyclohexa-1,3-diene or cyclohexane.

ASL01(II)_09

(a) (i) $C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$ [1]

$\Delta H^\circ_{c,298}[C_6H_{12}O_6(s)] = \sum \Delta H^\circ_f[product] - \sum \Delta H^\circ_f[reactant]$

$= 6(-394) + 6(-286) - (-1274)$ [1]

$= -2806\ kJ\ mol^{-1}$ [1]

(ii) No. of mole of glucose $= \frac{10}{180} = 0.0556$ [1]

Energy released $= 2806 \times 0.0556 = 156\ kJ$ [1]

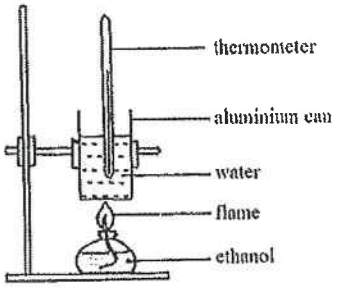
(b) No. of mole of tripalmitin $= \frac{10}{806} = 0.0124$ [1]

Energy released $= 31400 \times 0.0124 = 389\ kJ$ [1]

(c) Under the same mass of carbohydrate and fat, carbohydrate provides less amount of energy to support the plant with lower metabolic rate, while fat provides larger amount of energy to support animal with higher metabolic rate. [1] [1]

ASL02(II)_08

(a) (i) [2]



(ii) Energy liberated $= 200.0 \times 4.2 \times 6 = 5040\ J$ [1]

Mole of ethanol used $= \frac{0.185}{46} = 4.02 \times 10^{-3}$ [1]

Enthalpy change of combustion $= \frac{-5040}{4.02 \times 10^{-3}} = -1253\ kJ\ mol^{-1}$ [1]

(iii) There is no heat lost to the surrounding. [2]

Complete combustion of ethanol

(b) (i) No. As the side products such as CO_2 may form. [1]

(ii) $2C(graphite) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(l)$ [1]

$\Delta H^\circ_{f,298}[C_2H_5OH(l)] = \sum \Delta H^\circ_c[reactant] - \sum \Delta H^\circ_c[product]$

$= 2(-394) + 3(-286) - (-1368)$ [1]

$= -278\ kJ\ mol^{-1}$ [1]

(c) (i) Both HCl and HNO_3 are monobasic and they are completely ionized in water. [1]

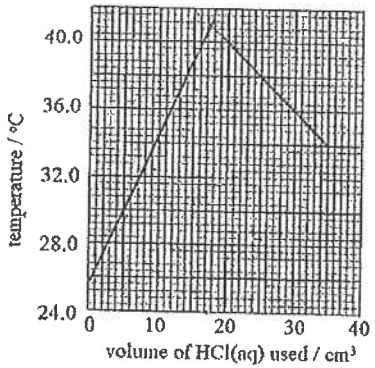
They neutralize with NaOH(aq) to give same amount of water molecule. [1]

(ii) HCl(aq) is a strong acid while $CH_3CO_2H(aq)$ is a weak acid. [1]

Part of heat released in the neutralization of $CH_3CO_2H(aq)$ with NaOH(aq) is absorbed for complete ionization of $CH_3CO_2H(aq)$. [1]

ASL03(II)_09

(a)



[3]

(b) (i) 40.7 °C [1]

(ii) Volume of HCl(aq) required to reach the end-point = 17.3 cm^3 [1]

$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$

Concentration of HCl(aq) $= \frac{2.0 \times 25}{17.3} = 2.89$ mol dm^{-3} [1]

(c) At the end-point of the titration, total volume of reaction mixture = 42.3 cm^3 [1]

Temperature rise = 14.9°C

Energy liberated $= 42.3 \times 4.2 \times 14.9 = 2647$ J [1]

Enthalpy change of neutralization $= \frac{-2647}{2 \times 25 \times 10^{-3}} = -52.9$ kJ mol^{-1} [1]

ASL04(II)_10

(a) (1) Molar enthalpy change of solution of $CuSO_4(s)$

$= -\frac{50 \times 4.2 \times 7.7}{0.025}$ [1]

$= -64680$ J $= -64.68$ kJ [1]

(2) Molar enthalpy change of solution of $CuSO_4 \cdot 5H_2O(s)$

$= +\frac{50 \times 4.2 \times 1.7}{0.025}$ [1]

$= +14280$ J $= +14.28$ kJ [1]

(b) $CuSO_4(s) + aq \longrightarrow CuSO_4(aq)$ $\Delta H_1 = -64.68$ kJ mol^{-1}

$CuSO_4 \cdot 5H_2O(s) + aq \longrightarrow CuSO_4(aq)$ $\Delta H_2 = +14.28$ kJ mol^{-1}

For the reaction,

$CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4 \cdot 5H_2O(s)$

$\Delta H = \Delta H_1 - \Delta H_2 = -64.68 - (+14.28)$ [1]

$= -78.96$ kJ mol^{-1} [1]

(c) It is difficult to measure the temperature of a solid. [1]

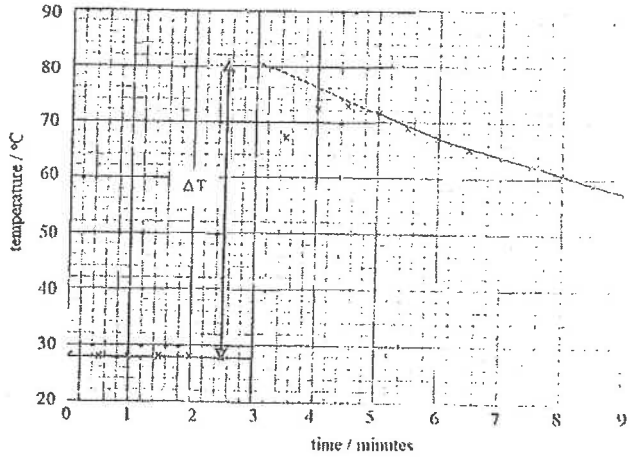
ASL05(I)_04

(a) no. of moles of Zn $= \frac{4.0}{65.4} = 0.061$ [1]

no. of moles of $Cu^{2+}(aq) = 1.0 \times 25 \times 10^{-3} = 0.025$

$\therefore CuSO_4(aq)$ is the limiting reactant. [1]

(b) Maximum temperature rise = 53 °C



[2]

(c) Heat evolved $= 25 \times 4.2 \times 53 = 5565$ J $= 5.565$ kJ [1]

$\Delta H = -\frac{5.565}{0.025}$ [1]

$= -222.6$ kJ mol^{-1} [1]

AL05(II)_05

(a) Complete combustion of octane:

$C_8H_{18}(l) + 12.5O_2(g) \longrightarrow 8CO_2(g) + 9H_2O(l)$

Standard enthalpy change

$= 8\Delta H^\circ_f[CO_2(g)] + 9\Delta H^\circ_f[H_2O(l)] - \Delta H^\circ_f[C_8H_{18}(l)]$

$= 8(-394) + 9(-286) - (-250)$ [1]

$= -5476$ kJ mol^{-1} [1]

Complete combustion of ethanol:

$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

Standard enthalpy change

$= 2\Delta H^\circ_f[CO_2(g)] + 3\Delta H^\circ_f[H_2O(l)] - \Delta H^\circ_f[C_2H_5OH(l)]$

$= 2(-394) + 3(-286) - (-278)$ [1]

$= -1368$ kJ mol^{-1} [1]

(b) Conversion of enthalpy changes of combustion from kJ mol^{-1} to kJ g^{-1} units

For octane, $\Delta H_c^\ominus$ per g $= \frac{-5476}{114} = -48.0$ kJ g^{-1} [1]

For ethanol, $\Delta H_c^\ominus$ per g $= \frac{-1368}{46} = -29.7$ kJ g^{-1} [1]

As the alternative fuel contains 90% octane & 10% ethanol, its enthalpy change of combustion

$= (0.9)(-48.0) + (0.1)(-29.7) = -46.2$ kJ g^{-1} [1]

For the same mass, the alternative fuel has a lower energy content. [1]

(c) Any one of the following: [1]

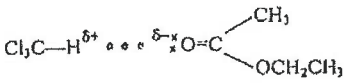
1. Ethanol is an oxygen-containing compound. It is easier for the alternative fuel to achieve complete combustion / less CO is produced / less particulates are formed / less air pollutants.
2. Ethanol is a renewable energy source. It can be obtained from agricultural products.
3. The cost for the production of ethanol is low in agricultural counties.

AL06(I)_02

The conversion of diamond to graphite has very high activation energy. The reaction is very slow under normal conditions. [1]

ASL06(I)_06

(a) A stronger intermolecular force, hydrogen bond, is formed between trichloromethane and ethyl ethanoate molecules. Energy is released accordingly. [1]



[1]

(b) no. of mole of trichloromethane $= \frac{8 \times 1.49}{119.5} = 0.0997$ [1]

no. of mole of ethyl ethanoate $= \frac{10 \times 09}{88.0} = 0.1023$

Trichloromethane is the limiting reactant.

Heat given out $= 8 \times 1.49 \times 0.97 \times 9.5 + 10 \times 0.9 \times 1.92 \times 9.5 = 274.0$ J [1]

$\Delta H = \frac{-274.0}{0.0997} = -2748$ J mol^{-1} $= -2.75$ kJ mol^{-1} [1]

ASL06(II)_11

(a) 2,2,4-trimethylpentane [1]

(b) Molar mass of $X = 12 \times 8 + 1 \times 18 = 114$ g mol^{-1} [1]

no. of mole of X burnt $= \frac{1}{114} = 0.00877$ [1]

$\Delta H_c^\ominus = -\frac{44.5}{0.00877} = -5074$ kJ mol^{-1} [1]

(c)

[1]

$\Delta H^\ominus_f [C_8H_{18}(l)] + (-5074) = 8(-393.5) + 9(-285.8)$ [1]

$\Delta H^\ominus_f [C_8H_{18}(l)] = -646$ kJ mol^{-1} [1]

AL08(II)_01

(a) The enthalpy change when 1 mol of the compound is formed from its constituent elements under standard conditions. [1]

(b) (i) $SiCl_4(l) + 2H_2O(l) \longrightarrow SiO_2(s) + 4HCl(g)$ [1]

[NOT accept: $SiO_2.2H_2O$ as one of the products]

(ii) $= \Delta H^\ominus_f [SiO_2(s)] + 4\Delta H^\ominus_f [HCl(g)] - \Delta H^\ominus_f [SiCl_4(l)] - 2\Delta H^\ominus_f [H_2O(l)]$

$= (-910) + 4(-92) - (-640) - 2(-286)$ [1]

$= -66$ kJ mol^{-1} [1]

Any ONE of the following: [1]

1. $SiCl_4(l)$ is in excess / The hydrolysis gives HCl(g) instead of HCl(aq)
2. The Hess' Law is followed. (NOT accept energy is conserved.)

ASL09(II)_01

(a) $2CH_3CH(NH_2)CO_2H(s) + 6O_2(g) \longrightarrow 5CO_2(g) + CO(NH_2)_2(s) + 5H_2O(l)$ [1]

(b) (i) $4CH_3CH(NH_2)CO_2H(s) + 15O_2(g) \longrightarrow 12CO_2(g) + 14H_2O(l) + 2N_2(g)$ [1]

(ii) $2CO(NH_2)_2(s) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(l) + 2N_2(g)$ [1]

(c) Enthalpy change for biological oxidation of alanine

$= \frac{4\Delta H_c^\ominus[\text{alanine}] - 2\Delta H_c^\ominus[\text{urea}]}{4} = \frac{4(-1577) - 2(-632)}{4}$ [1]

$= -1261$ kJ mol^{-1} [1]

Molar mass of alanine = 89.0 g

Energy obtained from the biological oxidation of 1.00 g of alaline [1]

$= \frac{-1261}{89} = -14.2$ kJ [1]

ASL10(II)_07

(a) The enthalpy change when 1 mol of the compound is formed from its constituent elements under standard conditions. [1]

(b) (i) $2NH_3(g) + H_2O_2(l) \longrightarrow N_2O_4(l) + 2H_2O(l)$ [1]

(ii) $\Delta H^\circ = \Delta H^\circ_f[N_2O_4(l)] + 2\Delta H^\circ_f[H_2O(l)] - 2\Delta H^\circ_f[NH_3(g)] - \Delta H^\circ_f[H_2O_2(l)]$

$= +51 + 2(-286) - 2(-46) - (-188)$ [1]

$= -241$ kJ mol^{-1} [1]

(c) No. The explosive property of hydrazine is due to the fact that the oxidation is very fast and there is evolution of a large volume of gases. [1]

The positive standard enthalpy change of formation hydrazine only means that it is unstable as compared to its constituent elements. [1]

AL10(II)_02

(a) (i) $3Al(s) + 3NH_4ClO_4(s) \longrightarrow Al_2O_3(s) + AlCl_3(s) + 3NO(g) + 6H_2O(g)$ [1]

(ii) $4CH_3NHNH_2(l) + 5N_2O_4(l) \longrightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$ [1]

(i) $\Delta H^\circ = \Delta H^\circ_f[Al_2O_3(s)] + \Delta H^\circ_f[AlCl_3(s)] + 3\Delta H^\circ_f[NO(g)] + 6\Delta H^\circ_f[6H_2O(g)] - (3\Delta H^\circ_f[Al(s)] + 3\Delta H^\circ_f[NH_4ClO_4(s)])$

$= (-1676) + (-704) + 3(+90) + 6(-242) - 3(0) - 3(-295)$ [1]

$= -2677$ kJ mol^{-1} [1]

(ii) $\Delta H^\circ = 4\Delta H^\circ_f[CO_2(g)] + 12\Delta H^\circ_f[H_2O(g)] + 9\Delta H^\circ_f[N_2(g)] - (4\Delta H^\circ_f[CH_3NHNH_2(l)] + 5\Delta H^\circ_f[N_2O_4(l)])$

$= 4(-394) + 12(-242) - 4(+53) - 5(-20)$ [1]

$= -4592$ kJ mol^{-1} [1]

(c) Any ONE of the following: [1]

1. Al(s) and $NH_4ClO_4(s)$ react only upon ignition. The take-off of the shuttle and rockets can be easily controlled.
2. The solid propellant has a high power density, i.e. energy liberated per unit mass is great.

(d) The cryogenic mixture acts as reacts in the H_2–O_2 fuel cell. The chemical processes involved are:

Anode: $2H_2(g) + 4OH^-(aq) \longrightarrow 4H_2O(l) + 4e^-$ [½]

Cathode: $O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$ [½]

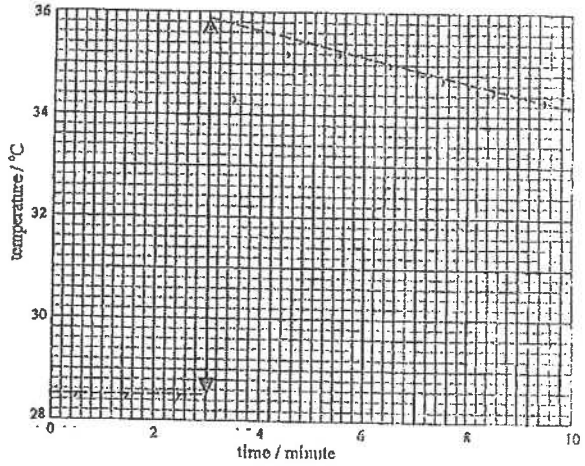
Overall: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ [1]

(e) $CH_3NHNH_2(l)$ reacts with $N_2O_4(l)$ on contact. The propulsion can easily be started and restarted. [1]

AL11(II)_03

(a) (i) $(35.9 - 28.5) = 7.4$ °C / K [2]

(Accept answers from 7.3 to 7.5 °C)



(1 mark for answer; 1 mark for working shown on the graph)

Working on graph: either the two dotted lines *OR* only the solid line but take note that cannot exceed the indicated region.

If all lines are drawn with intersection, even beyond the region, accept as correct.

(ii) No. of moles of ZnO(s) used $= \frac{0.75}{81.4} = 9.21 \times 10^{-3}$ [1]

No. of moles of $H^+(aq)$ present $= 1.1 \times 25 \times 10^{-3} = 2.75 \times 10^{-2}$

∴ ZnO(s) is the limiting reactant.

Heat liberated $= 25.0 \times 4.2 \times 7.4 = 0.777$ kJ [1]

For reaction (1), molar enthalpy change

$= -\frac{0.777}{9.21 \times 10^{-3}} = -84.4\ kJ\ (mol^{-1})$ [1]

(Acceptable range: –83.2 to –85.5 kJ)

(b) $Zn(s) + \frac{1}{2}O_2(g) \longrightarrow ZnO(s)$ [1]

$\Delta H_f[ZnO(s)] = \Delta H(2) - \Delta H(1) + \Delta H_f[H_2O(l)]$

$= -49 - (-84.4) + (-286)$ [1]

$= -250.6$ kJ mol^{-1} [1]

(Acceptable range: –252 to –250 kJ mol^{-1})

AL13(II)_09 (modified)

(a) From the graph, the volume ratio of NaOH(aq) : CCl_3CO_2H(aq) for complete neutralization = 25.5 : 24.5 [1]

(Accept volume ratio from 25.4 : 24.6 to 25.6 : 24.4)

No. of moles of NaOH (or CCl_3CO_2H) used

$= 1.02 \times 25 \times 10^{-3}$ [1]

Maximum rise in temperature = 7.1 °C (Acceceptable range: 7.0 to 7.2) [1]

Heat liberated = $50 \times 4.2 \times 7.1$ [1]

$$\Delta H = \frac{50 \times 4.2 \times 7.1}{1.02 \times 25.5 \times 10^{-3}} = -57.3 \text{ kJ mol}^{-1}$$ [1]

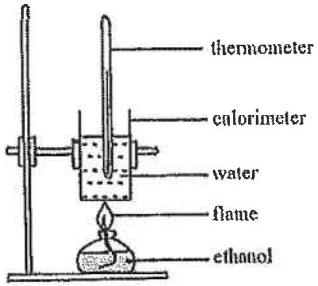
(Acceptable range: –59.0 to –55.0)

(b) The enthalpy change of neutralization of CCl_3CO_2H(aq) by NaOH(aq) is more negative (more exothermic) than that of CH_3CO_2H(aq) by NaOH(aq), i.e. CCl_3CO_2H is a stronger acid that CH_3CO_2H. [1]

Part of the heat is absorbed for complete ionization of CH_3CO_2H.

DSE11SP_05

(a)



[2]

(1 mark for an alcohol lamp containing some ethanol; 1 mark for a calorimeter containing some water.)

(b) Heat released = $200 \times 4.2 \times 6 = 5040$ J = 5.04 kJ [1]

Moles of C_2H_5OH(l) burnt

$$= \frac{0.185}{(12.0 \times 2 + 1.0 \times 6 + 16.0)} = 4.02 \times 10^{-3}$$ [1]

Enthalpy change of combustion of C_2H_5OH(l)

$$= \frac{-5.04}{4.02 \times 10^{-3}} = -1254 \text{ kJ mol}^{-1}$$ [1]

(c) No heat loss to the surroundings [1]

OR, The ethanol undergoes complete combustion

DSEI2PP_07

(a) (i) Moles of CaO(s)used $= \frac{3.0}{40.1 + 16} = 0.053$ [1]

Heat liberated = $53 \times 4.2 \times (46.7 - 28.2) = 4118$ J = 4.118 kJ

$$\Delta H = \frac{-4.118}{0.053} = -77.0 \text{ kJ mol}^{-1}$$ [1]

(Acceptable range: –72.6 to –77.0 kJ mol^{-1}) [2]

(ii) Any ONE of the following: [1]

- PP is not a perfect heat insulator; heat is lost to the surroundings.
- Some CaO(s) may have reacted with H_2O(l) in air.

(Accept other reasonable answers.)

(b) (i) (I) Any THREE of the following (at least 1 mark should be allocated to each part): [3]

- PP is a poor conductor of heat. Using PP container to hold CaO(s) will protect hands for skin burns.
- PP can withstand the high temperature caused by the reaction of CaO(s) with H_2O(l).

(II)
- Compounds of Al are non-toxic. They will not cause food poisoning.
- Al is a good conductor of heat. The heat liberated from the reaction of CaO(s) with H_2O(l) can readily be transmitted to the coffee beverage.
- Aluminium is covered by a layer of unreactive Al_2O_3(s), which prevents the metal from corrosion.

(Accept other reasonable answers.)

(ii) The reaction of CaO(s) and H_2O(l) is highely exothermic, and CaO(s) is an inexpensive material. [1]

(Accept other reasonable answers.)

DSE12_08

(a) CO_2 gas produced makes the bread rise / spongy / soft. [1]

(b) $$KHCO_3(s) \longrightarrow \frac{1}{2}K_2CO_3(s) + \frac{1}{2}H_2O(l) + \frac{1}{2}CO_2(g)$$ [1]

(c) (i) $q = 27.5 \times 4.3 \times (25.8 - 20.2) = 662.2$ J = 0.6622 kJ [1]

$$\Delta H = \frac{\frac{+0.6622}{3.39}}{39.1 + 1 + 12 + 16 \times 3}$$

$= +19.6$ kJ mol^{-1} / +19.55 kJ mol^{-1} / +19.5 kJ mol^{-1} [1]

If the candidate omitted the "+" sign for the positive numbers, and the numerical answers are correct, deduct 1 mark only.

(ii) $\Delta H = 19.6 - \left(-49.1 \times \frac{1}{2}\right)$ [1]

$= +44.15 \text{ kJ mol}^{-1}$ (Accept +44.1 to +44.2 kJ mol^{-1}) [1]

If the candidate omitted the "+" sign for the positive numbers, and the numerical answers are correct, deduct 1 mark only.

(d) (i) $\Delta H = \frac{1}{2}[-1146 - 394 - 286 - (-959 \times 2)] = +46 \text{ kJ mol}^{-1}$ [1]

If the candidate omitted the "+" sign for the positive numbers, and the numerical answers are correct, deduct 1 mark only

(ii) Not performing the experiment in standard conditions. / Heat transfer with the surroundings. / The heat capacity of the container was neglected. [1]

DSE14_06

(a) (iii) **The enthalpy change when one mole of a compound (substance / octane) burns completely under standard conditions / 25 °C and 1 atm.** [1]

$C_8H_{18}(l) + \frac{25}{2}O_2(g) \longrightarrow 8CO_2(g) + 9H_2O(l)$ [1]

(The equation shoud have correct state symbols)

(b) (i) Catalytic converter [1]

(ii) $\Delta H^\circ = 2(-394) - 2(-110.5) - 2(90.3)$ [2]

$= -747.6 \text{ kJ mol}^{-1}$ (the answer should have correct sign and unit) [1]

DSE15_08

(a) C_nH_{2n+2} [1]

(b) (i) Covalent bond(s) broken C–H and O=O [1]

Covalent bond(s) formed C=O and O–H [1]

(ii) (The total) Energy released in the bond forming process is larger than (the total) energy absorbed in the bond breaking process. [1]

(iii) $\Delta H^\circ_c = \Delta H^\circ_f[CO_2(g)] + 2\Delta H^\circ_f[H_2O(l)] - \Delta H^\circ_f[CH_4(g)]$

$= (-393.5) + 2(-285.9) - (-74.8)$ [1]

$= -890.5 \text{ kJ mol}^{-1}$ [1]

(c) - Natural gas **burns (more) completely** but coal does not. / Burning coal would produce soot / carbon monoxide but burning natural gas would not. [1]

- Compared with natural gas, coal contains more impurities. / Burning coal would produce more pollutant, such as SO_2, metal compound dust, NO_2. (If the answer mentions pollutants, the answer should have a correct example of pollutant. NOT accept CO, soot.)

(Accept natural gas or methane in the answer only. NOT accept other gaseous fuel such as LPG)

DSE16_07

(a) Constant pressure [1]

Do not accept answers like "1 atm", "1 atm and 25°C".

(b) It is very difficult for Mg(s), C(s) and $O_2(g)$ to react directly to form $MgCO_3(s)$. [1]

OR, $MgCO_3(s)$ cannot be formed from its elements.

OR, $MgCO_3(s)$ cannot be formed directly.

OR, There will be side products. / MgO will be formed. / CO_2 will be formed.

(c) (i) Heat loss to surrounding. / PS cup absorbs heat. / Thermometer absorbs heat [1]

(ii) No, because insoluble $CaSO_4$ will be formed. (and the reaction is stopped). [1]

(d) $Mg(s) + C(s) + \frac{3}{2}O_2(g) \longrightarrow MgCO_3(s)$ [1]

$y - 50 = -467 - 394 - 286$ [1]

$y = -1097 \text{ kJ mol}^{-1}$ [1]

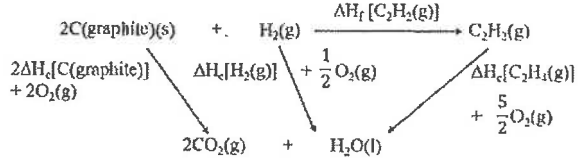
DSE17_07

(a) The reaction between carbon and hydrogen does not only give ethyne. / There will be side reactions / side products will be formed. [1]

Carbon and hydrogen gas have no reaction at room conditions.

(b) The total enthalpy change of a chemical reaction is independent of the pathway between the initial and final states. [1]

(c) (i)



[2]

(ii) (I) 298 K / 25 °C and 1 atm / 101 kPa / 101325 Nm^{-2} [1]

(II) $\Delta H^\circ_f[C_2H_2(g)] = 2 \times (-394) + (-286) - (-1300)$ [1]

$= +226 \text{ kJ mol}^{-1}$ [1]

Correct Unit. MUST show the positive sign.

DSE18_06

(a) (i) $6CO_2(g) + 6H_2O(l) \longrightarrow C_6H_{12}O_6(s) + 6O_2(g)$ [1]

(ii) $\Delta H = -1276 - 6 \times (-394 - 286) = +2806 \text{ kJ mol}^{-1}$ [2]

(Do not accept +2800, +2810 kJ mol^{-1})

(iii) Light / solar energy changes to chemical energy. [1]

(b) (i) Let C be the heat capacity of the calorimeter,

$$-715 \times \frac{1.58}{32} = -C \times 18.5 \quad (1)$$ [1]

$$\Delta H \times \frac{1.02}{100} = -C \times 25.8 \quad (2)$$ [1]

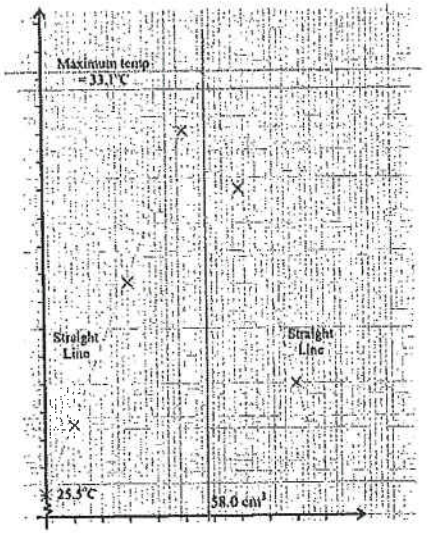
$\Delta H = -4826.8 \text{ kJ mol}^{-1}$ [1]

(Accept −4823 to −4831.1)

(ii) Incomplete combustion / some methanol or heptane evaporates. [1]

DSE19_08

(a) [1]



Drawing 2 best-fit slant straight lines to show how to obtain the possible maximum temperature using the volume of NaOH(aq) (58.0 cm^3).

(b) (i) No. of moles of NaOH(aq) used = 1.0 × (58.0 ÷ 1000) = 0.058 (mol) [1]

∵ At equivalent point, no. of moles of NaOH(aq) used = No. of moles of HCl(aq) reacted

∴ No. of moles of HCl(aq) reacted = 0.058 (mol)

Concentration of HCl(aq) = 0.058 ÷ (42.0 ÷ 1000) = 1.38 mol dm^{-3} [1]

OR 1.381 M

(ii) Energy released during the reaction = [1]

100.0 × 1.0 × 4.18 × (33.1 − 25.5) = 3176.8 J

Enthalpy change of neutralisation =

−3176.8 ÷ (0.058 × 1000) = −54.77 (kJ mol^{-1}) [1]

OR −54.772 / −54.8 (kJ mol^{-1})

OR Energy released during the reaction

= 100.0 × 1.0 × 4.18 × (33.1 − 25.5) = 3177 J

Enthalpy change of neutralisation

= −3177 ÷ (0.058 × 1000) = −54.776 (kJ mol^{-1})

OR −54.78 (kJ mol^{-1})

(c) The enthalpy change when an acid solution and a base / an alkali solution react together under standard conditions to produce 1 mole of water. [1]

DSE20_05

5. (a) Carboxyl (group) / $-CO_2H$ (group) / $-COOH$ (group) / $-CO_2H$ / $-COOH$ / CO_2H / $COOH$ 1

(Not accept: acid / alkanoic acid / organic acid / $COOH^-$ / CHO_2 / $HO_2CCH_2CH_2CO_2H$ / carboxylic acid group)

(b) (i) $HO_2CCH_2CH_2CO_2H$ / $HOOCCH_2CH_2COOH$ / $(CH_2COOH)_2$ 1

(Not accept: $HOOC_4H_8COOH$)

$HO_2CCH(CH_3)CO_2H$ / $HOOCCH(CH_3)COOH$ 1

$HO_2CCH_2COOCH_3$ / $HO_2CCOOCH_2CH_3$ (1)

(ii) • The enthalpy change when solutions of an acid and an alkali / a base react together / neutralise under standard conditions to produce 1 mole of water. 1

(Accept: 25°C (298K) and one atmospheric pressure (760 mmHg, 103 kPa))

• As indicated in the equation, the reaction produces 2 moles of water, hence y / 2 represents the standard enthalpy change of neutralisation. 1

(Accept: No unit)

(iii) • Less negative than −57.3 kJ mol^{-1} 1

• W is a weak acid when compared with HCl(aq), energy / heat energy / heat is needed to ionise the hydrogen in the carboxyl / $-CO_2H$ group. 1

/ W is a weak(er) acid, energy / heat energy / heat is needed to ionise the hydrogen in the carboxyl / $-CO_2H$ group.

(Accept: absorb energy to break the O–H bond in carboxyl group.)

(Not accept: dissociate)

DSE20_07

7. (a) • Put a moist red litmus paper / moist pH paper near the mouth of the conical flask. 1

• Ammonia / NH_3 gas dissolves in water to give OH^- ions / is alkaline which turn red litmus paper to blue / pH paper to blue. 1

• Put a glass rod with conc. HCl / HCl(g) near the mouth of the conical flask. (1)

• After reaction, (dense) white fumes containing $NH_4Cl(s)$ is formed. (1)

• Deliver the gas produced into water, then use a pH meter to measure the pH of the solution formed. (1)

• Ammonia / NH_3 gas dissolves in water to give OH^- ions / an alkaline solution with pH > 7. (1)

(b) Alkali is a water soluble substance reacts with an acid to give salt and water only. 1

/ Alkali is a substance when dissolved in water to give hydroxide ions as the only anion.

/ Alkali is a soluble base that reacts with an acid to give salt and water only.

(Not accept: alkali reacts with acid to give salt and water only.)

(Not accept: alkalis are water soluble base.)

(Not accept: alkali is a solution with $[OH^-]$ higher than $[H^+]$.)

(c) (i) $Ba(s) + 9H_2(g) + 5O_2(g) \rightarrow Ba(OH)_2 \cdot 8H_2O(s)$ $\Delta H^\ominus = -3345 \text{ kJ mol}^{-1}$ 1

/ $Ba(s) + 9H_2(g) + 5O_2(g) \rightarrow Ba(OH)_2 \cdot 8H_2O(s)$ $\Delta H = -3345 \text{ kJ mol}^{-1}$

(Not accept: $Ba(s) + 9H_2(g) + 5O_2(g) \rightarrow Ba(OH)_2 \cdot 8H_2O(s)$ $\Delta H < 0$)

(Correct state symbols and unit)

(ii) $\Delta H^\ominus = (-859) + 10\times(-286) + 2\times(-46) - (-3345) - 2\times(-314)$ 1*

$= +162 \text{ kJ mol}^{-1}$ (Show correct unit) 1

(Accept: +162.0 kJ mol^{-1})

(Not accept: 'wrong unit', 'missing unit', 'no plus sign', etc.)

(iii) (As the reaction has $\Delta H > 0$,) the reaction is endothermic / absorbs heat, thus the temperature would decrease. 1

SECTION 9 Rate of Reaction

Multiple-Choice Questions

CE90_08

Which of the following contains the largest number of ATOMS at room temperature and pressure?

(Relative atomic masses: H = 1.0, N = 14.0, Cl = 35.5; Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 2 mol of ammonia gas
B. 3 mol of nitrogen gas
C. 7 g of hydrogen gas
D. 90 dm^3 of hydrogen chloride gas

CE90_11

What volume of 0.5 M sulphuric acid is required to liberate 4.8 dm^3 of carbon dioxide at room temperature and pressure from excess solid hydrogencarbonate?

(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 0.2 dm^3
B. 0.4 dm^3
C. 2.0 dm^3
D. 4.0 dm^3

CE91_03

Solid X undergoes complete thermal dissociation according to the following equation:

$$X(s) \longrightarrow Y(g) + Z(s)$$

On heating 4.90 g of solid X, 1.40 dm^3 of gas Y and 2.30 g od solid Z are obtained at room temperature and pressure. What is the relative molecular mass of Y?

(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 32.0
B. 39.4
C. 44.6
D. 84.0

CE91_32

Which of the following gases contain the same number of molecules as 300cm^3 of oxygen under the same temperature and pressure?

(1) 150 cm^3 of NH_3
(2) 200 cm^3 of O_3
(3) 300 cm^3 of He
(4) 300 cm^3 of HCl

A. (1) and (2) only
B. (3) and (4) only
C. (1), (3) and (4) only
D. (2), (3) and (4) only

CE93_09

0.21 g of a gaseous hydrocarbon occupies 0.12 dm^3 at room temperature and pressure. If this hydrocarbon has the empirical formula CH_2, what is its molecular formula?

(Relative atomic masses: H = 1.0, C = 12.0;

Molar volume of gas at room temperature and pressure = 24 dm^3)

A. C_2H_4
B. C_3H_6
C. C_4H_8
D. C_5H_{10}

CE94_47

1st statement	2nd statement
At room temperature and pressure, the molar volume of oxygen gas is greater than that of hydrogen gas.	The relative atomic mass of oxygen is greater than that of hydrogen.

CE95_31

Question 31 refers to the following chemical equation:

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$$

What volume of carbon dioxide, measured at room temperature and pressure, is produced if 224 g of iron are formed?

(Relative atomic mass: Fe = 56;

Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 16 dm^3
B. 36 dm^3
C. 72 dm^3
D. 144 dm^3

CE96_11

In an experiment, 1.6 g of sulphur are burnt completely in air to form sulphur dioxide. What volume of sulphur dioxide, measured at room temperature and pressure, is formed?

(Relative atomic mass: S = 32.0;

Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 0.6 dm^3
B. 1.2 dm^3
C. 2.4 dm^3
D. 12.0 dm^3

CE96_19

Under certain conditions, 60 cm^3 of a gaseous compound, N_xO_y, decompose completely to give 60cm^3 nitrogen gas and 30 cm^3 of oxygen gas. (All gas volumes are measured at room temperature and pressure.)

Which of the following combinations is correct?

	x	y
A.	1	1
B.	1	2
C.	2	1
D.	2	3

CE96_32

Which of the following statements concerning one mole of nitrogen gas is/are correct?

(1) It has a mass of 14.0 g.
(2) It occupies the same volume as 4.0 g of helium gas at room temperature and pressure.
(3) It contains 6.02×10^{23} atoms of nitrogen.

(Relative atomic masses: He = 4.0, N = 14.0; Avogadro's constant = 6.02×10^{23} mol^{-1})

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE97_17

Which of the following gases occupies the largest volume at room temperature and pressure?
(Relative atomic masses: H = 1.0, C =12.0, N = 14.0, O = 16.0; molar volume of gas at room temperature and pressure = 24 dm^3)

A. 1.0 g of ammonia
B. 2.0 g of nitrogen
C. 3.0 g of oxygen
D. 4.0 g of carbon dioxide

CE97_34

One mole of sulphur atoms has a mass twice that of one mole of oxygen atoms. Which of the following statements is/are correct?

(1) 2 g of sulphur and 1 g of oxygen each occupy the same volume at room temperature and pressure.
(2) 2 g of sulphur and 1 g of oxygen each contain the same number of atoms.
(3) The number of atoms contained in one mole of sulphur is twice that contained in one mole of oxygen.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE98_28

7.5 g of calcium carbonate is added to 50.0 cm^3 of 2 M hydrochloric acid. What is the volume of carbon dioxide liberated at room temperature and pressure?
(Relative atomic masses: C =12.0, O = 16.0, Ca = 40.0; molar volume of gas at room temperature and pressure = 24.0 dm^3)

A. 0.9 dm^3
B. 1.2 dm^3
C. 1.8 dm^3
D. 2.4 dm^3

CE98_46

1st statement	2nd statement
One mole of water occupies the same volume as one mole of carbon dioxide at room temperature and pressure.	One mole of water contains the same number of atoms as one mole of carbon dioxide.

CE99_16

At room temperature and pressure, 8.0 g of oxygen and 20.0 g of gas X occupy the same volume. What is the molar mass of X?
(Relative atomic mass: O = 16.0; molar volume of gas at room temperature and pressure = 24 dm^3)

A. 20.0 g
B. 40.0 g
C. 60.0 g
D. 80.0 g

CE01_10

Consider the reaction:

$4H_2(g) + Fe_3O_4(s) \longrightarrow 3Fe(s) + 4H_2O(l)$

What mass of iron would be obtained if 96.0 cm^3 of hydrogen, measured at room temperature and pressure, is consumed in the reaction?
(Relative atomic mass: Fe = 56.0; molar volume of gas at room temperature and pressure = 24 dm^3)

A. 0.056 g
B. 0.084 g
C. 0.168 g
D. 0.224 g

CE01_27

Suppose that the Avogadro number is L. How many atoms does 600 cm^3 of oxygen at room temperature and pressure contain?
(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 1/40 L
B. 1/20 L
C. 25 L
D. 50 L

CE01_33

Consider the information below about the reaction of hydrogen with chlorine:

$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g) \quad \Delta H < 0$

Which of the following statements can be deduced from the above information?

(1) Heat is liberated when hydrogen chloride is formed.
(2) Hydrogen and chlorine react at room temperature.
(3) When measured at room temperature and pressure, the total gas volume before the reaction equals that after the reaction.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE02_16

Gases X and Y react to give a gaseous product Z. The reaction can be represented by the equation:

$X(g) + 3Y(g) \longrightarrow 2Z(g)$

In an experiment, 40 cm^3 of X and 60 cm^3 of Y are mixed and are allowed to react in a closed vessel. What is the volume of the resultant gaseous mixture?
(All volumes of are measured at room temperature and pressure.)

A. 40 cm^3
B. 60 cm^3
C. 80 cm^3
D. 100 cm^3

CE03_06

Sodium azide, NaN_3, is used in air bags in cars. When there is a serious collision, the azide will decompose to give nitrogen. The decomposition can be represented by the equation:

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

What is the mass of sodium azide required to produce 72 dm^3 of nitrogen at room temperature and pressure?

(Relative atomic masses: N = 14.0, Na = 23.0;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. 65.0 g
B. 130.0 g
C. 195.0 g
D. 292.5 g

CE03_20

A sample of zinc granules of mass 1.8 g was added to 100 cm^3 of 0.25 M hydrochloric acid. What is the theoretical volume of hydrogen produced at room temperature and pressure?

(Relative atomic mass: Zn = 65.4; molar volume of gas at room temperature and pressure = 24 dm^3)

A. 0.30 dm^3
B. 0.33 dm^3
C. 0.60 dm^3
D. 0.66 dm^3

CE05SP_38

In an experiment, 8.1 g of magnesium was treated with 250 cm^3 of 2.0 M hydrochloric acid. What volume of hydrogen was liberated at room temperature and pressure?

(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 4 dm^3
B. 6 dm^3
C. 8 dm^3
D. 12 dm^3

CE05SP_50

1st statement	2nd statement
The volume of 10.0 g of gaseous carbon dioxide is the same as the volume of 10.0 g of solid carbon dioxide.	10.0 g of gaseous carbon dioxide contains the same number of molecules as 10.0 g of solid carbon dioxide.

CE04_03

The relative atomic masses of hydrogen and oxygen are 1.0 and 16.0 respectively. Which of the following statements concerning 36.0 g of water is correct?

(Molar volume of gas at room temperature and pressure = 24 dm^3;
Avogadro constant = 6.02×10^{23} mol^{-1})

A. It contains 4 mol of hydrogen atoms.
B. It contains $3 \times 6.02 \times 10^{23}$ atoms.
C. It contains $6 \times 6.02 \times 10^{23}$ molecules.
D. It has a volume of 48 dm^3 at room temperature and pressure.

CE04_06

Decomposition of $KClO_3(s)$ at elevated temperatures gives KCl(s) and $O_2(g)$ as the only products. What is the volume of $O_2(g)$ produced, measured at room temperature and pressure, when 63.1 g of $KClO_3(s)$ undergoes complete decomposition?

(Relative atomic masses: O = 16.0, Cl = 35.5, K = 39.1;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. 3 dm^3
B. 12 dm^3
C. 18 dm^3
D. 36 dm^3

CE05_35

$NaHCO_3$ decomposes upon heating to form Na_2CO_3, CO_2 and H_2O. What is the volume of CO_2 formed at room temperature and pressure if 336 g of $NaHCO_3$ undergoes complete decomposition?

(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0, Na = 23.0;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. 12 cm^3
B. 24 cm^3
C. 48 cm^3
D. 96 cm^3

CE05_44

Which of the following statements concerning 1 mole of aluminium is/are correct?

(Avogadro's constant = 6.02×10^{23};
molar volume of gas at room temperature and pressure = 24 dm^3)

(1) It can form 1 mole of Al^{3+} ions.
(2) It can form $3 \times 6.02 \times 10^{23}$ Al^{3+} ions.
(3) It occupies 24 cm^3 at room temperature and pressure.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE06_41

Metal X forms an oxide with the formula X_2O. Upon strong heating, the oxide undergoes decomposition according to the following equation:

$$2X_2O(s) \longrightarrow 4X(s) + O_2(g)$$

Complete decomposition of 2.90 g of the oxide gives 150 cm^3 of oxygen, measured at room temperature and pressure. What is the relative atomic mass of X?

(Relative atomic mass: O =16.0; molar volume of gas at room temperature and pressure = 24dm^3)

A. 54.0
B. 108.0
C. 216.0
D. 232.0

CE06_50

1st statement	2nd statement
Under room temperature and pressure, 1 mol of $O_2(g)$ occupies a smaller volume than 1 mol of $O_3(g)$.	The number of atoms in 1 mol of $O_2(g)$ is less than that in 1 mol of $O_3(g)$.

CE07_39

$CO_2(g)$, $SO_3(g)$ and $O_2(g)$ are composed of atoms of different elements. At room temperature and pressure, what is the ratio of the number of atoms involved in 100 cm^3 of $CO_2(g)$, 100 cm^3 of $SO_3(g)$ and 200 cm^3 of $O_2(g)$?
(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 3 : 4 : 4
B. 3 : 4 : 2
C. 2 : 3 : 4
D. 1 : 1 : 2

CE07_40

When 10 g of PURE calcium carbonate (molar mass = 100.1 g) reacted with excess hydrochloric acid, 2.40 dm^3 carbon dioxide was obtained at room temperature and pressure. However, in a similar experiment using 10 g of IMPURE calcium carbonate, 2.50 dm^3 of carbon dioxide was obtained. Assuming that the impurity is a metallic carbonate, what would this impurity be?
(Molar masses: $MgCO_3$ = 84.3 g, $ZnCO_3$ = 125.4 g, $FeCO_3$ = 115.8 g, $CuCO_3$ = 123.5 g;
molar volume of gas at room temperature and pressure = 24dm^3)

A. $MgCO_3$
B. $ZnCO_3$
C. $FeCO_3$
D. $CuCO_3$

CE08_32

Nitroglycerin ($C_3H_5N_3O_9$) is an explosive and can explode according to the following equation:

$$4C_3H_5N_3O_9(l) \longrightarrow 12CO_2(g) + 12H_2O(g) + 6N_2(g) + O_2(g)$$

0.1 mole of nitroglycerin undergoes explosion and the products are allowed to cool to room temperature. What is the total volume of gases left behind at room temperature and pressure?
(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 11.4 dm^3
B. 17.4 dm^3
C. 45.6 dm^3
D. 69.6 dm^3

CE08_50

1st statement	2nd statement
When equal mass of Mg and Zn granules is added separately to excess dilute H_2SO_4, a greater amount of gas will be produced by Mg than Zn.	Mg is more reactive than Zn.

CE08_39

Consider the following information on two reactions involving magnesium ribbons of the same shape:

	Reaction mixture
Reaction 1	1.5 g Mg + 100 cm^3 of 1 M HCl
Reaction 2	1.5 g Mg + 100 cm^3 of 1 M H_2SO_4

Which of the following statements is correct?
(Relative atomic mass: Mg = 24.3)

A. The magnesium reacts completely in Reaction 1.
B. The sulphuric acid reacts completely in Reaction 2.
C. The initial rates of Reaction 1 and Reaction 2 are the same.
D. The initial rate of Reaction 1 is smaller than that of Reaction 2.

CE09_33

An oxide of metal M reacts completely with carbon to give 12.6 g of metal M and 2.38 dm^3 of carbon dioxide measured at room temperature and pressure. What is the chemical formula of the oxide?
(Relative atomic masses: M = 63.5, O =16.0;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. MO
B. MO_2
C. M_2O
D. M_2O_3

CE09_40

Assuming that air contains 20% of oxygen by volume, how much air is required to burn completely 100 cm^3 of ethane? (All volumes are measured at the same temperature and pressure.)

A. 350 cm^3
B. 1000 cm^3
C. 1750 cm^3
D. 3500 cm^3

CE09_43

Beaker A contains 100 cm^3 of 1 M HCl(aq), while beaker B contains 50 cm^3 of 2 MHCl(aq). Equal mass of magnesium ribbons are added to the two beakers. Both magnesium ribbons disappear after reaction. Which of the following statements is/are correct?

(1) The reaction occurring in both beakers have the same initial rate.
(2) Same volume of gas, measured at the same temperature and pressure, is given out in both beakers.
(3) Magnesium chloride solutions of the same concentration are produced in both beakers.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE10_37

What is the theoretical volume of carbon dioxide gas, measured at room temperature and pressure, that can be obtained by adding 100 cm^3 of 2.0 M HCl(aq) to 0.80 g of $Na_2CO_3(s)$?
(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0, Na = 23.0, Cl = 35.5;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. 90 dm^3
B. 180 dm^3
C. 240 dm^3
D. 480 dm^3

CE10_46

At room temperature and pressure, 1 mole of gas A and 2 moles of gas B react completely to form 1 mole of gas C and 1 mole of gas D. If the temperature and pressure remain unchanged, which of the following will decrease after the reaction?

(1) the mass of the gaseous mixture
(2) the volume of the gaseous mixture
(3) the total number of atoms making up the gases in the gaseous mixture

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE11_33

In an experiment, excess calcium granules are added to 100.0 cm^3 of 2.0M hydrochloric acid. What is the theoretical volume of hydrogen gas liberated at room temperature and pressure?
(Molar volume of gas at room temperature and pressure = 24 dm^3)

A. 0.6 dm^3
B. 1.2 dm^3
C. 2.4 dm^3
D. 4.8 dm^3

CE11_45

In an experiment to determine the initial rate of the reaction between dilute hydrochloric acid and magnesium carbonate powder, which of the following items may be measured at regular intervals as the reaction proceeds?

(1) the colour intensity of the reaction mixture
(2) the mass of the reaction mixture
(3) the volume of gas liberated

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE11SP_25

Which of the following changes will NOT increase the initial rate of the reaction between 50 cm^3 of 1 M HCl(aq) and excess calcium carbonate granules?

A. Using 100 cm^3 of HCl(aq) instead of 50 cm^3 of HCl(aq).
B. Using 2 M HCl(aq) instead of 1 M HCl(aq).
C. Using 25 cm^3 of 2 M HCl(aq) instead of 50 cm^3 of 1 M HCl(aq)
D. Using calcium carbonate powder instead of calcium carbonate granules.

Directions: Questions DSE11SP_32 to DSE11SP_33 refer to the following information.

An experiment was performed on the study of the rate of reaction between hydrochloric acid and sodium thiosulphate solution. 10 cm^3 portions of 2.0 M hydrochloric acid were added to four separate conical flasks, W, X, Y and Z, each containing sodium thiosulphate solution which was prepared respectively as follows:

Conical flask	Sodium thiosulphate solution		Volume of water
	Concentration	Volume	
W	1.0 M	80 cm^3	10 cm^3
X	1.5 M	60 cm^3	30 cm^3
Y	2.5 M	30 cm^3	60 cm^3
Z	3.0 M	20 cm^3	70 cm^3

DSE11SP_32

In which of the above conical flasks does the reaction proceed at the fastest rate?

A. W
B. X
C. Y
D. Z

DSE11SP_33

Which of the following apparatus should be used when carrying out the above experiment in addition to the conical flasks?

(1) syringe
(2) stop watch
(3) measuring cylinder

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE12PP_07

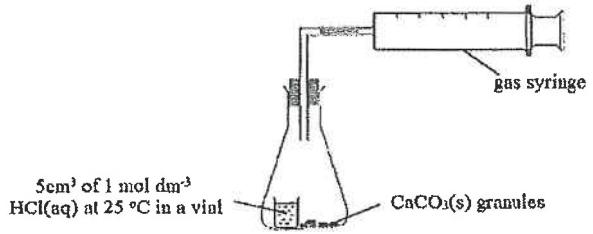
A scientist extracted a sample of 'nitrogen' from air by removing the oxygen and carbon dioxide. The scientist then compared the mass of a known volume of the 'nitrogen' sample (m_1) with that of the same volume of pure nitrogen (m_2) under the same set of conditions. The experiment was repeated a number of times. It was found that m_1 was consistently greater than m_2.
Which of the following gases is likely to be present in the 'nitrogen' obtained to account for the result that m_1 is greater than m_2?

A. Neon
B. Argon
C. Methane
D. Water vapor

DSE12PP_25

The set-up shown below is used in an experiment to study the rate of the reaction:

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$



The conical flask is shaken to overturn the vial in order to start the reaction. The initial rate of the reaction with respect to the gas liberated is determined. The experiment is then repeated with only one of the conditions changed while the others remain unchanged.

Under which of the following situations would the initial rate be the same as that in the original experiment.

A. using 10 cm^3 of 1 mol dm^{-3} HCl(aq)
B. using 5 cm^3 of 2 mol dm^{-3} HCl(aq)
C. using 5 cm^3 of 1 mol dm^{-3} HCl(aq) which is preheated to 50 °C
D. using powdered $CaCO_3(s)$ of the same mass

DSE12PP_29

0.40 g of an impure sample of zinc granules reacts with excess dilute sulphuric acid to give 100 cm^3 of hydrogen, measured at room temperature and pressure. Assuming that the impurities in the zinc granules do not react with sulphuric acid, what is the percentage by mass of zinc in the sample?

(Relative atomic masses: H = 1.0, Zn = 65.4;
molar volume of gas at room temperature and pressure = 24 dm^3)

A. 25 B. 34
C. 68 D. 73

DSE12PP_32

Some brands of washing powder contain enzymes. Which of the following statements about the action of the enzymes is/are correct?

(1) The activity of the enzymes increases with temperature.
(2) The enzymes facilitate the removal of specific kinds of dirt.
(3) The enzymes reduce the surface tension of water.

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE12_25

What is the theoretical volume of carbon dioxide that can be obtained, at room temperature and pressure, when 1.2 g of $Na_2CO_3(s)$ reacts with 50 cm^3 of 1.0 M HNO_3?

(Molar volume of gas at room temperature and pressure = 24 dm^3;
Relative atomic masses: H = 1.0, C = 12.0, N = 14.0, O = 16.0, Na = 23.0)

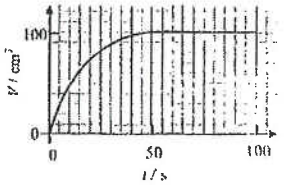
A. 272 cm^3 B. 544 cm^3
C. 600 cm^3 D. 1200 cm^3

DSE13_25

In an experiment to study the rate of the following reaction, a small amount of powdered calcium carbonate was added to excess hydrochloric acid and the volume of gas liberated was recorded.

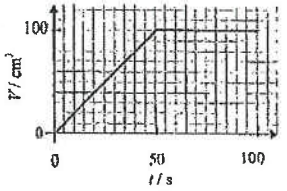
$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The graph below shows the volumes of gas liberated (V) a different times (t) during the experiment:

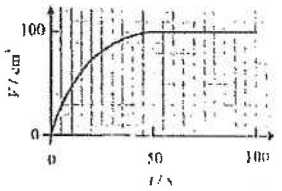


The experiment was repeated under the same conditions using the same mass of calcium carbonate granules instead of powdered calcium carbonate. Which of the following graphs would best represent the results obtained in the repeated experiment?

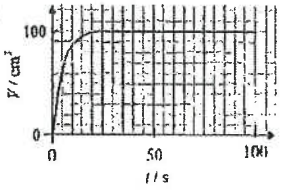
A.



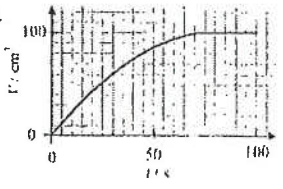
B.



C.



D.



DSE13_33

For which of the following can their progress of reaction be followed by colorimetry?

(1) $2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$

(2) $SO_3^{2-}(aq) + 2H^+(aq) \longrightarrow SO_2(g) + H_2O(l)$

(3) $Br_2(aq) + HCO_2H(aq) \longrightarrow 2Br^-(aq) + CO_2(g) + 2H^+(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE14_25

$H_2O_2(aq)$ decomposes into $H_2O(l)$ and $O_2(g)$ in the presence of $MnO_2(s)$. Two experiments are performed to study this decomposition under the same conditions, except that 50 cm^3 of 2M $H_2O_2(aq)$ is used in Experiment (1), while 100 cm^3 of 1M $H_2O_2(aq)$ is used in Experiment (2). Which of the following combinations is correct?

	Rate of formation of $O_2(g)$ at the start	Total volume of $O_2(g)$ formed
A.	Experiment (1) > Experiment (2)	Experiment (1) = Experiment (2)
B.	Experiment (1) > Experiment (2)	Experiment (1) > Experiment (2)
C.	Experiment (1) = Experiment (2)	Experiment (1) = Experiment (2)
D.	Experiment (1) = Experiment (2)	Experiment (1) > Experiment (2)

DSE15_28

Which of the following pairs of chemicals, upon mixing under the same temperature, has the highest rate of gas formation?

A. 0.10 g of Zn powder and 100 cm^3 of 1.0 M HCl(aq)
B. 0.10 g of Zn granules and 200 cm^3 of 1.0 M HCl(aq)
C. 0.10 g of Zn granules and 200 cm^3 of 1.0 M $H_2SO_4(aq)$
D. 0.10 g of Zn powder and 100 cm^3 of 1.0 M $H_2SO_4(aq)$

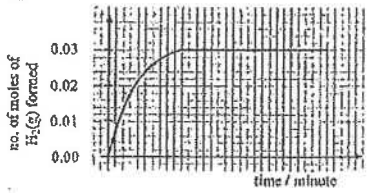
DSE15_36

1st statement	2nd statement
At room conditions, the volume of 1 mol of $SO_2(g)$ is larger than that of 1 mol of $N_2(g)$.	The number of atoms constituting 1 mol of $SO_2(g)$ is greater than that constituting 1 mol of $N_2(g)$

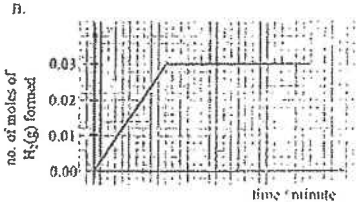
DSE16_25

In an experiment, 0.03 mol of Mg(s) is allowed to react with 20.0 cm^3 of 1.0 M HCl(aq). Which of the following graphs best represents the results of the experiment?

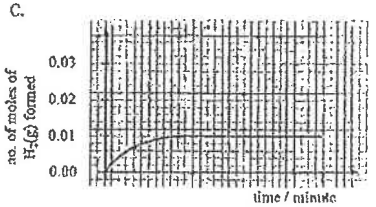
A.



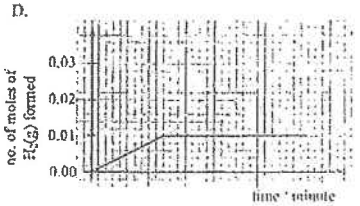
B.



C.



D.



DSE16_33

Which of the following statements are correct?

(1) Magnesium oxide dissolves faster in 1 M HCl(aq) than 1 M $CH_3CO_2H(aq)$.
(2) Powdered marble dissolves faster in 1 M HCl(aq) than granular marble does.
(3) $H_2O_2(aq)$ decomposes faster in the presence of $MnO_2(s)$ than without $MnO_2(s)$.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE16_34

Consider the following reaction:

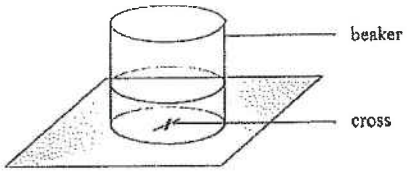
$$Br_2(aq) + HCOOH(aq) \longrightarrow CO_2(g) + 2HBr(aq)$$

Which of the following can be measured in order to follow the progress of the reaction?

(1) The volume of gas formed
(2) The turbidity of the reaction mixture
(3) The color intensity of the reaction mixture

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Direction: Question DSE17_27 and DSE17_28 refer to the following set-up.



DSE17_27

A(aq) and B(aq) react to form a turbid mixture. Three trials of an experiment were performed to study the rate of the reaction. In each trial, A(aq) was mixed with $H_2O(l)$ in the beaker. After that, B(aq) was added to the mixture, and immediately started to measure the time needed for the cross to become invisible when viewed from above. The table below shows the relevant data.

Trial	Volume used / cm^3			Time / s
	A(aq)	$H_2O(l)$	B(aq)	
1	10.0	20.0	10.0	82
2	10.0	10.0	20.0	41
3	20.0	10.0	10.0	82

Which of the following statements concerning the rate of the reaction is correct?

A. It depends on [A(aq)], and also depends on [B(aq)].
B. It increases with [A(aq)], but does not increase with [B(aq)].
C. It increases with [B(aq)], but does not increase with [A(aq)].
D. It does not depend on [A(aq)], and also does not depend on [B(aq)].

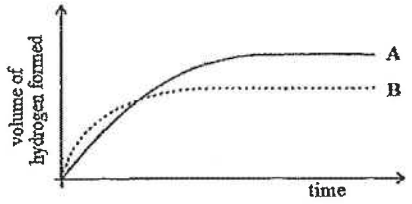
DSE17_28

Of which of the following reactions can the rate be studies by the above set-up?

A. $CaCl_2(aq) + H_2SO_4(aq) \longrightarrow CaSO_4(aq) + 2HCl(aq)$
B. $Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$
C. $2FeSO_4(aq) + 2H_2SO_4(aq) \longrightarrow Fe_2(SO_4)_3(aq) + 2H_2O(l) + SO_2(g)$
D. $Na_2S_2O_3(aq) + 2HCl(aq) \longrightarrow S(s) + SO_2(aq) + H_2O(l) + 2NaCl(aq)$

DSE18_25

100 cm^3 of 1.0 M HCl(aq) reacts with excess zinc granules giving curve A in the graph below.



Which of the following changes may give curve B?

A. Increase the temperature by 5 °C.
B. Use the same mass of zinc powder instead of zinc granules.
C. Use 200 cm^3 of 0.8 M HCl instead of 100 cm^3 of 1.0 M HCl(aq).
D. Use 50 cm^3 of 1.50 M HCl(aq) instead of 100 cm^3 of 1.0 M HCl(aq).

DSE18_33

Consider the following two reactions:

Reaction	Reactants
(I)	1.0 g of $Na_2CO_3(s)$ + 100 cm^3 of 1.0 M HCl(aq)
(II)	1.0 g of $Na_2CO_3(s)$ + 100 cm^3 of 1.0 M $CH_3COOH(aq)$

Which of the following statements are correct if the two reactions are performed under the same experimental conditions?

(Relative atomic masses : C = 12.0, O = 16.0, Na = 23.0)

(1) The decrease in mass for the two reaction mixture is the same.
(2) The initial rate of Reaction (I) is higher than that of Reaction (II).
(3) The heat given out for the two reactions is the same.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE18_36

Consider the following statements and choose the best answer:

1st statement	2nd statement
The molar volume of bromine is larger than that of fluorine at room temperature and pressure.	The molecular size of bromine is larger than that of fluorine.

DSE19_34

Consider the following reaction :

$$2H_2O_2(aq) \xrightarrow{MnO_2(s)} 2H_2O(l) + O_2(g)$$

Which of the following statements is / are correct if the concentration of $H_2O_2(aq)$ changes from 2 M to 1 M, while the other conditions remain unchanged?

(1) The consumption of $MnO_2(s)$ will decrease.
(2) The rate of formation of $O_2(g)$ will decrease.
(3) The volume of $O_2(g)$ formed will decrease.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE19_35

Consider the following reaction :

$$5NaBr(aq) + NaBrO_3(aq) + 6HCl(aq) \longrightarrow 3Br_2(aq) + 6NaCl(aq) + 3H_2O(l)$$

(colourless)

Which of the following can be measured in order to follow the progress of the reaction ?

(1) pH of the reacting mixture
(2) pressure of the reaction system
(3) colour intensity of the reacting mixture

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE20_25

25. Consider the following reaction :

$$4H_2(g) + Fe_3O_4(s) \rightarrow 3Fe(s) + 4H_2O(l)$$

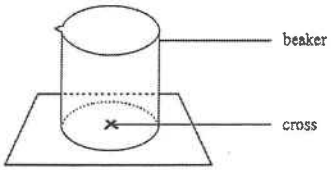
What is the minimum volume of $H_2(g)$ at room conditions required to form 0.168 g of Fe(s) ?

(Molar volume of gas at room conditions = 24 dm^3;
Relative atomic mass : Fe = 55.8)

A. 24 cm^3
B. 48 cm^3
C. 96 cm^3
D. 192 cm^3

DSE20_35

35. Refer to the following set-up :



Which of the following reactions can the effect of concentration on rate be studied by the above set-up ?

(1) $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$
(2) $Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + H_2O(l) + 2NaCl(aq)$
(3) $Mg(s) + ZnSO_4(aq) \rightarrow MgSO_4(aq) + Zn(s)$

A. (1) and (2) only
B. (1) and (3) only
C. **(2) and (3) only**
D. (1), (2) and (3)

DSE21_25

Direction: Questions 25 and 26 refer to the following experiment on the study of the rate of reaction between $HCO_2H(aq)$ and $Br_2(aq)$ at a certain temperature. It is given that the rate depends on both the concentrations of $HCO_2H(aq)$ and $Br_2(aq)$:

$$HCO_2H(aq) + Br_2(aq) \rightarrow 2HBr(aq) + CO_2(g)$$

5.0 cm^3 of 0.05 M $HCO_2H(aq)$ are separately added to four conical flasks each containing $Br_2(aq)$ prepared by mixing different volumes of 0.05 M $Br_2(aq)$ and water as shown in the table below :

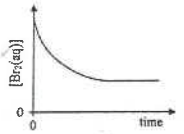
Conical flask	Volume of 0.05 M $Br_2(aq)$ / cm^3	Volume of water / cm^3
A	1.0	4.0
B	2.0	3.0
C	3.0	2.0
D	4.0	1.0

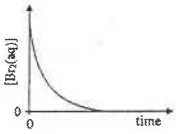
25. In which of the above conical flasks does the reaction have the fastest initial rate ?

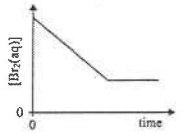
A. A
B. B
C. C
D. D

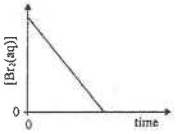
DSE21_26

26. Which of the following graphs best represents the variation of $[Br_2(aq)]$ in the reaction mixture of conical flask B with time ?

A.


B.


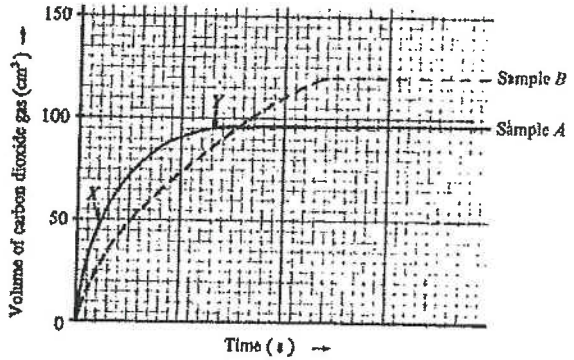
C.


D.


Structural Questions

CE90_02b

Two different samples of calcium carbonate (A and B), each weighing 0.8 g and containing inert impurities, were allowed to react with excess dilute hydrochloric acid under the same laboratory conditions. The volumes of carbon dioxide gas evolved with time are shown in the graph below:



(i) Draw a diagram to show how the above experiment can be performed in the laboratory.

(ii) Explain why the slope of the curve for sample A is steeper at X than at Y.

(iii) From the two curves, deduce TWO differences between sample A and sample B.

(iv) (1) What is the total volume of gas liberated from sample B?

(2) Hence, calculate the percentage of calcium carbonate in sample B.

(Relative atomic masses: C = 12.0, O = 16.0, Ca = 40.0;
Molar volume of gas under the laboratory conditions = 24 dm^3)

(10 marks)

CE92_02c

1.0 g of calcium carbonate is added to 50.0 cm^3 of 0.1 M nitric acid. At the end of the reaction, 55.0cm^3 of a certain gas are collected at room temperature and pressure.

(i) Draw a diagram of the set-up suitable for this experiment.

(ii) Calculate the theoretical volume of the gas which would be liberated at room temperature and pressure.

(iii) Explain any difference between the theoretical volume and the volume of the gas collected.

(Relative atomic masses: C = 12.0, O = 16.0, Ca = 40.0;
Molar volume of gas at room temperature and pressure = 24.0 dm^3)

(6 marks)

CE92_03b

Neon, a monatomic gas, occurs naturally as a mixture of three isotopes. The relative abundance of these isotopes is tabulated below:

Isotope	$^{20}_{10}Ne$	$^{21}_{10}Ne$	$^{22}_{10}Ne$
Abundance / %	90.52	0.31	9.17

(i) State the number of electrons in the outermost shell of a neon atom.

(ii) Explain why neon gas is monatomic.

(iii) What is meant by the term 'isotope'?

(iv) Calculate

(1) the relative atomic mass of neon.

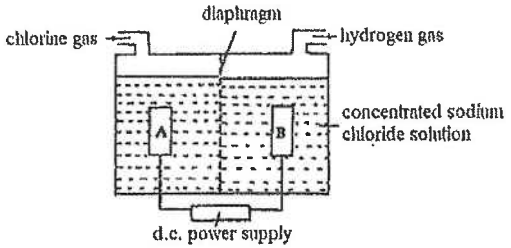
(2) the density (in g dm^{-3}) of neon gas at room temperature and pressure.

(Molar volume of gas at room temperature and pressure = 24.0 dm^3)

(7 marks)

CE92_05a

Sodium hydroxide can be manufactured by the electrolysis of concentrated sodium chloride solution in the following set-up, where A and B are inert electrodes.



(i) Explain which electrode, A or B, is the cathode.

(ii) Using the concept of preferential discharge of ions, explain the electrode reactions and why sodium hydroxide can be manufactured by the above electrolysis.

(iii) If 234 g of sodium chloride are used up during the electrolysis, calculate the volume of hydrogen liberated at room temperature and pressure.

(Relative atomic masses: Na = 23.0, Cl = 35.5;
Molar volume of gas at room temperature and pressure = 24.0 dm^3)

(9 marks)

CE93_04b

To determine the percentage by mass of calcium carbonate in egg shells, a student added 100 cm^3 of 2 M hydrochloric acid to 0.3 g of egg shells in a container. After 30 minutes, all the egg shells dissolved and 67 cm^3 of carbon dioxide were collected at room temperature and pressure.

(i) Write an equation for the reaction between calcium carbonate and hydrochloric acid.

(ii) Calculate the percentage by mass of calcium carbonate in the egg shells.

(iii) The rate of reaction between the egg shells and 2 M hydrochloric acid was slow. Suggest TWO method to increase the rate of this reaction without using other chemicals. Explain your answer in each case.

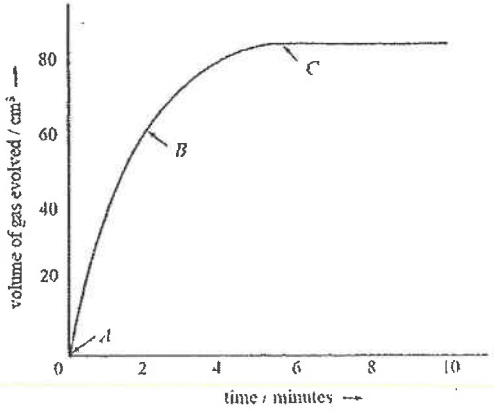
(Relative atomic masses: H = 1.0, C =12.0, O = 16.0, Ca = 40.0;
Molar volume of gas at room temperature and pressure = 24.0 dm^3)

(8 marks)

CE94_08a

The rate of decomposition of hydrogen peroxide solution in the presence of manganese(IV) oxide was studied by means of the following experiment.

50.0 cm^3 of a hydrogen peroxide solution was mixed with 0.5 g of powdered manganese(IV) oxide in a conical flask. The volumes of gas evolved at room temperature and pressure at different times are shown in the graph below.



(i) Write an equation for the decomposition of hydrogen peroxide.

(ii) Compare the rates of decomposition of the hydrogen peroxide solution at points A, B and C, and explain why these rates are different.

(iii) Calculate the original molarity of the hydrogen peroxide solution.

(iv) If the experiment is repeated with an equal volume of the hydrogen peroxide solution and 1.0 g of powdered manganese(IV) oxide, would the shape of the curve obtained be the same? Explain your answer.

(Molar volume of gas at room temperature and pressure = 24.0 dm^3)

(8 mraks)

CE95_07a

The label on a bottle of 'Effervescent Calcium' tablets is shown below.

Effervescent Calcium	
Each bottle contains 10 tablets.	
Each tablet contains:	
Calcium carbonate	625 mg
Vitamin C	1000 mg
Citric acid	1350 mg
Dosage: 1 tablet daily	
Administration : Dissolve one tablet in a glass of water.	
Warning : (1) Keep out of reach of children.	
(2) Keep	

(i) Effervescence occurs when a tablet of 'Effervescent Calcium' is added to water. Based on the information given on the label, explain why effervescence occurs.

(ii) Suppose that a student puts a tablet of 'Effervescent Calcium' into an excess amount of water and collects the gas liberated.

(1) Assuming that the tablet completely dissolves, calculate the theoretical volume of gas liberated.

(2) It is found that the volume of gas collected in the experiment is less than the theoretical volume calculated in (1). Give ONE reason to explain the difference, assuming that there is no leakage of gas in the experiment.

(8 marks)

CE96_07a

The boxes below show some information about two atoms.

Hydrogen (H) and deuterium (D):

Mass number → 1, Atomic number → 1, **H**

Mass number → 2, Atomic number → 1, **D**

(i) Suggest a term to indicate the relationship between a hydrogen atom and a deuterium atom.

(ii) State the number of neutrons in a deuterium atom.

(iii) Deuterium reacts with oxygen in the same way as hydrogen.

$2D_2(g) + O_2(g) \longrightarrow 2D_2O(l)$ ΔH is negative

The product of the reaction is known as 'heavy water'.

(1) Explain why deuterium reacts with oxygen in the same way as hydrogen.

(2) Draw the electronic structure of 'heavy water', showing the electrons in the outermost shells ONLY.

(3) What is meant by 'ΔH is negative'?

(4) What is the formula mass of 'heavy water'?

(5) 100 cm^3 of deuterium and 100 cm^3 of oxygen, both measured at room temperature and pressure, are allowed to react. Calculate the mass of 'heavy water' produced.

(9 marks)

CE00_09a

X, Y and Z are three different metals. The table below shows the result of two experiments carried out using the metals or their oxides.

Experiment	X	Y	Z
Adding the metal to water	Effervescence	No observable change	No observable change
Heating the metal oxide	No observable change	Metal produced	No observable change

(i) Based on the above information, arrange the three metals in order of increasing reactivity. Explain your answer.

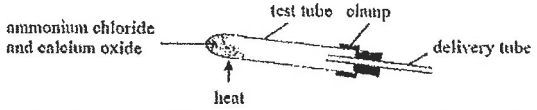
(ii) An oxide of Y has the formula YO. When 1.08 g of this oxide is heated strongly, it decomposes completely to give 60.0 cm^3 of oxygen, measured at room temperature and pressure. Calculate the relative atomic mass of Y.

(Relative atomic mass: O = 16.0;
molar volume of gas at room temperature and pressure = 24.0 dm^3)

(6 marks)

CE03_06a

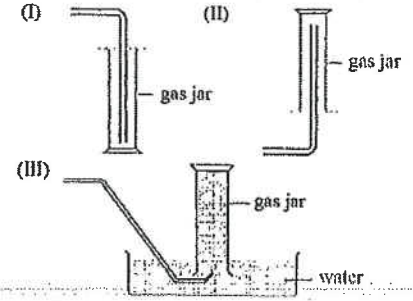
Ammonia gas can be prepared by heating a mixture of ammonium chloride and calcium oxide in the set-up shown below:



(i) The reaction of ammonium chloride with calcium oxide also gives calcium chloride as a product. Write the chemical equation for the reaction of ammonium chloride with calcium oxide.

(ii) Why is it necessary to clamp the test tube with its mouth pointing downwards as shown?

(iii) Decide which of the following set-ups, (I), (II) or (III), should be connected to the delivery tube to collect the ammonia gas produced. Explain your answer.



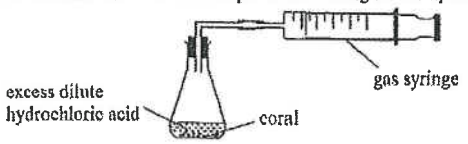
(iv) Calculate the theoretical volume of ammonia gas, measured at room temperature and pressure, which can be obtained from the reaction of 1.0 g of ammonium chloride with excess calcium oxide.

(Relative atomic masses: H = 1.0, N = 14.0, Cl = 35.5;
molar volume of gas at room temperature and pressure = 24.0 dm^3)

(9 marks)

CE04_08a

Coral consists mainly of calcium carbonate. An experiment was carried out to determine the percentage by mass of calcium carbonate in a sample of coral using the set-up shown below:



(i) Write a chemical equation for the reaction of calcium carbonate with dilute hydrochloric acid.

(ii) The mass of the sample used was 0.36 g. At the end of the experiment, 78 cm^3 of carbon dioxide was collected at room temperature and pressure.
Calculate
(1) the number of moles of carbon dioxide collected; and
(2) the percentage by mass of calcium carbonate in the sample.

(iii) Assuming that there was no leakage of gas in the set-up, suggest ONE source of error in the experiment.

(Molar volume of gas at room temperature and pressure = 24.0 dm^3;
relative atomic masses: C = 12.0, O = 16.0, Ca = 40.0)

(7 marks)

CE06_12

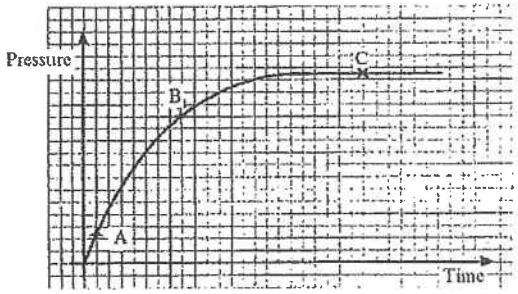
For question 12, candidates are required to give answers in paragraph form. For this question, 6 marks will be awarded for chemical knowledge and 3 marks for effective communication.

You are provided with the following materials:
magnesium ribbon and 2M hydrochloric acid
Design an experiment to determine the molar volume of hydrogen at room temperature and pressure.
(You may use apparatus commonly available in a school laboratory.)

(6 + 3 marks)

CE09_10

In an experiment, a data-logger with pressure sensor was used to study the rate of decomposition of hydrogen peroxide (H_2O_2) in the presence of manganese(IV) oxide. The relation between the pressure and time measured is shown in the curve below.



(a) The decomposition of hydrogen peroxide gives water and oxygen. After the experiment, it was found that the manganese(IV) oxide used did not undergo any chemical change.

(i) State the function of manganese(IV) oxide.

(ii) Explain why a pressure sensor could be used in this experiment.

(iii) Write a chemical equation for the decomposition of hydrogen peroxide. Hence discuss the changes, if any, in the oxidation numbers of hydrogen and oxygen in the reaction.

(5 marks)

(b) (i) Explain why the respective rates of decomposition of hydrogen peroxide differ at points A, B and C on the curve.

(ii) On the graph above, sketch a curve that should be obtained if the initial concentration of the hydrogen peroxide is *half* of its original value, while all other conditions remain unchanged.

(4 marks)

AL99(I)_07

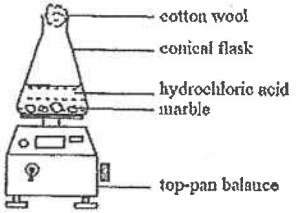
In a chemical kinetics experiment, samples of the reaction mixture are removed at regular time intervals for titrimetric analysis.

Suggest TWO methods by which the reaction in the samples removed can be stopped or slowed down.

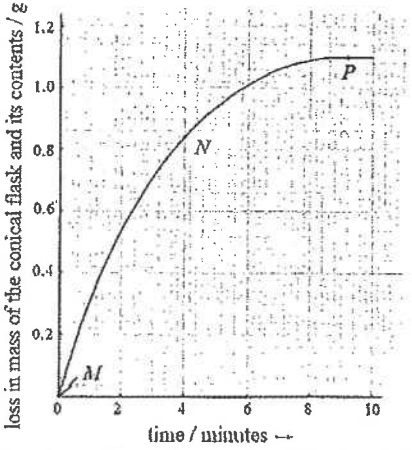
(2 marks)

ASL99(II)_11

In an experiment, 50.0 cm^3 of 1.0 M hydrochloric acid was allowed to react with 10.0 g of marble (in excess). The progress of the reaction was monitored using the set-up shown below.



The graph below shows the loss in mass of the conical flask and its contents against time.



(a) Write a balanced equation for the reaction of marble with hydrochloric acid.

(1 mark)

(b) What is the purpose of placing some cotton wool at the mouth of the flask?

(1 mark)

(c) Suggest how to determine the rate of loss in mass of the conical flask and its contents at point *N* from the graph.

(2 marks)

(d) Account for the change in shape of the curve from point *M* to point *P*.

(3 marks)

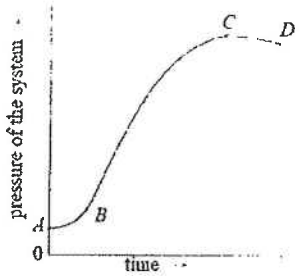
(e) The experiment was repeated using 50.0 cm^3 of 0.5 M hydrochloric acid and 10.0 g of marble.

Sketch a curve on the same graph to show the variation of the loss in mass of the conical flask and its contents against time.

(1 mark)

ASL00(II)_07

A chemical kinetics experiment was carried out using a roll of magnesium ribbon which had been exposed to air for some time. A piece of the magnesium ribbon of mass 0.12 g was placed in a flask containing 15.0 cm^3 of 1.0 M hydrochloric acid. The progress of the reaction was followed by measuring the pressure of the system at different times. The graph on below shows the results of the experiment.



(a) Show, by calculation, that magnesium was the limiting reactant.

(2 marks)

(b) Account for the variation of pressure of the system as shown in the graph

(i) from *A* to *B*,

(2 marks)

(ii) from *B* to *C*, and

(1 mark)

(iii) from *C* to *D*.

(2 marks)

(c) The experiment was repeated using the same mass of the magnesium ribbon and 15.0 cm^3 of 2.0 M hydrochloric acid. Sketch, on the same graph, the variation of pressure of the system in the repeated experiment. Explain your answer.

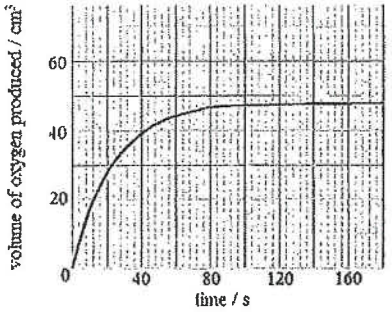
(4 marks)

ASL01(II)_07 [Similar to DSE17_10]

The decomposition of hydrogen peroxide can be catalysed by catalase which is an enzyme.

$$2H_2O_2(aq) \xrightarrow{\text{catalyst}} 2H_2O(l) + O_2(g)$$

In an experiment to study the rate of decomposition of hydrogen peroxide, 10.0 cm^3 of 0.40 M hydrogen peroxide solution and a small amount of catalase were used. The graph on below shows the results of the experiment.



(a) Draw a labelled diagram of the experimental set-up used.

(2 marks)

(b) Account for the change in the rate of decomposition of hydrogen peroxide as shown in the graph.

(3 marks)

(c) The experiment was repeated using 30.0 cm^3 of 0.20 M hydrogen peroxide solution while keeping other conditions unchanged. Sketch, on the same graph, the results of the repeated experiment.

(1 mark)

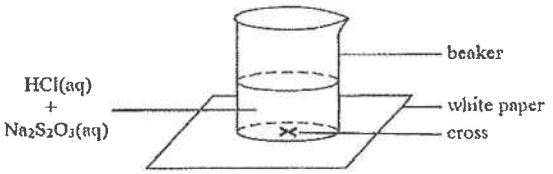
(d) Suggest another substance which can catalyse the decomposition of hydrogen peroxide.

(1 mark)

ASL02(II)_11

The set-up shown below was used to investigate how the concentration of $S_2O_3^{2-}(aq)$ affects the rate of the following reaction.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow S(s) + SO_2(g) + H_2O(l)$$



10.0 cm^3 of 1.0 M HCl(aq) and 25.0 cm^3 of $H_2O(l)$ were mixed in a beaker. 5.0 cm^3 of 0.040 M $Na_2S_2O_3(aq)$ was then added to the mixture and simultaneously a stop-watch was started. The time, t, required for the cross to disappear when viewed from above was recorded. The experiment was repeated using the same volume of HCl(aq) but different volumes of $H_2O(l)$ and $Na_2S_2O_3(aq)$. The table below lists the results obtained.

Experiment	Volume used / cm^3			t / s
	1.0 M HCl(aq)	$H_2O(l)$	0.040 M $Na_2S_2O_3(aq)$	
1	10.0	25.0	5.0	170
2	10.0	20.0	10.0	83
3	10.0	15.0	15.0	56
4	10.0	10.0	20.0	42
5	10.0	5.0	25.0	33
6	10.0	0.0	30.0	y

(a) Explain why

(i) different volumes of water were used in this investigation, and

(1 mark)

(ii) the cross, when viewed from above, disappeared after time t.

(1 mark)

(b) Plot a graph of $\frac{1}{t}$ aginst the volume of 0.040 M $Na_2S_2O_3(aq)$used.

(3 marks)

(c) What conclusion can be drawn from this investigation? Explain.

(2 marks)

(d) From your graph, estimate the value of *y* in the table.

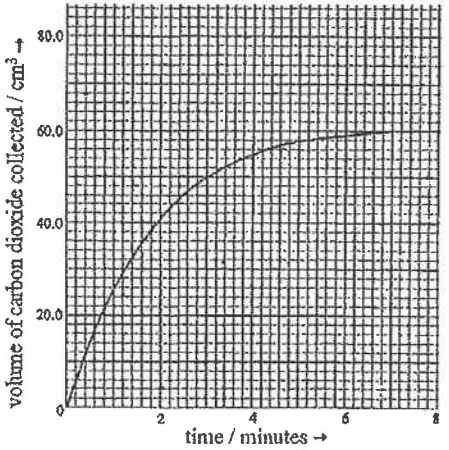
(1 mark)

ASL03(II)_10

An experiment was carried out to study the rate of the following reaction:

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A sample of marble chips was allowed to react wth 0.1 M hydrochloric acid, which had been saturated with carbon dioxide. The graph below shows the experimental results obtained.



(a) (i) Suggest how hydrochloric acid can be saturated with carbon dioxide.

(1 mark)

(ii) If the hydrochloric acid used has not been saturated with carbon dioxide, different experimental results would be obtained. Sketch the results that would be obtained on the graph.

(1 mark)

(b) (i) Suggest how the rate of the reaction at a particular time can be determined from the graph.

(2 marks)

(ii) Explain why the rate of the reaction decreases with time.

(1 mark)

(c) Keeping the other conditions unchanged, the experiment was repeated using

(i) the same mass of powdered calcium carbonate instead of marble chips, and

(1 mark)

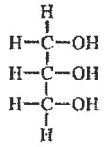
(ii) The same volume of 0.1 M ethanoic instead of 0.1 M hydrochloric acid.

(1 mark)

State and explain the respective changes in the reaction rate.

ASL04(I)_05 (modified)

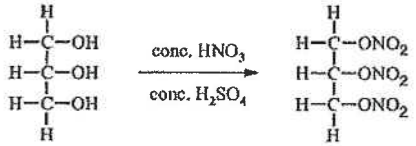
Glycerine has the following structure:



(a) Give the systematic name of glycerine.

(1 mark)

(b) When glycerine is treated with a mixture of concentrated nitric(V) acid and concentrated sulphuric(VI) acid, trinitroglycerine is formed.



trinitroglycerine

Trinitroglycerine is an explosive. Nitroglycerin can explode to give carbon dioxide, water, nitrogen and oxygen gas as following equation.

$$\_\_C_3H_5N_3O_9(l) \longrightarrow \_\_CO_2(g) + \_\_H_2O(g) + \_\_N_2(g) + \_\_O_2(g)$$

(i) Balance the above equation for the explosion of nitroglycerin.

(1 mark)

(ii) Calculate the theoretical volume in cm^3, measured at room temperature and pressure, of gas produced when 1 g of trinitroglycerine explodes completely.
(Formula masses: $C_3H_5N_3O_9 = 227$;
Molar volume of gas at room temperature and pressure = 24 dm^3)

(2 marks)

(iii) Calculate the enthalpy change of decomposition of trinitroglycerine, from the enthalpy terms given below.

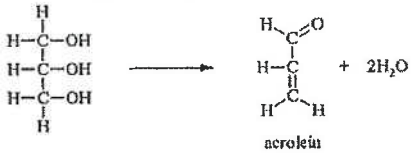
	$\Delta H^\circ_{f,298K}$ / kJ mol^{-1}
$C_3H_5N_3O_9(l)$	–364
$CO_2(g)$	–394
$H_2O(g)$	–242

(2 marks)

(iv) Besides forming a large volume of gases, give another TWO reasons why trinitroglycerine would undergo explosion upon ignition.

(2 marks)

(c) A sample of glycerine, after being stored for a long time, may contain acrolein. The formation of acrolein can be represented by the following equation:



acrolein

(i) Suggest a chemical test to show the possible presence of acrolein in a sample of glycerine.

(2 marks)

(ii) Acrolein readily undergoes addition polymerization. Draw the repeating unit of the polymer formed.

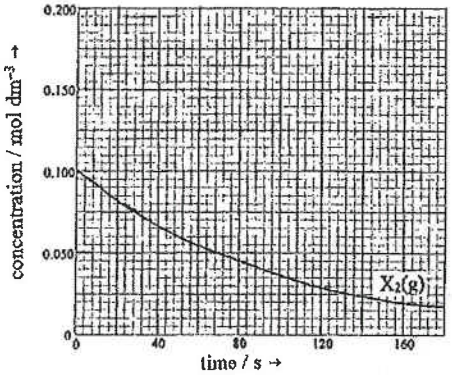
(1 mark)

ASL05(II)_08

$X_2(g)$ undergoes decomposition according to the following equation:

$$X_2(g) \longrightarrow 2X(g)$$

In an experiment to study the decomposition of $X_2(g)$, 0.100 mol of $X_2(g)$ was charged into a closed container of volume 1 dm^3 kept at a constant temperature. The graph below shows the variation of the concentration of $X_2(g)$ in the container with time.



(a) From the graph, calculate the average rate of decomposition of $X_2(g)$ in the time internal from the start of the experiment to the 40th seconard.

(2 marks)

(b) Sketch, on the same graph, the variation of the concentration of X(g) with time during the experiment.

(2 marks)

(c) Explain, in molecular terms, why the decomposition of $X_2(g)$ is faster at a higher temperature.

(2 marks)

ASL06(I)_07

A student performed an experiment to investigate the rate of reaction between zinc and and acid. 6 g of zinc granules was added to a conical flask containing 100 cm^3 of 2 M hydrochloric acid at 20 °C. Afterwards the experiment was repeated with the following changes. In each case, state and explain whether the expected reaction rate would increase or decrease.

(a) 6 g of zinc powder was used instead of zinc granules.

(1 mark)

(b) 100 cm^3 of 2 M ethanoic acid was used instead of hydrochloric acid.

(1 mark)

(c) The temperature was raised to 50 °C.

(1 mark)

ASL06(II)_10

Ammonia reacts with oxygen in the presence of platinum to give nitrogen monoxide.

$$4NH_3(g) + 5O_2(g) \xrightarrow{Pt} 4NO(g) + 6H_2O(g) \quad \Delta H < 0$$

(a) $NH_3(g)$ and $O_2(g)$ are allowed to react in a vessel of constant volume. Find the rate of consumption of $O_2(g)$ if the rate of formation of NO(g) is 1.24×10^{-4} mol dm^{-3} s^{-1}.

(2 marks)

(b) Platinum is a catalyst in the above reaction. What is meant by the term 'catalyst'?

(1 mark)

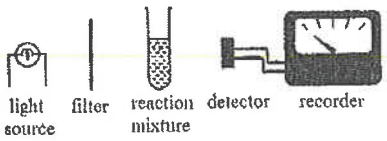
(c) State an important industrial product that can be obtained from NO(g).

(1 mark)

ASL08(I)_07

The diagram below shows the essential components of an instrument for studing the kinetics of the reaction:

$$Br_2(aq) + HCO_2H(aq) \xrightarrow{H^+} 2Br^-(aq) + 2H^+(aq) + CO_2(g)$$



(a) What is this instrument?

(1 mark)

(b) What physical parameter of the reaction mixture is measured by this instrument?

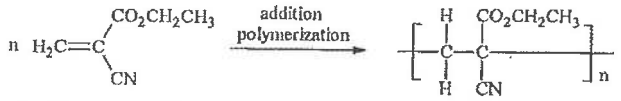
(1 mark)

(c) Sketch a graph to show the variation of the measured physical parameter with time.

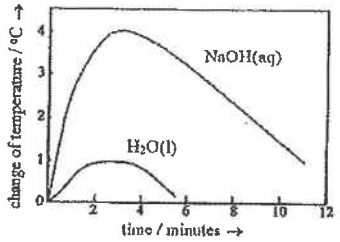
(1 mark)

AL08(I)_08a

Super glue works as an adhesive by addition polymerization as shown below:



Two experiments were carried out to study the effects of NaOH(aq) and $H_2O(l)$ on the polymerization. The conditions of the experiments were the same except that one was conducted in the presence of NaOH(aq) and the other in the presence of $H_2O(l)$, Figure shows the change of temperature of two reaction mixtures with time.



(i) Account for the increase and decrease in temperature of the reaction mixtures.

(2 marks)

(ii) Suggest a reason for the significant difference in the two curves.

(1 mark)

ASL10(I)_02

A student made the following remark:

'The rate of an elementary gaseous reaction increases with temperature because the average kinetic energy of the reactant molecules increases with temperature.'

Is the explanation provided by the student regarding the increase in reaction rate appropriate? Elaborate your answer.

(3 marks)

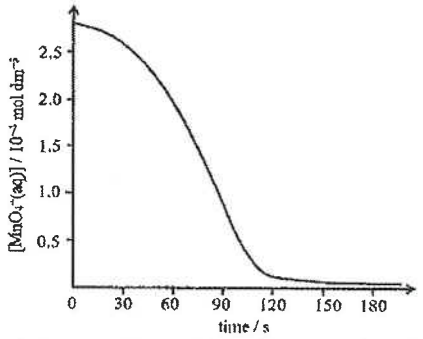
AL10(II)_02b [Similar to DSE12PP_10]

(i) Complete and balance the equation of the following reaction under an acidic condition:

$$MnO_4^-(aq) + C_2O_4^{2-}(aq) + \_\_\_\_\_ \longrightarrow Mn^{2+}(aq) + CO_2(g) + \_\_\_\_\_$$

(1 mark)

(ii) An experiment was performed to study the kinetics of the reaction in (i). The graph below shows the results obtained:



(I) Suggest a physical method for monitoring the concentration of $MnO_4^-(aq)$ ions in the reaction mixture.

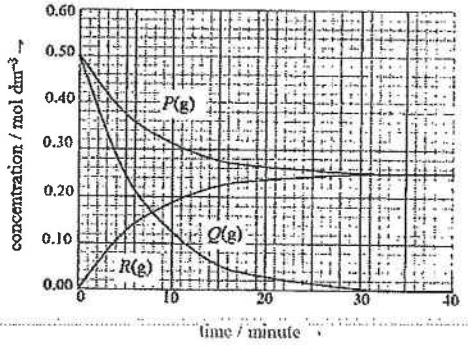
(1 mark)

(II) Suggest an explanation for the variation of the concentration of $MnO_4^-(aq)$ ions with time.

(3 marks)

DSE11SP_10

$P(g)$ reacts with $Q(g)$ irreversibly to give $R(g)$. A mixture of $P(g)$ and $Q(g)$ is allowed to react in a closed container of volume 1 dm^3 kept at a constant temperature. The graph below shows the changes in concentrations of $P(g)$, $Q(g)$ and $R(g)$ in the container with time.



(a) With reference to the above graph, deduce the chemical equation for the reaction in terms of $P(g)$, $Q(g)$ and $R(g)$.

(2 marks)

(b) If the mixture of $P(g)$ and $Q(g)$ is allowed to react at the same temperature but in a closed container of volume 2 dm^3 instead, will the time required for the reaction to complete remain the same? Explain.

(1 mark)

(c) Explain why the collisions between molecules of $P(g)$ and $Q(g)$ will not necessarily lead to a reaction.

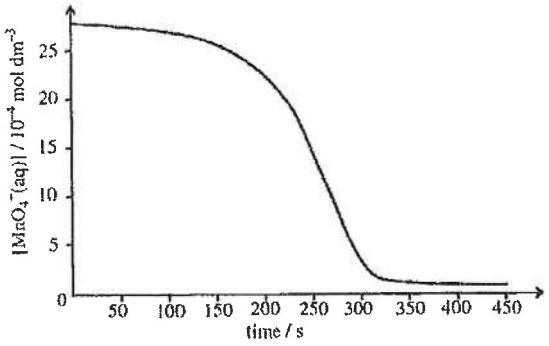
(2 marks)

DSE12PP_10 [Similar to AL10(II)_02b]

The equation below shows the reaction of potassium permanganate with sodium ethanedioate under acidic conditions:

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

A student conducted an experiment to study the rate of this reaction. The results are shown in the graph below:



(a) Suggest ONE physical method that can be used to monitor the concentration of $MnO_4^-(aq)$ ions in the reaction mixture.

(1 mark)

(b) Based on the experimental results, the student suggested that one of the products might have catalysed the reaction.

(i) What evidence from the above graph supports the student's suggestion? Explain your answer.

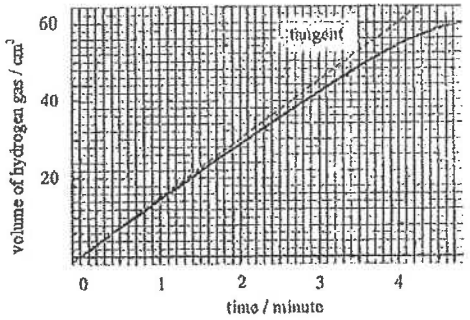
(2 marks)

(ii) Suggest how the student can show whether or not $Mn^{2+}(aq)$ is a catalyst for this reaction.

(2 marks)

DSE12_11

In an experiment, 50 cm^3 of 2.0 M HCl(aq) was added to a conical flask containing 2.0 g of zinc powder. The curve in the graph below shows the volume, measured at room temperature and pressure, of the hydrogen gas liberated in the first few minutes of the experiment. The dotted line in the graph is the tangent to the curve at the start of the reaction.



(a) The 'initial rate' of a reaction is defined as the instantaneous rate at the start of the reaction. With reference to the graph above, calculate the initial rate of the reaction with respect to the volume of hydrogen gas liberated.

(1 mark)

(b) Explain qualitatively the effect on the initial rate of the reaction of replacing the 2.0 M HCl(aq) with 2.0 M H_2SO_4(aq).

(1 mark)

(c) Upon completion of the reaction, all the zinc powder was used up. Calculate the theoretical volume of hydrogen gas liberated measured at room temperature and pressure.
(Molar volume of gas at room temperature and pressure = 24 dm^3; Relative atomic mass: Zn = 65.4)

(3 marks)

DSE13_11

Safety airbags are important devices installed in vehicles. During a serious car crash, the chemicals in the airbag immediately react to release a large amount of gas. An airbag hence inflates instantly, protecting the passenger. The main chemicals in safety airbags are sodium azide (NaN_3) and potassium nitrate (KNO_3). The equations below show the reactions involved when an airbag is inflated.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$
$$10Na(s) + 2KNO_3(s) \longrightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$$

(a) Explain why the NaN_3(s) and KNO_3(s) used in the airbags are in the form of fine powder.

(1 mark)

(b) An airbag contains 100.0 g of NaN_3(s) and 200.0 g of KNO_3(s). Calculate the theoretical

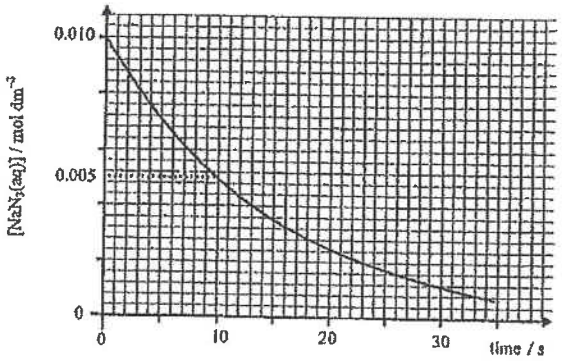
volume, measured at room temperature and pressure, of the gas produced when the bag is inflated.
(Formula masses: NaN_3 = 65.0, KNO_3 = 101.1;
Molar volume of gas at room temperature and pressure = 24 dm^3)

(3 marks)

(c) The main function of NaN_3(s) is to produce N_2(g) for inflating the airbags. Suggest why it is necessary to include KNO_3(s) in the airbags.

(1 mark)

(d) Sodium azide is a toxic chemical. Thus any NaN_3 waste remained during the manufacture of safety airbags needs special treatment before disposal. The treatment involves first dissolving NaN_3 in water, and then reacting the solution formed with excess nitrous, HNO_2(aq). The graph below shows the variation of the concentration of NaN_3(aq) in the reaction mixture with time in one such process:



(i) Calculate the average rate of consumption of NaN_3(aq) in the first 10 seconds.

(1 mark)

(ii) Suggest how the instantaneous rate of consumption of NaN_3(aq) at the 10th second can be determined from the graph.

(1 mark)

DSE14_10

You are provided with common laboratory apparatus, calcium carbonate and 1M hydrochloric acid. Outline how you would perform a fair comparison in studying the effect of different concentrations of acid on the rate of production of carbon dioxide from the following reaction:

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

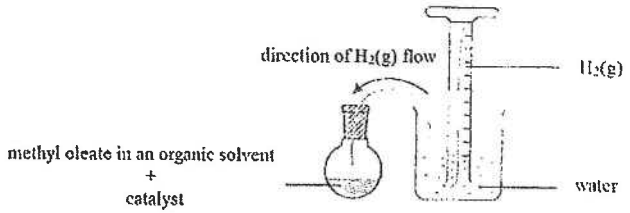
(4 marks + 1 mark)

DSE15_09

Consider the reaction below:

$$\underset{\text{methyl oleate}}{CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2CH_3(l)} + H_2(g) \xrightarrow{\text{catalyst}} CH_3(CH_2)_7CH_2CH_2(CH_2)_7CO_2CH_3(l)$$

At room temperature and pressure, a micro-scale experiment was performed using the set-up shown below in which 0.080 g of methyl oleate in an organic solvent was allowed to react with excess $H_2(g)$. The $H_2(g)$ flowed from the inverted measuring cylinder to the reacting flask through the tubing.



(a) State one advantage of conducting this reaction in a micro-scale experiment.

(1 mark)

(b) Explain why the right end of the tubing was placed at the uppermost position of the inverted measuring cylinder.

(1 mark)

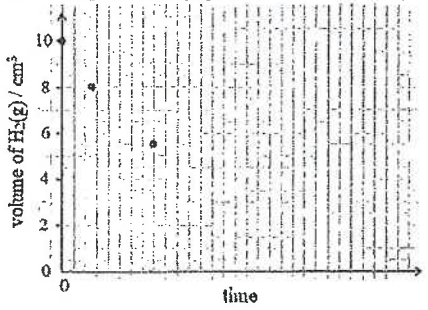
(c) State an expected observation in the inverted measuring cylinder during the reaction.

(1 mark)

(d) Calculate the theoretical volume of $H_2(g)$ needed for the reaction to complete at room temperature and pressure.
(Molar volume of gas at room temperature and pressure = 24 dm^3;
Relative molecular mass: methyl oleate = 296.0)

(3 marks)

(c) (i) Sketch, in the graph below, the variation of the volume of $H_2(g)$ in the measuring cylinder with time from start until the completion of the reaction. You should label this sketch as 'A'. (The measuring cylinder initially contained 10.0 cm^3 of $H_2(g)$. The first few points have been given in the graph to facilitate the sketch.)



(1 mark)

(ii) In the same graph above, give another sketch as required in (i) but only using 0.040 g of methyl oleate for the reaction while the other conditions remain unchanged. You should label this sketch as 'B'.

(1 mark)

DSE16_11

Under certain conditions, a pink compound X react with NaOH(aq) to give a colorless product. Three trials of an experiment were conducted to study the kinetics of the reaction. Firstly, three NaOH(aq) solutions were prepared by mixing different volume of 2.0 M NaOH(aq) and $H_2O(l)$ at 25 °C. after that, one drop of X was added top each of the them and the time needed for the pink color to disappear was recorded. The relevant data is shown below:

	Volume of 2.0 M NaOH(aq) used / cm^3	Volume of $H_2O(l)$ used / cm^3	Time needed for the pink color to disappear / s
Trial 1	5.0	0	61
Trial 2	4.0	1.0	76
Trial 3	3.0	2.0	101

(a) Why is it necessary to make the total volume of the reaction mixtures the same for the trials?

(1 mark)

(b) Given that at 25 °C, $[H^+(aq)][OH^-(aq)] = 1.0\times10^{-14}$ mol^2 dm^{-6}, calculate the pH of the NaOH(aq) solution prepared in Trial 2.

(2 marks)

(c) Based on the information provided, deduce one factor which affects the rate of this reaction.

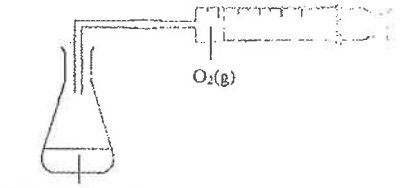
(2 marks)

(d) Detection of color change using naked eye is not accurate enough. Suggest an instrumental method that can be used to more accurately detect the color change.

(1 mark)

DSE17_10 [Similar as ASL01(II)_07]

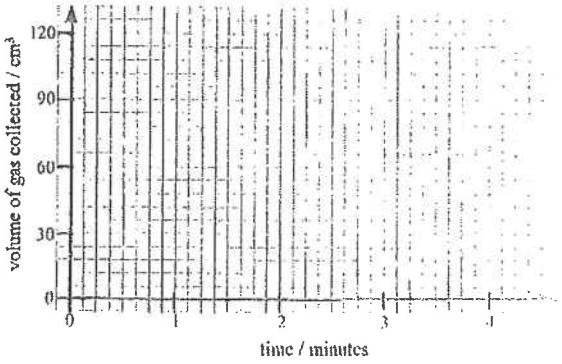
In an experiment performed under room conditions as shown below, 5.00 cm^3 of $H_2O_2(aq)$ decomposed into $O_2(g)$ and $H_2O(l)$ in the presence of a catalyst. $O_2(g)$ was continuous released from the start of the experiment until the third minute when a total of 60 cm^3 of gas was collected. After that, no more gas was collected.



(a) Calculate the initial concentration of $H_2O_2(aq)$, in mol dm^{-3}.

(2 marks)

(b) In the graph below, sketch the variation of the volume of gas collected with time in the first 4 minutes.



(2 marks)

(c) The experiment is repeated using $H_2O_2(aq)$ at a higher temperature but other conditions remain unchanged. Explain whether the total volume of gas obtained would still be 60 cm^3. (The volume of gas is measured at room conditions.)

(1 mark)

(d) Suggest another method that can be used to follow the progress of this reaction.

(1 mark)

DSE18_02

This question involves the preparation of ammonia gas and the investigation of the properties of ammonia gas in a laboratory.

(a) Solid calcium hydroxide reacts with solid ammonium chloride to form ammonia gas. Draw a labelled diagram to show the set-up involved and how ammonia gas is collected.

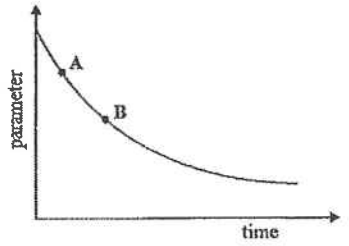
(2 marks)

DSE18_11

Consider the following reaction:

$$Br_2(aq) + HCO_2H(aq) \longrightarrow 2HBr(aq) + CO_2(g)$$

In an experiment to study the rate of consumption of $Br_2(aq)$, equal volumes of 0.01 M $Br_2(aq)$ and 1.0 M $HCO_2H(aq)$ were mixed. The progress of the reaction was followed by measuring a certain parameter of the reaction system using a colorimeter. The graph below shows the results from the start of the reaction.



(a) Assume that the rate of change of the parameter with time can represent the rate of reaction.

(i) According to the shape of the curve above, suggest what the parameter should be.

(1 mark)

(ii) The initial rate of the reaction can be determined by a suitable sketch on the above graph. Draw the suitable sketch on the above graph, and describe how the initial rate of the reaction can be obtained from the sketch.

(2 marks)

(iii) According to the graph above, the rate of reaction at A is higher than that at B. Explain this at molecular level.

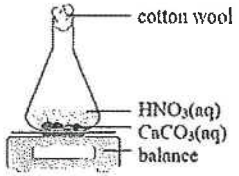
(2 marks)

(b) Suggest another method that can follow the progress of the reaction.

(1 mark)

DSE19_11

Two trials of an experiment were performed using the set-up below to study the reaction between nitric acid and calcium carbonate. A gas was formed in the reaction.



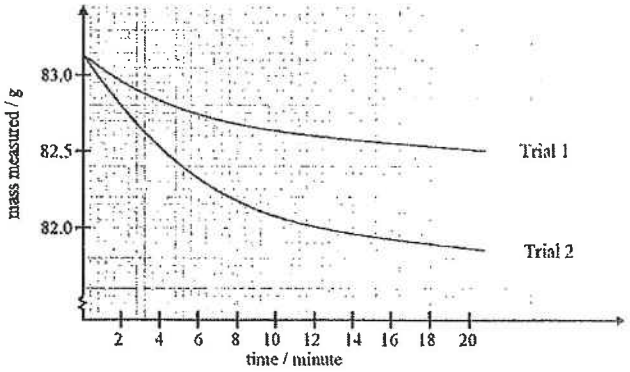
The chemicals used are listed in the table below while other experimental conditions were the same.

Trial	Mass of $CaCO_3(s)$ added / g	Volume of 3.0 M $HNO_3(aq)$ added / cm^3	Volume of $H_2O(l)$ added / cm^3
1	3.0	10.0	20.0
2	3.0	20.0	10.0

(a) Write the chemical equation for the reaction between nitric acid and calcium carbonate.

(1 mark)

(b)



(i) Calculate the average rate of formation of the gas from the 2nd minute to the 12th minute for Trial 2.

(2 marks)

(ii) Explain ONE difference in the shape of the curves for Trial 1 and Trial 2.

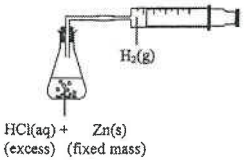
(2 marks)

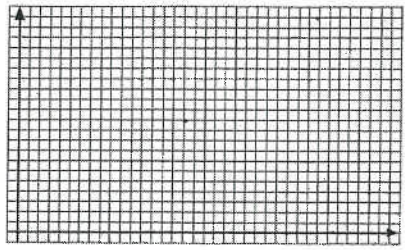
(c) Suggest how the effect of surface area of solid reactant on the rate of reaction can be studied using the above set-up.

(1 mark)

DSE20_13 *13. With reference to the set-up shown below, describe how the effect of concentration of HCl(aq) on the rate of the reaction can be studied. Your answer should include **TWO** labelled curves sketched on the graph below, one using **solid line** and the other one using **dotted line**. Label all curves and axes.

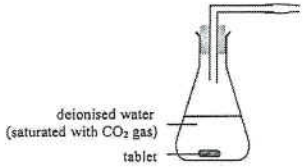
(6 marks)





DSE21_10 10. A tablet contains solid sodium hydrogencarbonate and solid citric acid (water soluble). An experiment was performed under room conditions to study the rate of formation of CO_2 gas when the tablet was placed in deionised water.

(a) The diagram below shows an incomplete set-up for the experiment :

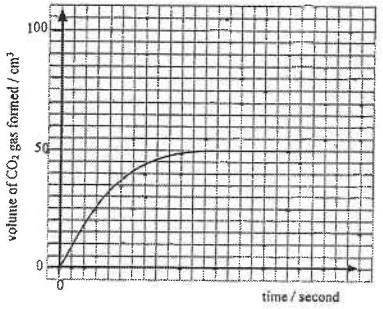


(i) Explain why the deionised water used should be saturated with CO_2 gas before the start of the experiment.

(ii) Add suitable drawing (with label) to the above diagram to show how the volume of the CO_2 gas formed can be measured.

(2 marks)

10. (b) (i) The graph below shows the variation of the volume of CO_2 gas formed with time for the experiment :



Assuming that citric acid was in excess and no other substances reacted with sodium hydrogencarbonate, calculate the mass of sodium hydrogencarbonate in the tablet.
(Molar masses : sodium hydrogencarbonate = 84.0 g, citric acid = 192.0 g;
Molar volume of gas at room conditions = 24 dm^3)

(ii) Sketch another curve (using **dotted line**) on the above graph to show the expected experimental result if the tablet is ground into a powder, with all other experimental conditions remaining unchanged.

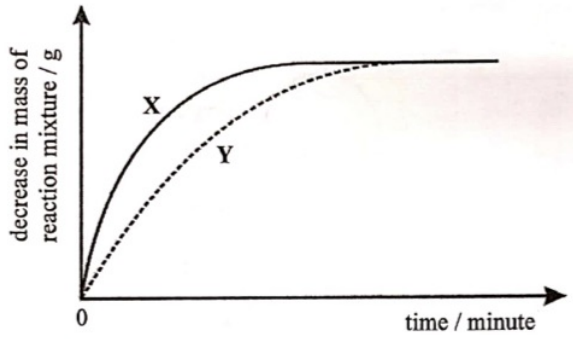
(3 marks)

25. A mixture consists of methane and ethane. 50 cm^3 of this mixture completely burns in oxygen to form 80 cm^3 of carbon dioxide at room conditions. What is the volume of methane in this mixture at room conditions ?

(Molar volume of gas at room conditions = 24 dm^3)

A. 10 cm^3
B. 20 cm^3
C. 30 cm^3
D. 40 cm^3

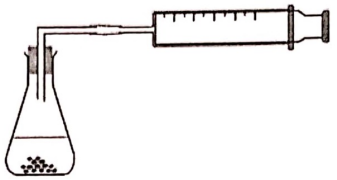
26. 50 cm^3 of 0.10 M HCl(aq) reacts with excess calcium carbonate powder in an open conical flask giving curve **X** in the graph below.



Which of the following changes may give curve **Y** ?

A. Increase the temperature by 10 °C.
B. Use 25 cm^3 of 0.10 M HCl(aq) instead of 50 cm^3 of 0.10 M HCl(aq).
C. Use 50 cm^3 of 0.05 M HCl(aq) instead of 50 cm^3 of 0.10 M HCl(aq).
D. Use the same mass of calcium carbonate granules instead of calcium carbonate powder.

31. Consider the experimental set-up shown below :

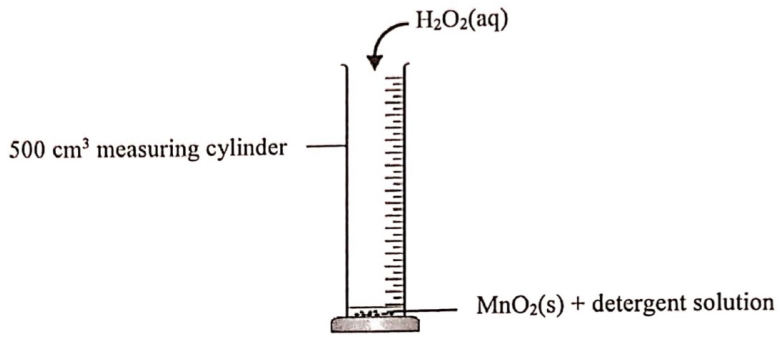


Under room conditions, which of the following pairs of reactants can the progress of their reaction be followed by the above set-up ?

(1) $Zn(OH)_2(s)$ and $HNO_3(aq)$
(2) Mg(s) and HCl(aq)
(3) KBr(s) and $Cl_2(aq)$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

10. At room conditions, $H_2O_2(aq)$ would decompose into $O_2(g)$ and $H_2O(l)$ very slowly in the absence of $MnO_2(s)$. An experiment was performed as shown in the set-up below :



When 10.0 cm^3 of 3.00 M $H_2O_2(aq)$ was mixed with a small amount of $MnO_2(s)$ and detergent solution at room conditions, $O_2(g)$ started to be released rapidly and foam was produced. The $MnO_2(s)$ remained chemically unchanged at the end of the reaction.

(a) Write a chemical equation for the decomposition of $H_2O_2(aq)$.

10. (c) Upon completion of the reaction, all the $H_2O_2(aq)$ was used up. Calculate the theoretical volume of $O_2(g)$ released at room conditions.
(Molar volume of gas at room conditions = 24 dm^3)

(2 marks)

(d) In the experiment, the time taken for the foam to rise from the mark at 100 cm^3 to the mark at 200 cm^3 of the measuring cylinder was 18 seconds, while the time taken for the foam to rise from the mark at 200 cm^3 to the mark at 300 cm^3 was 63 seconds. Explain these results.

Section C Analytical Chemistry

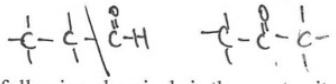
Answer **ALL** parts of the question.

3. (a) Answer the following short questions :

(i) Suggest a chemical test to show how $SO_2(g)$ and $CO_2(g)$ can be distinguished.

(2 marks)

(ii) Illustrate how $CH_3CH_2CHO(l)$ and $CH_3COCH_3(l)$ can be distinguished from their respective mass spectra.



(2 marks)

(iii) Which one of the following chemicals is the most suitable for drying ethyl butanoate ?

concentrated sulphuric acid, solid sodium hydroxide, anhydrous sodium sulphate

(1 mark)

(b) A solid sample consists of a compound **Y** and a small amount of an impurity **Z**. The following steps were performed in an experiment to obtain pure **Y**(s) from this solid sample.
(Given : **Y** is more soluble in deionised water at 80 °C than at 25 °C.)

Step (1) : 1.40 g of this solid sample was added to 50 cm^3 of deionised water and heated to 80 °C.
Step (2) : Water-insoluble activated charcoal was then added to remove **Z**. The mixture obtained was filtered when it was still hot.
Step (3) : The hot filtrate obtained was allowed to cool slowly to 25 °C. **Y**(s) was formed.
Step (4) : The cooled mixture was filtered to collect **Y**(s). After washing and drying, 0.75 g of **Y**(s) was collected.

(i) It is given that no more than 3.04 g of **Y**(s) can dissolve in 100 cm^3 of deionised water at 80 °C. Show, by calculation, that all of **Y** in this solid sample should have dissolved in Step (1).

(1 mark)

(ii) Explain why the mixture was filtered in Step (2).

(1 mark)

(iii) Name the process of the formation of **Y**(s) in Step (3).

(1 mark)

(iv) Suggest one reason why the mass of **Y**(s) collected in Step (4) was smaller than the mass of **Y** in this solid sample.

(1 mark)

(v) **Y** and **Z** can be separated by chromatography. Thin layer chromatography (TLC) and column chromatography were performed separately with this solid sample using the same stationary phase and mobile phase.
(Given : R_f value of **Y** is greater than that of **Z**.)

(1) Sketch a labelled chromatogram of TLC to show the expected result.

(2) Explain whether the first-collected fraction in the column chromatography is **Y** or **Z**.

(3 marks)

Marking Scheme

MCQ

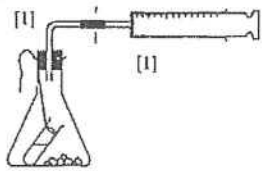
CE90_08	A	CE90_11	A	CE91_03	C	CE91_32	B
CE93_09	B	CE94_47	C	CE95_31	D	CE96_11	B
CE96_19	C	CE96_32	B	CE97_17	C	CE97_34	B
CE98_28	B	CE98_46	C	CE99_16	D	CE01_10	C
CE01_27	B	CE01_33	C	CE02_16	B	CE03_06	B (63%)
CE03_20	A (41%)	CE05SP_38	B	CE05SP_50	C	CE04_03	A (35%)
CE04_06	C (58%)	CE05_35	C (68%)	CE05_44	A (52%)	CE06_41	B (57%)
CE06_50	C (54%)	CE07_39	A (42%)	CE07_40	A (43%)	CE08_32	A (32%)
CE08_50	B (24%)	CE08_39	D (54%)	CE09_33	A (51%)	CE09_40	C (60%)
CE09_43	B (49%)	CE10_37	B (67%)	CE10_46	B (51%)	CE11_33	C (65%)
CE11_45	D (72%)	DSE11SP_25	A	DSE11SP_32	B	DSE11SP_33	C
DSE12PP_07	B	DSE12PP_25	A	DSE12PP_29	C	DSE12PP_32	B
DSE12_25	A (69%)	DSE13_25	D (79%)	DSE13_33	B (81%)	DSE14_25	A (73%)
DSE15_28	D (78%)	DSE15_36	C (60%)	DSE16_25	C (77%)	DSE16_33	D (72%)
DSE16_34	B (77%)	DSE17_27	C (73%)	DSE17_28	D (57%)	DSE18_25	D (76%)
DSE18_33	A (58%)	DSE18_36	C (65%)	DSE19_34	D	DSE19_35	B

DSE20_25 C
DSE20_35 A

Structural Questions

CE90_02b

(i) [1] [1] [2]



(ii) at X, the rate is faster. Concentration of acid for reaction is higher and the mass of calcium carbonate is larger. [1]

OR, at Y, the rate is slower. All the calcium carbonate is used up and the reaction stops.

(iii) More carbon dioxide gas is collected from B (120 cm^3) than from A (96 cm^3) [1]
thus sample B has a higher purity (or less impurities) than sample A [1]
The initial rate of sample A is greater than that of sample B (steeper slope for A than B) [1]
thus more surface area / smaller particle size in A than in B [1]

(iv) (1) volume of CO_2 = 120 cm^3 [1]

(2) $CaCO_3 + 2HCl \longrightarrow CO_2 + H_2O + CaCl_2$

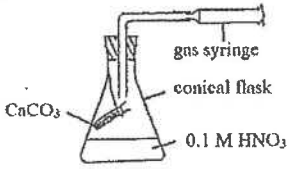
$$\text{mole of } CaCO_3 = \text{moles of } CO_2 = \frac{0.12}{24} = 0.005$$ [1]

mass of $CaCO_3 = 0.005 \times (40 + 12 + 16 \times 3) = 0.5$ g [1]

$$\%\text{ of } CaCO_3 = \frac{0.5}{0.8} \times 100\% = 62.5\%$$ [1]

CE92_02c

(i) [2]



(ii) $CaCO_3 + 2HNO_3 \longrightarrow CO_2 + H_2O + Ca(NO_3)_2$

$$\text{moles of } CaCO_3 = \frac{0.1}{40 + 12 + 16 \times 3} = 0.01$$

$$\text{moles of } HNO_3 = 0.1 \times \frac{50}{1000} = 0.005$$ [1]

0.005 mole of HNO_3 can only react 0.0025 mole $CaCO_3$, so $CaCO_3$ is in excess.
mole of $CaCO_3$ reacted = mole of CO_2 formed = 0.0025 mole [1]
volume of $CO_2 = 0.0025 \times 24 = 0.06$ dm^3 or 60 cm^3 [1]

(iii) The actual volume of CO_2 formed is smaller than the theoretical volume because some CO_2 formed dissolves in water. [1]

CE92_03b

(i) 8 electrons [1]

(ii) Neon has a stable octet structure with 8 outermost shell electrons. [1]

(iii) Isotopes are atoms with same number of protons but different number of neutrons. [1]

(iv) (1) $\text{Relative atomic mass of Ne} = \frac{20 \times 90.52 + 21 \times 0.31 + 22 \times 9.17}{100} = 20.19$ [2]

(2) $\text{Density of Ne gas} = \frac{20.19}{24} = 0.84\ \text{g dm}^{-3}$ [2]

CE92_05a

(i) B is the cathode because reduction occurs at B, $2H^+ + 2e^- \longrightarrow H_2$ [1]

(ii) Cathode (B) attracts Na^+ and H^+ ions. [1]

H^+ is preferentially discharged because H is in a lower position than Na in the electrochemical series. [1]

Anode (A) attracts Cl^- and OH^- ions. [1]

Cl^- is preferentially discharged because the concentration of Cl^- is high. [1]

Finally, as H^+ and Cl^- are preferentially discharged, Na^+ and OH^- are left. [1]

(iii)

Oxidation:	$2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$
Reduction:	$2e^- + 2H^+(aq) \longrightarrow H_2(g)$
Overall:	$2Cl^-(aq) + 2H^+(aq) \longrightarrow Cl_2(g) + H_2(g)$

When 1 mole H_2 if formed, 2 moles of Cl^- is used.

$\text{moles of NaCl used} = \frac{234}{23 + 35.5} = 4$ [1]

$\text{moles of } H_2 \text{ formed} = \frac{4}{2} = 2$ [1]

$\text{volume of } H_2 \text{ formed} = 2 \times 2.4 = 48\ \text{dm}^3$ [1]

CE93_04b

(i) $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$ [1]

(ii) 1 mole $CaCO_3$ gives 1 mole of CO_2

$\text{moles of } CO_2 \text{ formed} = \frac{67 \times 10^{-3}}{24} = 0.0028$ [1]

$\text{mass of } CaCO_3 = 0.0028 \times (40 + 12 + 16 \times 3) = 0.028\ \text{g}$ [1]

$\%\text{ mass of } CaCO_3 \text{ in egg shell} = \frac{0.28}{0.3} \times 100\% = 93\%$ [1]

(iii) method: crush the egg shell into small piece [1]

reason: to increase the reacting surface area [1]

method: heating [1]

reason: heating can increase the energy of the particles of reactants [1]

CE94_08a

(i) $2H_2O_2 \longrightarrow 2H_2O + O_2$ [1]

(ii) The rate of decomposition of H_2O_2 in descending order is A > B > C.

The rate of decomposition depends on the concentration of H_2O_2.

The concentration of H_2O_2 is highest at A, so the rate of decomposition is the fastest. [1]

At C, all the H_2O_2 are used up, the reaction stops. [1]

(iii) $\text{moles of } O_2 = \frac{84 \times 10^{-3}}{24} = 0.0035$ [1]

$\text{moles of } H_2O_2 = 0.0035 \times 2 = 0.0070$ [1]

$[H_2O_2] = \frac{0.007}{50 \times 10^{-3}} = 0.14\ \text{M}$ [1]

(iv) No, the slope of the curve will increase

As MnO_2 is a catalyst [1]

powdered MnO_2 increase the surface area of catalyst that can increase the rate of reaction. [1]

CE95_07a

(i) Citric acid / vitamin C (ascorbic acid) when dissolves in water gives $H^+(aq)$ [1]

which reacts with calcium carbonate to give gas (CO_2) bubbles. [1]

$CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + CO_2 + H_2O$ [1]

(ii) (1) $CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + CO_2 + H_2O$

no. of moles of CO_2 evolved = no. of moles of $CaCO_3$ present [1]

$\text{moles of } CaCO_3 \text{ present} = \frac{625 \times 10^{-3}}{100} = 6.25 \times 10^{-3}$ [1]

[1]

Theoretical volume of gas = $6.25 \times 10^{-3} \times 24 = 0.15\ \text{dm}^3$ [1]

(2) Some of the CO_2 produced dissolved in water / CO_2 is (fairly) soluble in water. [1]

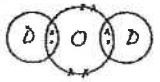
CE96_07a

(i) isotope [1]

(ii) One / 1 [1]

(iii) (1) H and D have the same electronic structure (or electronic arrangement). [1]

(DO NOT accept H and D have same no. of electrons in their outermost shells)

(2)  [1]

(3) The reaction is exothermic / gives out heat / release energy [1]

(4) Formula mass = 2 + 2 + 16 = 20 [1]

(5) $2D_2(g) + O_2(g) \longrightarrow 2D_2O(l)$

In the mixture, no. of moles of D_2 = no. of moles of O_2

$\text{moles of } D_2 = \frac{100 \times 10^{-3}}{24} = 0.004167$ [1]

O_2 is in excess, no. of moles of D_2O produced = 0.004167 mole

mass of D_2O produced = $0.004167 \times 20 = 0.0833\ \text{g}$ (0.083 – 0.084 g) [2]

CE00_09a

(i) Reactivity: Y < Z < X [1]

Y is the least reactive because only the oxide of Y decomposes on heating and the oxides of X and Z are stable to heat. [1]

X is the most reactive metal because only X can react with water but Y and Z do not react with water. [1]

(ii) $moles\ of\ O_2\ produced = \frac{60 \times 10^{-3}}{24} = 2.5 \times 10^{-3}$ [1]

$2YO \longrightarrow 2Y + O_2$

$moles\ of\ YO\ heated = \frac{2.5 \times 10^{-3}}{2} = 1.25 \times 10^{-3}$

$1.25 \times 10^{-3} = \frac{mass}{molar\ mass\ of\ YO} = \frac{1.08}{atomic\ mass\ of\ Y + 16}$ [1]

So, relative atomic mass of Y = 200 [1]

CE03_06a

(i) $2NH_4Cl + CaO \longrightarrow CaCl_2 + H_2O + 2NH_3$ [1]

(ii) The water vapour produced will condense near the mouth of the test tube. [1]

The test tube will crack when the cold water flows back to the hot test tube. [1]

(iii) (II) should be used [1]

Ammonia is less dense than air [1]

and is very soluble in water. [1]

(iv) $2NH_4Cl + CaO \longrightarrow CaCl_2 + H_2O + 2NH_3$ [1]

$moles\ of\ NH_4Cl = \frac{1}{53.5} = 0.01869$ [1]

$Theoretical\ volume\ of\ NH_3(g) = 0.01869 \times 24 = 0.45\ dm^3$ [1]

CE04_08a

(i) $CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ [1]

OR, $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

(ii) (1) $moles\ of\ CO_2\ collected = \frac{78 \times 10^{-3}}{24} = 3.25 \times 10^{-3}$ [2]

(2) $mass\ of\ CaCO_3\ in\ the\ sample = 3.25 \times 10^{-3} \times 100 = 0.325\ g$ [1]

$\%\ by\ mass\ of\ CaCO_3 = \frac{0.325}{0.36} \times 100\% = 90.27\%$ [2]

(iii) Any ONE of the following: [1]

- the sample of coral contains other substances which react with HCl(aq) to liberate a gas
- some $CO_2(g)$ dissolves in water

CE06_12

Chemical knowledge [6]

Description of procedure (max. 4M)

Use sand paper to remove oxide layer on the magnesium ribbon.

Weigh the piece of magnesium ribbon in grams (w).

Put the piece of magnesium ribbon in a conical flask connected to a gas syringe.

Add 2M hydrochloric acid to the Mg ribbon until in excess.

Collect the hydrogen gas liberated using the syringe.

Measure the volume of $H_2(g)$ collected ($v\ cm^3$).

Treatment of data

$Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$

Molar volume of $H_2(g)$

$= \frac{v}{w} \times$ molar mass of Mg (cm^3)

Effective communication [3]

CE09_10

(a) (i) catalyst / increase the rate of the reaction (decomposition). [1]

(ii) Gas evolved in the reaction. / Oxygen affects the pressure. [1]

(iii) $H_2O_2 \longrightarrow 2H_2O + O_2$ [1]

Oxidation number of hydrogen remains unchanged. [1]

Oxidation number of oxygen (increases) from -1 to 0, [1]

and (decreases) from -1 to -2.

(b) (i) At A: The rate of reaction is high because the concentration of H_2O_2 is high. [1]

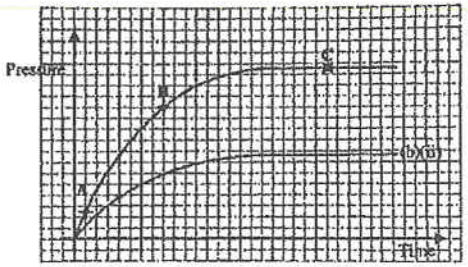
At B: The rate of reaction decreases because the concentration of H_2O_2 decreases during reaction. [1]

At C: The reaction stops because all the H_2O_2 has been used up. [1]

(ii) Curve: [1]

The slope of curve is smaller.

The value at the end of the curve is about half the original one.



AL09(I)_07

Any TWO of the following: [2]

Lower the temperature of the sample of reaction mixture removed by immersing it in ice/ice-salt mixture.

Dilute the sample with water / an appropriate solvent.

Remove one of the reactant/catalyst by adding an appropriate quenching agent.

ASL09(II)_11

(a) $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$ [2]

(b) Allow $CO_2(g)$ to escape but prevent the splashing of hydrochloric acid out of the flask. [1]

(c) Draw a tangent line to the curve at point *N*. [1]

Determine the slope of the tangent line. [1]

(d) At the point *M* (beginning), the concentration (amount) of hydrochloric acid is the highest, and the reaction rate increases with the amount of acid. [1]

From point *M* to *N*, the concentration (amount) of hydrochloric acid decreases gradually, and the reaction rate also decreases with decreasing concentration of acid. [1]

At point *P*, all acid is used up and the reaction stop. ∴ reaction rate drops to zero. [1]

(e) Slope of curve: smaller [1]

Maximum height of the curve: reduced by half

ASL00(II)_07

(a) $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$

Mole of HCl used = $1 \times 15 \times 10^{-3} = 0.015$ [1]

Mole of Mg used = $\frac{0.12}{24.3} = 4.94 \times 10^{-3}$ [1]

Since mole ratio of Mg to HCl is 1 : 2, Mg is a limiting reagent.

(b) (i) Acid is firstly used to dissolve the oxide layer on magnesium, and no H_2 gas forms at the beginning. [1]

$MgO(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2O(l)$

Once MgO layer is removed, acid starts to react to Mg to give H_2 gas and build up the pressure. [1]

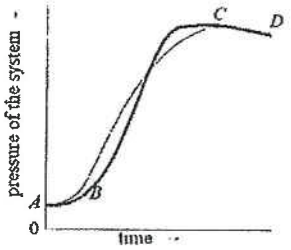
$Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$

(ii) Acid reacts with Mg to give H_2 gas and the reaction rate decreases with time as the concentration of acid gradually decreases. Hence, the increases in pressure gradually decrease till point *C*. [1]

(iii) When the Mg ribbon is completely used, no more H_2 gas formed, and the pressure of the system reaches the maximum. [1]

Reaction stops and solution cools down to the room temperature. Volume of H_2 gas shrinks and reduces the pressure. [1]

(c)



[2]

Similar shape of the curve.

Higher rate from *B* to *C*

Same level of maximum pressure built in the system.

Explanation:

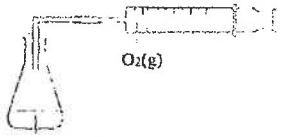
As the concentration of hydrochloric acid used increases from 1.0 M to 2.0 M, which turns to increase in the reaction rate at the beginning. [1]

As the mass of magnesium ribbon remains unchanged and Mg is a limiting reagent, there is no change in the total amount of H_2 gas formation. [1]

∴ pressure reaches the same level earlier, as the one using 1.0 M hydrochloric acid.

ASL01(II)_07

(a)



[2]

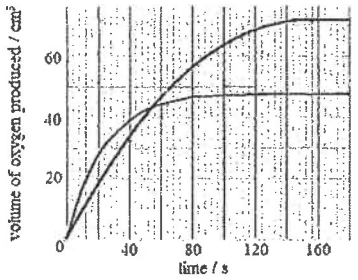
$H_2O_2(aq)$ + catalyst

(b) At the beginning, $H_2O_2(aq)$ has the highest concentration, and the reaction rate reaches the maximum. [1]

As time goes by, the reaction rate decreases as the concentration of $H_2O_2(aq)$ decreases with time. [1]

The reaction stops when all $H_2O_2(aq)$ are used up. No more O_2 gas produces after 120th second. [1]

(c) [1]



Lower reaction rate

Maximum reaches 72 cm^3

(d) Manganese(IV) oxide / MnO_2 / potassium iodide / KI [1]

ASL02(II)_11

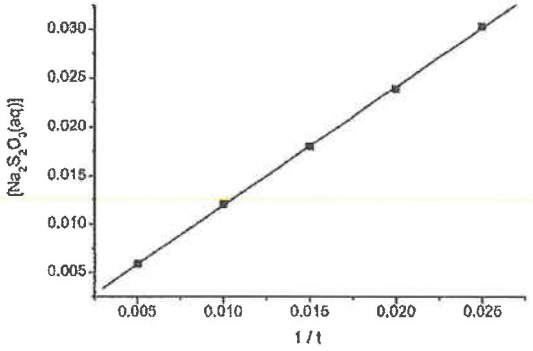
(a) (i) To keep the same total volume of solution in different trial. [1]

(ii) Cross is masked by sufficient amount of suspended sulphur particle formed in the reaction. [1]

(b)

Experiment	$[Na_2S_2O_3(aq)]$	$1/t$
1	0.005	0.00588
2	0.010	0.0120
3	0.015	0.0179
4	0.020	0.0238
5	0.025	0.0303

[1]



[2]

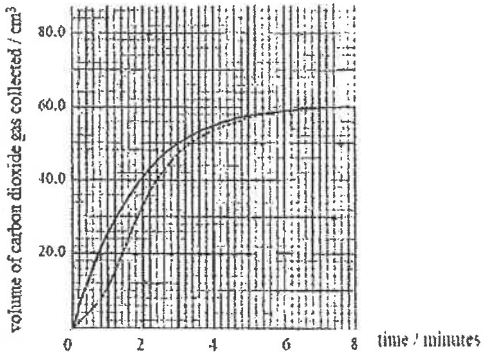
(c) A straight line passing those the original of the graph. It shows that the reaction rate $(1/t)$ is inversely proportional to the concentration of $Na_2S_2O_3(aq)$. [1]

(d) 28 sec [1]

ASL03(II)_10

(a) (i) Add a suitable amount of marble chips to the acid until the acid is saturated with dissolved CO_2. [1]

(ii)



[1]

(b) (i) Draw a tangent line to the curve at the particular time. [1]

Determine the slope of the tangent line. [1]

(ii) HCl is consumed during the reaction. ∴ The concentration of hydrochloric acid in the mixture drops during the course of the reaction. [1]

(c) (i) The rate increases because powdered $CaCO_3(s)$ has greater surface area. [1]

(ii) The rate decreases because CH_3COOH is a weak acid and hence the solution contains a lower concentration of $H^+(aq)$ ions. [1]

ASL04(I)_05

(a) Propane-1,2,3-triol [1]

(b) (i) $4C_3H_5N_3O_9(l) \longrightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$ [1]

(ii) ∵ water vapor condenses back to liquid at 298 K.

∴ 1 mole of nitroglycerin gives 4.75 moles of gaseous product after cooling.

Mole of trinitroglycerine $= \frac{1}{227} = 4.41 \times 10^{-3}$ [1]

Volume of gases left behind

$= 4.41 \times 10^{-3} \times 4.75 \times 24 = 0.502\ dm^3 = 502\ cm^3$ [1]

(iii) $4C_3H_5N_3O_9(l) \longrightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$

$4\Delta H^\circ_{rxn} = 12\Delta H^\circ_f[CO_2(g)] + 10\Delta H^\circ_f[H_2O(g)] - 4\Delta H^\circ_f[C_3H_5N_3O_9(l)]$

$4\Delta H^\circ_{rxn} = 12(-394) + 10(-242) - 4(-364)$ [1]

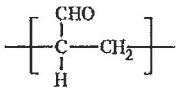
$\Delta H^\circ_{rxn} = -1423\ kJ\ mol^{-1}$ [1]

(iv) Any TWO of the following: [2]

- The decomposition of trinitroglycerine is highly exothermic.
- The decomposition of trinitroglycerine is very rapid.
- It is a chain reaction with low activation energy.
- Trinitroglycerine contains a hydrocarbon chain which is combustible and NO_2 groups which are oxidizing groups.

(c) (i) Shake the sample with acidified $KMnO_4(aq)$, presence of acrolein can decoloize purple color of $KMnO_4(aq)$. [1]

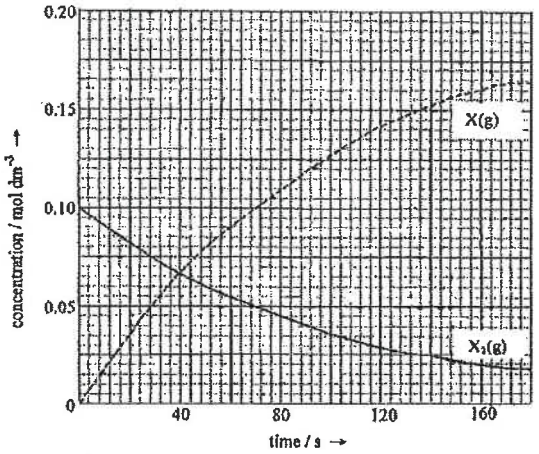
OR, Shake with Tollen's reagent, presence of acrolein can form a silver mirror. [1]

(ii)  [1]

ASL05(II)_08

(a) Change in concentration = $0.100 - 0.067 = 0.033$ mol dm^{-3} [1]

Average rate $= \frac{0.033}{40} = 8.25 \times 10^{-4}$ mol dm^{-3} s^{-1} [1]

(b) 

[2]

(c) The kinetic energy of molecules increases with temperature. [1]

At a higher temperature, the percentage of molecules with K.E. greater than the activation energy increases. [1]

∴ rate of decomposition increases

ASL06(I)_07

(a) Increase, because there is an increase in the total surface area for the contact of reactants. [1]

(b) Decrease, because 2 M ethanoic acid solution has a smaller concentration of $H^+(aq)$ than 2 M hydrochloric acid. [1]

(c) Increase, because higher temperature leads to an increase in the fraction of reactant particles with energy not less than the activation energy / in effective collision frequency. [1]

ASL06(II)_10

(a) rate of consumption of $O_2 = \frac{5}{4}(1.24 \times 10^{-4})$ mol dm^{-3} s^{-1} [1]

$= 1.55 \times 10^{-4}$ mol dm^{-3} s^{-1} [1]

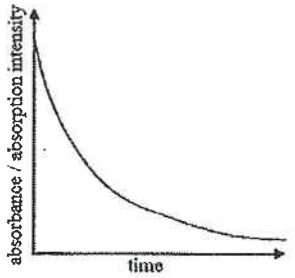
(b) Catalyst is a substance which can change the rate of reaction but itself remains chemically unchanged after the reaction. [1]

(c) Nitric acid / nitrogenous fertilizers, etc. [1]

ASL08(I)_07

(a) Colorimeter [1]

(b) Absorbance [1]

(c) 

[1]

AL08(I)_08a

(i) The polymerization is an exothermic reaction. [1]

A lot of heat is evolved at the initial stage of the reaction as the concentration of the monomer is high and the rate of reaction is fast. [½]

When the reaction has proceeded from some time, the chain of polymer grows and the viscosity of the reaction mixture increases. Rate of reaction decreases. [½]

OR, Reaction stops at the end and heat is lost to surrounding.

(ii) NaOH(aq) can catalyze the polymerization better than $H_2O(l)$. [1]

ASL10(I)_02

Accept both 'yes' and 'no' answers. Mark will be awarded only to the elaboration.

The rate of reaction depends on the collision frequency of the reactant molecules. [½]

Only those colliding molecules with KE greater than activation energy (E_a) of the reaction can react. [1]

When temperature increases, average KE of molecules increases. [½]

Chance of collision between molecules increases and, more importantly, a greater percentage of colliding molecules has KE> E_a [1]

AL10(II)_02b

(i) $2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$ [1]

(ii) (I) Colorimetry [1]

(II) The reaction of $MnO_4^-(aq)$ with $C_2O_4^{2-}(aq)$ is slow possibly because both $MnO_4^-(aq)$ and $C_2O_4^{2-}(aq)$ are negatively charged (repulsion) / the reaction involves breaking the strong non-polar C–C bond. [1]

It is likely that one of the products ($Mn^{2+}(aq)$) is a catalyst for the reaction (autocatalysis). [1]

The rate of reaction is slow at the beginning because of the low concentration of $Mn^{2+}(aq)$. When $[Mn^{2+}(aq)]$ builds up, the reaction will proceed rapidly. When $MnO_4^-(aq)$ ions are almost used up, the rate slows down. [1]

DSE11SP_10

(a) From the curve, 1 mole of P(g) reacts with 2 moles of Q(g) to give 1 mole of R(g). [1]

$P(g) + 2Q(g) \longrightarrow R(g)$ [1]

(b) The time required will become longer.

In a larger container, the concentrations of reactants become less and hence the collision frequency decreases. [1]

(c) Colliding molecules will undergo reaction only if they possess an energy greater than the activation energy and collide in the right orientation. [1]

DSE12PP_10

(a) Colorimetry / using colorimeter [1]

(b) (i) The rate of consumption of $MnO_4^-(aq)$ ions is slow at the beginning (from 0 to 180 s) and then increases rapidly (from 200 to 340 s). [1]

It is likely to be due to the building up of the concentration of the products which catalyzes the reaction. [1]

(ii) Repeat the experiment with a few drops of $Mn^{2+}(aq)$ firstly added to the reaction mixture. [1]

Consumption of $MnO_4^-(aq)$ ions will be faster at the beginning if $Mn^{2+}(aq)$ is a catalyst. [1]

DSE12_II

(a) Initial rate $= \frac{60}{4} = 15\ cm^3/min\ (0.25cm^3/s)$ (Accept 14.8 - 15.2) [1]

(b) **HCl is a monobasic acid, while H_2SO_4 is a dibasic acid. Initial rate increases if H_2SO_4 is used. / Initial rate increases as the concentration of H^+ increases in 2.0 M H_2SO_4.** [1]

Therefore, the frequency of effective collisions increases.

(c) Mole of Zn $= \frac{2}{65.4} = 0.0306$ [1]

Vol of H_2 formed $= 0.0306 \times 24000$ [1]

$= 734\ cm^3$ / $0.734\ dm^3$ (Accept 730 – 744 cm^3 / 0.73 – 0.74 dm^3) [1]

DSE13_II

(a) The airbag has to be inflated instantly when a car crash occurs.

Fine powder can greatly increase the reaction rate / can give a fast reaction by providing a (very) large surface area for a reaction involving solid reactants. [1]

(b) Reaction 1:

Mole of N_2 produced from the decomposition of $NaN_3 = \frac{100}{65} \times \frac{3}{2} = 2.31$ [1]

Reaction 2:

Moles of Na produced $= \frac{100}{65} = 1.54$

Moles of KNH_3 produced $= \frac{200}{101.1} = 1.98$

Since 5 mol of Na react with 1 mol of KNO_3, KNO_3 is in excess

No. of mole of N_2 produced from reaction 2 $= \frac{100}{65} \times \frac{1}{10} = 0.154$ [1]

Volume of gas produced $= (2.31 + 0.154) \times 24 = 59.1\ dm^3$ [1]

Accept: 58.8 – 59.2 dm^3

(c) KNO_3 is added to react with sodium which is (highly) reactive / corrosive / flammable / strongly reducing. [1]

(d) (i) $\frac{0.01 - 0.005}{10} = 0.0005\ mol\ dm^{-3}s^{-1}$ $(5.0 \times 10^{-4}\ mol\ dm^{-3}s^{-1})$ [1]

(Accept 0.0005 M s^{-1} / 0.03 mol dm^{-3} min^{-1} / 1.8 mol dm^{-3} hr^{-1})

(ii) Determine the slope of the tangent of curve at t = 10 s. [1]

DSE14_10

- Proper way to follow the progress of the reaction (e.g. measure the volume of CO_2 evolved / measure the loss in mass of the reaction mixture over a certain time interval / measure the pressure of the CO_2 formed in a sealed reaction vessels.) (accept graphical representation) [1]
- Dilute 1M HCl to different concentrations by adding water. [1]
- Repeat the experiment with dilute HCl. [1]
- State one requirement for carrying out fair comparison (e.g. $CaCO_3$ used should be of the same amount / under same experimental conditions such as same temperature or pressure) [1]
- Communication mark [1]

DSE15_09

(a) Save cost (on chemicals) / minimize (chemical) hazards / save time on carrying out experiment / reduce the consumption of chemicals / reduce chemical waste. [1]

(b) Prevent sucking back of water / prevent water from entering the reacting flask. [1]

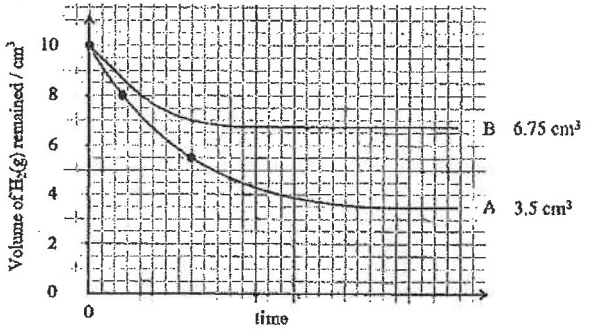
(c) Water level inside the measuring cylinder rises / The gas volume inside the measuring cylinder reduces. [1]

(d) Mole of methyl oleate use $= \frac{0.08}{298} = 2.70 \times 10^{-4}$ [1]

Minimum volume of $H_2(g)$ required $= 2.70 \times 10^{-4} \times 24\ dm^3$ [1]

$= 6.49\ dm^3$ [1]

(e) (i), (ii)



[2]

DSE16_11

(a) To ensure fair comparisons between the trials. [1]

OR, To ensure the concentration of NaOH(aq) / reactant is the only variable.

OR, The volume of NaOH(aq) used can represent the concentration of NaOH(aq) / reactant in the reaction mixtures.

(Not accept if the answer is expressed in terms of "amount of NaOH(aq)")

(b) $[OH^-(aq)] = 2.0 \times (4.0/5.0) = 1.6\ mol\ dm^{-3}$ [1]

$pH = 14 - (-\log[OH^-(aq)])$

$= 14 - (-\log(1.6)) = 14.20$ [1]

(c) The concentration of NaOH(aq) [1]

The shorter the time for the (pink) color disappeared, the faster the reaction. An increase in concentration of NaOH(aq) (reactant) will result in an increase in the reaction rate. [1]

(d) Using colorimeter / measuring relative transmittance / absorbance of the mixture / spectrophotometer [1]

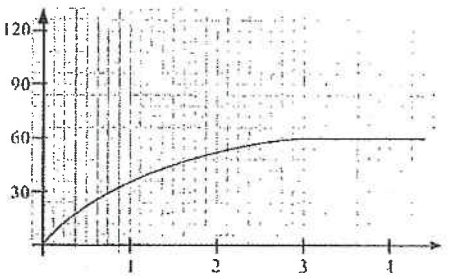
DSE17_10

(a) $\frac{60}{24000} \times 2 = 0.005y$ [1]

$y = 1.0\ mol\ dm^{-3}$ [1]

(Accept maximum 3 decimal places)

(b)



The curve starts from point (0, 0), the slope decreases and becomes a horizontal line at the 3rd minute. [1]

The total volume of gas obtained is 60 cm^3. [1]

(c) 60 cm^3 of gas would be collected because the number of moles of H_2O_2 is the same for both experiments. [1]

OR, 60 cm^3 of gas would be collected because increasing the temperature will only increase the rate of the reaction, but not affect the amount of product formed.

(Not accept ambiguous answer like "same amount of H_2O_2").

(d) Follow the change in (total) pressure / mass in the system. [1]

(Accept: monitor the system with a pressure gauge / an electronic balance.)

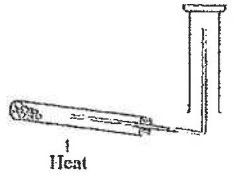
DSE18_02

(a) Set-up for preparation – boiling tube with reagents and HEAT (with stopper) [1]

(Accept heating the reagents in a flask)

Upward delivery of ammonia gas (without stopper) [1]

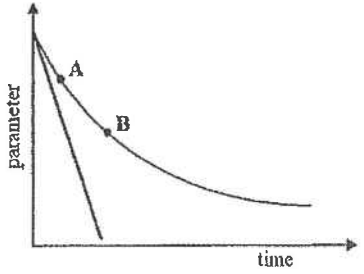
(Accept collecting the gas with a gas syringe.)



DSE18_I1

(a) (i) Color intensity / absorbance (Not accept transmittance) [1]

(ii) [1]



(On the graph) Plot a tangent (a straight line) at time = 0 on the curve.

The initial rate equals to the slope of the tangent / straight line. [1]

(iii) The absorbance is (directly) proportional to [Br_2(aq)] / number of Br_2 molecules in the reaction mixture. [1]

OR [Br_2(aq)] / number of Br_2 molecules in the reaction mixture at A is higher than that at B,

therefore the frequency of (effective) collisions between molecules at A is higher than that at B. [1]

(b) Any ONE of the followings: [1]

Measure the volume of CO_2 gas formed (at different time)

Measure the (total pressure) of the system (at different time). (the reaction proceeds in a closed system)

Measure the mass of the reaction mixture (at different time).

NOT accept measuring the pH of the reaction mixture

DSE19_I1

(a) $CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$ [1]

OR, $CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

(b) (i) $\frac{82.8 - 82.0}{12 - 2} = 0.08\ g\ min^{-1}$ $(or\ 1.33 \times 10^{-3}\ g\ s^{-1})$ [2]

Not accept 1.30×10^{-3} g s^{-1}, 1.3333×10^{-3} g s^{-1}, correct unit is required

(ii) • The slope / curvature (of the tangent) of the curve (at t=0) for Trial 2 is larger than that for Trial 1. [1]

• Showing a higher (initial) rate of reaction as the concentration of HNO_3 / H^+ in Trial 2 is higher than that in Trial 1. [1]

OR

• The decrease in mass for Trial 1 is smaller than that for Trial 2.

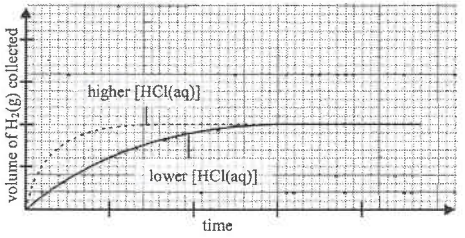
• In Trial 1 less CO_2 is given out because the number of moles of HNO_3 / H^+ used in Trial 1 is less than that in Trial 2.

(c) Use same mass of calcium carbonate of different sizes to perform the experiment. [1]

All other conditions of the experiment should be kept unchanged.

13. • Correct sketch of both curves (Correct shape of the curves, and the two curves merged at the later stage of the experiment) 1

• Correct labels for the two curves (The curve representing a higher concentration of HCl(aq) has a higher initial slope.), and correct labels of the graph (y-axis: volume of H_2(g) collected, x-axis: time) 1



(Any 3 points from below: 1 mark for each point) 3

• Measure the volume of H_2(g) formed at different time intervals (and plot a curve).

• The slope of the curve represents the rate of reaction.

• Repeat the experiment with different concentrations of HCl(aq).

• Fair comparison - other than concentration of HCl(aq), all other conditions should be the same. (or explicitly give at least one condition that have to be kept constant.)

• Communication mark 1

(Chemical knowledge = 0 to 3, communication mark = 0

Chemical knowledge = 4 to 5, communication mark = 0 or 1

Incomplete answer or difficult to understand, communication mark = 0)

SECTION 10 Chemical Equilibrium

Multiple-Choice Questions

ASL05(I)_01

In which of the following systems will the equilibrium position shifts to the left in response to an increase in pressure of the system?

A. $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

B. $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

C. $4Fe(s) + 3O_2(g) \rightleftharpoons 2Fe_2O_3(s)$

D. $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$

DSE11SP_29

Consider the following system at equilibrium:

$$A(g) + 2B(g) \rightleftharpoons 2C(g) \qquad \Delta H = +200 \text{ kJ mol}^{-1}$$

What would be the effect on the rates of the forward and backward reactions if the temperature of the system were lowered?

	Forward reaction rate	Backward reaction rate
A.	Decreases	Increases
B.	Decreases	No change
C.	Decreases	Decreases
D.	Increases	Decreases

DSE11SP_35

1st statement	2nd statement
Catalysts are used in many industrial processes.	Catalysts would not affect the percentage of the product in the equilibrium mixture.

DSE12PP_26

A mixture of $N_2O_4(g)$ and $NO_2(g)$ is allowed to attain equilibrium in a gas syringe at room temperature:

$N_2O_4(g)$	$\rightleftharpoons$	$2NO_2(g)$
Light brown		Dark brown

The gas mixture in the syringe is compressed rapidly. Which of the following statements correctly describes the expected observation?

A. The colour of the mixture becomes paler.

B. The colour of the mixture becomes darker.

C. The colour of the mixture becomes paler instantaneously and then darker.

D. The colour of the mixture becomes darker instantaneously and then paler.

DSE12PP_31

Which of the following is/are characteristic(s) of chemical equilibrium?

(1) When a catalyst is added to an equilibrium mixture, the equilibrium position changes.

(2) When equilibrium is attained, the rate of forward reaction and that of backward reaction are equal.

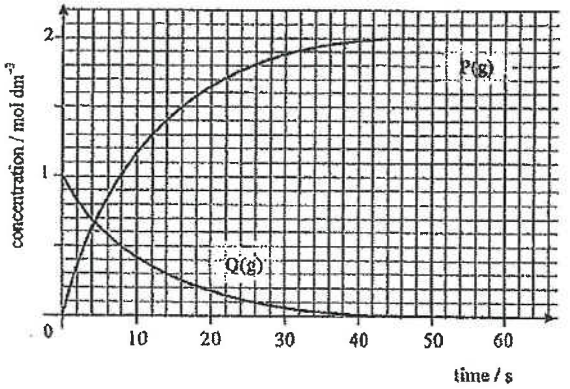
(3) Equilibrium can be attained from either direction of the reaction.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

DSE12_26

The concentration-time graph for a certain chemical reaction in a closed vessel of fixed volume is shown below:



Which of the following chemical equations correctly represents the reaction?

A. $P(g) \longrightarrow Q(g)$ B. $Q(g) \longrightarrow P(g)$

C. $P(g) \longrightarrow 2Q(g)$ D. $Q(g) \longrightarrow 2P(g)$

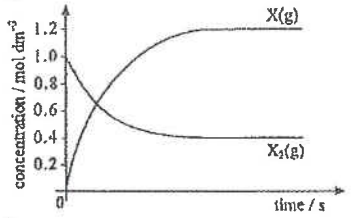
DSE12_27

In a 1 dm^3 closed container, 1 mole of $X_2(g)$ undergoes decomposition to form X(g) until equilibrium is attained. The chemical equation concerned is shown below:

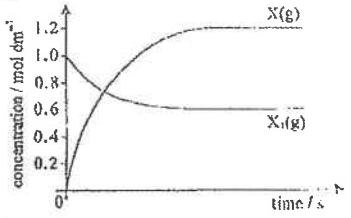
$$X_2(g) \rightleftharpoons 2X(g)$$

Which of the following graphs correctly shows the variation in concentration of $X_2(g)$ and X(g) with time?

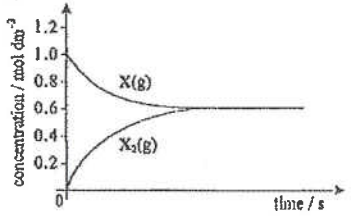
A.



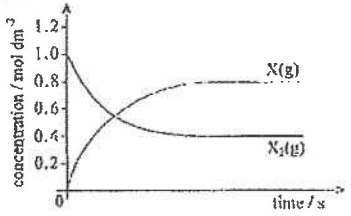
B.



C.



D.



DSE13_35

1st statement	2nd statement
Increasing reaction temperature can increase the yield for all reversible chemical reactions.	Increasing reaction temperature can shorten the time needed to attain equilibrium for all reversible chemical reactions.

DSE13_27

$$X_2(g) + 3Y_2(g) \rightleftharpoons 2XY_3(g)$$

A mixture of $X_2(g)$ and $Y_2(g)$ was introduced into a 2.0 dm^3 closed vessel kept at a fixed temperature. When the system attained equilibrium, the vessel contained 0.4 mol of $X_2(g)$, 0.3 mol of $Y_2(g)$ and 0.4 mol of $XY_3(g)$.

Which of the following is the numerical value of K_c for the above reaction at this temperature?

A. 3.3
B. 6.7
C. 14.8
D. 59.3

DSE13_28

$$X_2(g) + 3Y_2(g) \rightleftharpoons 2XY_3(g)$$

Which of the following combinations shows the effects of a catalyst on the rate of forward reaction, rate of backward reaction and the yield of $XY_3(g)$?

	Rate of forward reaction	Rate of backward reaction	Yield of $XY_3(g)$
A.	Increased	Increased	Unchanged
B.	Unchanged	Unchanged	Unchanged
C.	Increased	Decreased	Increased
D.	Decreased	Increased	Decreased

DSE14_26

Consider the information below:

Reaction	Equilibrium constant at 25°C
$A(aq) + B(aq) \rightleftharpoons C(aq) + D(aq)$	K_1
$C(aq) + D(aq) \rightleftharpoons E(aq) + F(aq) + G(aq)$	K_2
$E(aq) + F(aq) + G(aq) \rightleftharpoons A(aq) + B(aq)$	K_3

Which of the following combinations is correct

	Relationship of K_1, K_2 and K_3	Unit of K_3
A.	$K_3 = \frac{1}{K_1 \times K_2}$	mol dm^{-3}
B.	$K_3 = \frac{1}{K_1 \times K_2}$	mol^{-1} dm^3
C.	$K_3 = K_1 \times K_2$	mol dm^{-3}
D.	$K_3 = K_1 \times K_2$	mol^{-1} dm^3

DSE14_31

The following system attained equilibrium at a certain temperature:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Which of the following statements is / are correct when the volume of the system is decreased while the temperature remains unchanged?

(1) The value of K_c increases.
(2) The equilibrium position shifts to the right.
(3) The rate of decomposition of $SO_3(g)$ increases.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE14_35

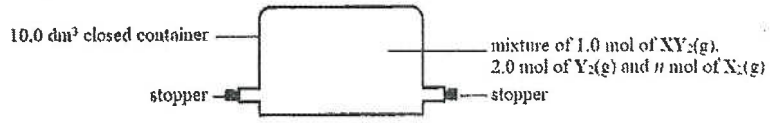
1st statement	2nd statement
At chemical equilibrium state, the forward reaction rate equals zero.	At chemical equilibrium state, the reactants would not react to give the products.

DSE15_27

Consider the following reaction at a certain temperature?

$$2XY_2(g) \rightleftharpoons X_2(g) + 2Y_2(g) \quad K_c = 0.60 \text{ mol dm}^{-3}$$

An equilibrium mixture was obtained at this temperature as shown below:



What is n?

A. 1.5
B. 3.0
C. 0.15
D. 0.30

DSE15_31

In a closed container and at a certain temperature, the following equilibrium was attained:

$$COCl_2(g) \rightleftharpoons CO(g) + CCl_2(g)$$

Which of the following statements is / are correct ?

(1) CO(g) and Cl_2(g) must be of the same concentration.
(2) The rate of decomposition of $COCl_2$(g) is equal to the rate of formation of CO(g).
(3) The equilibrium constant K_c for the reaction increases when the volume of the container increases.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE15_33 (modified)

Consider the following equilibrium reaction system in a closed container of fixed volume:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \quad \Delta H < 0$$

Which of the following, when applied to the system, would lead to an increase in the rate of formation of H_2(g)?

(1) adding CO(g)
(2) decreasing the temperature
(3) adding a suitable catalyst

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE16_26

The following reaction has attained equilibrium in a fixed volume container:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \quad \Delta H = -41.1 \text{ kJ mol}^{-1}$$

Which of the following is correct if the temperature of the system is increased?

A. The pressure of the system remains unchanged.
B. Both the rates of forward and backward reaction increase.
C. The equilibrium constant of the reaction remains unchanged.
D. The respective yield of CO_2(g) and H_2(g) increase to the same extent.

DSE16_27

Consider the following equilibrium system:

$$Br_2(aq) + H_2O(l) \rightleftharpoons HOBr(aq) + H^+(aq) + Br^-(aq)$$

Which of the following can turn the color of the system paler?

A. Passing HCl(g) into the system
B. Passing HBr(g) into the system
C. Adding NaBr(s) to the system
D. Adding NaOH(s) to the system

Direction: Questions DSE17_31 and DSE17_32 refer to the following reaction involving four miscible liquids.

$$W(l) + X(l) \rightleftharpoons Y(l) + Z(l) \quad \Delta H = +45 \text{ kJ mol}^{-1}$$

At 25°C, the equilibrium constant K_c for the reaction is 2.5. In an experiment, 1.0 mol of W(l) and 1.0 mol of X(l) are placed in a closed container keeping at 25°C. when equilibrium is attained, the total volume of the reaction mixture is 0.20 dm^3.

DSE17_31

How many moles of Y(l) would be present in the container when equilibrium is attained?

A. 0.44 B. 0.61
C. 0.71 D. 0.83

DSE17_32

When equilibrium is attained, which of the following would increase the number of moles of Y(l)?

(1) Removing Z(l) from the reaction mixture
(2) Increasing the volume of the container
(3) Increasing the temperature of the reaction mixture

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE17_34

Consider the following equilibrium system:

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

Which of the following statements are INCORRECT?

(1) $[CrO_4^{2-}(aq)]$ must be equal to $[Cr_2O_7^{2-}(aq)]$.
(2) Both the forward reaction and the backward reactive have stopped.
(3) The number of moles of $CrO_4^{2-}(aq)$ must be double the number of moles of $Cr_2O_7^{2-}(aq)$.

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE18_26

Consider the following equilibrium system in a certain liquid medium at 25 °C:

$$CH_3COCH_3 + HCN \rightleftharpoons (CH_3)_2C(OH)CN \quad \Delta H > 0$$

Which of the following statements is correct (assuming the total volume of the system remains unchanged)?

A. Adding $(CH_3)_2C(OH)CN$ would increase the equilibrium constant K_c.
B. Increasing the temperature would increase the concentration of $(CH_3)_2C(OH)CN$.
C. The concentration of CH_3COCH_3 must be equal to the concentration of $(CH_3)_2C(OH)CN$.
D. After adding HCN and when a new equilibrium is attained, the concentration of HCN would be restored to the value before the addition of HCN.

DSE18_29

The equilibrium constant K_c for the reaction

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

at 70 °C is 0.13 mol dm^{-3}. In a 5.0 dm^3 closed container kept at 70 °C, there is a mixture of 0.20 mol of $N_2O_4(g)$ and 0.30 mol of $NO_2(g)$ at a certain amount. Which of the following combinations is correct at that moment?

	Reaction quotient Q_c / mol dm^{-3}	Rate of the reaction
A.	0.09	Backward > forward
B.	0.09	Forward > backward
C.	0.45	Backward > forward
D.	0.45	Forward > backward

DSE19_26

Consider the following two reactions at a certain temperature:

Reaction (1) : $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ Equilibrium constant $K_c = 0.8$
Reaction (2) : $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ Equilibrium constant $K_c = X$

What is X ?

A. 0.8 B. 1.25
C. 0.8 $mol^{-1}dm^3$ D. 1.25 $mol^{-1}dm^3$

DSE19_27

The decomposition of HI(g) into $H_2(g)$ and $I_2(g)$ is reversible. In a closed container of 3.0 dm^3 keeping at a fixed temperature, an equilibrium mixture contains 0.10 mol of HI(g), 0.60 mol of $H_2(g)$ and 0.60 mol of $I_2(g)$. What is the equilibrium constant K_c for the decomposition at this temperature ?

A. 0.4 B. 3.6
C. 9.0 D. 36.0

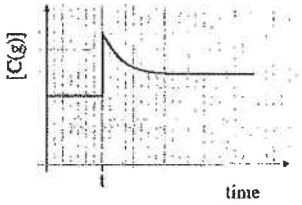
DSE19_25

Consider the following equilibrium system in a closed container of fixed volume:

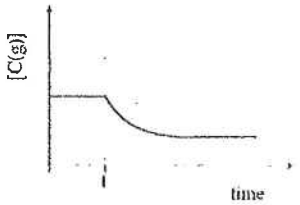
$$A(g) + B(g) \rightleftharpoons 2C(g)$$

A small amount of B(g) is added at time t and finally a new equilibrium is attained at the same temperature. Which of the following graphs can represent the variation of [C(g)] with time ?

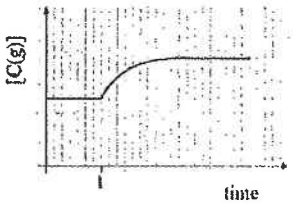
A.



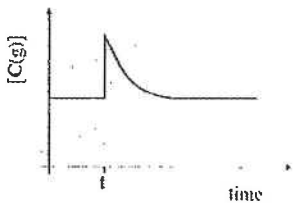
B.



C.



D.



DSE20_26

26. Consider the information below :

Reaction	Equilibrium constant at 25 °C
$H_2A(aq) \rightleftharpoons H^+(aq) + HA^-(aq)$	1.3×10^{-3} mol dm^{-3}
$HA^-(aq) \rightleftharpoons H^+(aq) + A^{2-}(aq)$	3.1×10^{-6} mol dm^{-3}
$2HA^-(aq) \rightleftharpoons H_2A(aq) + A^{2-}(aq)$	X

What is the numerical value of X ?

A. 4.2×10^{2}
B. 2.4×10^{-3}
C. 4.0×10^{-9}
D. 2.5×10^{4}

DSE20_33

33. Refer to the following chemical reaction :

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H > 0$$

The pH of a pure water sample is 7.0 at 25 °C. Which of the following statements is / are correct when the sample has been heated to 50 °C ?

(1) The $[OH^-(aq)]$ of the sample is 1.0×10^{-7} mol dm^{-3}.
(2) The pH of the sample is smaller than 7.0.
(3) The sample remains neutral.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE21_31

31. Consider the following reaction under certain conditions :

$$2X_3(g) \rightleftharpoons 3X_2(g) \qquad K_c = 4.0 \text{ mol dm}^{-3}$$

The reaction quotient is 2.0 mol dm^{-3} at a certain moment. Which of the following statements is / are correct ?

(1) The reaction quotient is larger than 2.0 mol dm^{-3} after a period of time.
(2) The backward reaction is faster than the forward reaction at that moment.
(3) The concentration of $X_3(g)$ must be equal to the concentration of $X_2(g)$ at that moment.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE21_32

32. Consider the following equilibrium system :

$$\underset{\text{colourless}}{HA(aq)} \rightleftharpoons \underset{\text{pink}}{H^+(aq) + A^-(aq)} \qquad \Delta H > 0$$

Which of the following statements is / are correct ?

(1) Adding $Na_2CO_3(s)$ would make its colour become paler.
(2) Increasing the temperature would make its colour become darker.
(3) Adding a few drops of concentrated HCl(aq) would increase the concentration of $A^-(aq)$.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

Structural Questions

ASL99(I)_03

The table below lists the equilibrium constants, K_c, for the reversible reaction.

$$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

at three different temperatures.

Temperature / K	500	700	900
K_c	7.76×10^{-3}	1.23×10^{-1}	6.03×10^{-1}

(a) Based on the above information, deduce whether the forward reaction is exothermic or endothermic.

(1 mark)

(b) 2.0 mol of $H_2(g)$ and 2.0 mol of $CO_2(g)$ are allowd to react in a 4.0 dm^3 closed container. Calculate the concentration of CO(g), in mol dm^{-3} in the equilibrium mxiture at 700 K.

(3 marks)

(c) State the effect of an increase in pressure on the percentage yield of CO(g). Explain your answer.

(2 marks)

AL99(II)_04a

In the Haber process, ammonia is synthesized by the exothermic reaction of nitrogen and hydrogen at around 723 K.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In a simulation of the process, a mixture of nitrogen and hydrogen was placed in a closed container. The initial concentrations of nitrogen and hydrogen were 0.50 mol dm^{-3} and 1.50 mol dm^{-3} respectively. When the equilibrium was attained at 723 K, 25.0% of the original nitrogen was consumed.

(i) Calculate the respective concentrations of nitrogen, hydrogen and ammonia in the equilibrium mixture.

(3 marks)

(ii) Calculate K_c for the reaction at 723 K.

(2 marks)

(iii) (I) State, with explanation, the effect of temperature on K_c for the reaction.

(1 mark)

(II) Explain why the Haber process is not operated at temperatures much higher or much lower than 723 K.

(1 mark)

ASL00(I)_04

An experiment, consisting of four stages, was conducted to determine the equilibrium constant K_c, of an esterification reaction:

Stage 1: 0.25 mol of ethanoic acid and 0.25 mol of propan-2-ol were mixed in a pear-shaped flask. 1.0 cm^3 of this mixture was withdrawn and added to a conical flask containing 25 cm^3 of deionized water. The contents of the conical flask were then titrated against 0.30 M sodium hydroxide solution.

Stage 2: A few drops of concentrated sulphuric (VI) acid were added to the remaining acid-alcohol mixture in the pear-shaped flask wit shaking. 1.0 cm^3 of this mixture was withdrawn and immediately titrated against 0.30 M sodium hydroxide solution as in Stage 1.

Stage 3: Some pumice stones were added to the pear-shaped flask which as then heated under reflux for an hour. After rapid cooling, 1.0 cm^3 of this mixture was withdrawn and immediately titrated against 0.30 M sodium hydroxide solution as in Stage 1.

Stage 4: The remaining mixture in the pear shaped flask was heated under reflux for another half an hour. After rapid cooling, 1.0 cm^3 of this mixture was withdrawn and immediately titrated against 0.30 M sodium hydroxide as in Stage 1.

The table below lists the titration results:

	Volume of 0.30 M NaOH(aq) used / cm^3
Stage 1	36.80
Stage 2	36.90
Stage 3	17.55
Stage 4	17.15

(a) Write a chemical equation for the esterification reaction.

(1 mark)

(b) What is the purpose of adding concentrated sulphuric(VI) acid in Stage 2?

(1 mark)

(c) (i) Explain why the titration in stage 2 should be carried out immediately.

(1 mark)

(ii) Suggest a suitable indicator for the titration.

(1 mark)

(d) Why are pumice stones used in Stage 3?

(1 mark)

(e) Assuming that equilibrium had been attained in Stage 4, calculate K_c for the esterification reaction.

(4 marks)

(f) Suggest what further actions should be taken after Stage 4 to confirm that equilibrium has been attained.

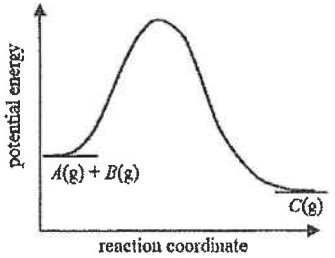
(1 mark)

ASL01(I)_02

The energy profile of a reversible reaction

$$A(g) + B(g) \rightleftharpoons C(g)$$

is shown below:



A mixture of A(g), B(g) and C(g) was allowed to reach equilibrium in a closed vessel with a fixed volume.

State the effects as listed in the table below of (i) adding a catalyst to the mixture, and (ii) increasing the temperature of the mixture.

	(i) Adding a catalyst to the mixture	(ii) increasing the temperature of the mixture
Effect on the rate of the forward reaction		
Effect on the rate of the backward reaction		
Effect on the equilibrium position		

AL02(I)_01a

The pH of human blood is maintained within a narrow range from 7.35 to 7.45 by a natural buffer system consisting of carbonic acid, $H_2CO_3(aq)$, and hydrogencarbonate ions, $HCO_3^-(aq)$.

(i) A buffer solution containing $H_2CO_3(aq)$ and $HCO_3^-(aq)$ in equal concentrations has a pH of 6.10. Calculate the dissociation constant, K_a, for $H_2CO_3(aq)$.

(2 marks)

(ii) Calculate the ratio of concentrations of $HCO_3^-(aq)$ and $H_2CO_3(aq)$ in blood at pH 7.40.

(2 marks)

(iii) (I) Would the blood pH of a person increase or decrease in the course of physical exertion ? Explain your answer.

(2 marks)

(II) Briefly explain why the $H_2CO_3(aq)$ / $HCO_3^-(aq)$ buffer system can maintain the blood pH.

(1 mark)

AL02(I)_02a

A closed system consisting of a mixture of $N_2O_4(g)$ and $NO_2(g)$ is allowed to attain equilibrium at 350 K and 700 kPa. The mixture has a light brown color.

$$\underset{\text{pale yellow}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

describe the color change of the mixture when its temperature is increased under the same pressure. Explain your answer.

(2 marks)

AL02(II)_03

At 298 K, the equilibrium constants, K_c, for the reaction (1) and (2) below are 1.8×10^{7} mol^{-2} dm^{6} and 2.0×10^{-10} mol^{2} dm^{-6} respectively.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) \quad (1)$$
$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \quad (2)$$

(a) For each of the reactions (1) and (2), write an expression for its K_c.

(2 marks)

(b) Calculate the K_c at 298 K for the following reaction:

$$AgCl(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$$

(3 marks)

(c) Using your result in (b), calculate the solubility, in mol dm^{-3}, of AgCl(s) in 0.10 M NH_3(aq) at 298 K.

(2 marks)

ASL02(II)_09 (modified)

The dissociation of butan-1-amine in water can be represented by the following equation.

$$CH_3(CH_2)_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3(CH_2)_3NH_3^+(aq) + OH^-(aq)$$

(a) Give all acidic species in an aqueous solution of butan-1-amine.

(1 mark)

(b) The dissociation constant, K_c, of butan-1-amine is 5.9×10^{-4} mol dm^{-3} at 298 K. Calculate the pH of a 0.10 M aqueous solution of butan-1-amine at 298 K.

(3 marks)

ASL03(I)_01

H_3PO_4(aq) ionizes in three stages to give $H_2PO_4^-$(aq), HPO_4^{2-}(aq) and PO_4^{3-}(aq).

(a) At 298 K, the dissociation constants, K_a, of H_3PO_4(aq), $H_2PO_4^-$(aq) and HPO_4^{2-}(aq) are as follows:

	K_c / mol dm^{-3}
$H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$	7.9×10^{-3}
$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$	6.2×10^{-8}
$HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq)$	4.4×10^{-13}

Explain why the dissociation constant decreases with the successive loss of hydrogen ions.

(1 mark)

(b) Sketch the expected pH titration curve when H_3PO_4(aq) is titrated with NaOH(aq).

(3 marks)

ASL03(I)_05

At 298 K, the pH of a 0.10 M aqueous solution of butanoic acid is 2.9.

(a) (i) Calcuate the degree of dissociation of butanoic acid in the solution.

(2 marks)

(ii) Calculate the K_c of butanoic acid at 298K.

(2 marks)

(b) 25.0 cm^3 of 0.10 M butanoic acid is titrated against 0.10 M sodium hydroxide solution. Sketch a graph to show he change in pH during the titration.

(3 marks)

ASL03(II)_11

Consider the following reversible reaction:

$$\underset{\text{Colorless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{Dark brown}}{2NO_2(g)}$$

A gas syringe containing a mixture of N_2O_4(g) and NO_2(g) was allowed to attain equilibrium at room temperature and pressure. The syringe was then immersed in ice-water. The color of the mixture gradually became lighter.

(a) State the effect of decreasing the temperature on the rate of the backward reaction. Explain your answer.

(3 marks)

(b) (i) Based on the given information, deduce whether the forward reaction is exothermic or endothermic.

(2 marks)

(ii) Explain your answer in (1) in terms of chemical bonding.

(1 mark)

(c) Suggest a chemical method to dispose of the gaseous mixture in the syringe at the end of the experiment.

(1 mark)

ASL04(I)_04 (modified)

(a) Write an equation, with state symbols, for the auto-ionization of water.

(1 mark)

(b) Write an expression for the equilibrium constant, K_c of auto-ionization of water.

(1 mark)

(c) The table below lists the K_w of water at three different temperatures.

Temperature / °C	K_w / mol^2 dm^{-6}
10	0.3×10^{-14}
30	1.5×10^{-14}
50	5.5×10^{-14}

(i) Calculate the pH of pure water at 50 °C.

(2 marks)

(ii) Is pure water alkaline, neutral or acidic at 50 °C. Explain your answer.

(1 mark)

(iii) With reference to the given information, deduce whether the auto-ionization of water is an exothermic process or an endothermic process.

(2 marks)

ASL04(II)_08 [Similar to DSE17_11]

Chlorate(I) salts, in the form of NaClO or $Ca(ClO)_2$, are commonly used as disinfectant.

(a) In aqueous solution, chlorate(I) ions undergo hydrolysis to give chloric(I) acid, HClO(aq). Write the chemical equation for the hydrolysis of chlorate(I) ions.

(1 mark)

(b) Many swimming pools se chlorate(I) salts to sterilize the pool water. The HClO(aq) formed is very effective for killing microorganism.

(i) The pH of a sample of pool water is 7.50 at 298 K. Calculate the ratio of concentration of ClO^-(aq) to that of HClO(aq) in the sample.
(At 298 K, the dissociation constant, K_c, of HClO(aq) is 2.95×10^{-8} mol dm^{-3}.)

(2 marks)

(ii) The concentration of HClO(aq) in pool water increases with decrease in pH, yet the pH of pool water should not be kept too low. Briefly explain.

(1 mark)

(c) (i) Write a chemical equation to represent the dissociation of HClO in water.

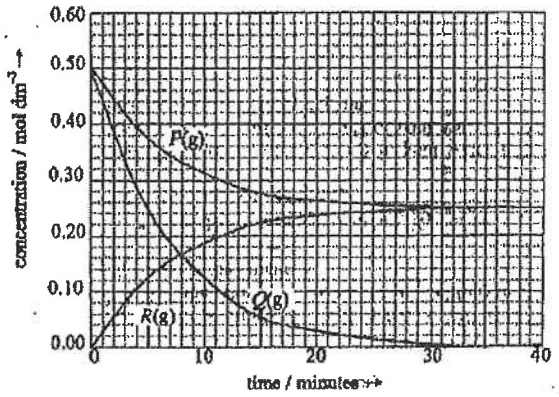
(1 mark)

(ii) Will the equilibrium position of the system in (i) shift upon the addition of wate? Specify the direction of the shift, if any, and explain your answer.

(2 marks)

ASL04(II)_09 [Similar to DSE18_13]

(a) P(g) reacts with Q(g) irreversibly to give R(g). A mixture of P(g) and Q(g) is allowed to react in a closed container of volume 1 dm^3 kept at a constant temperature. The graph below shows the changes in concentration of P(g), Q(g) and R(g) in the container with time. (P, Q, R do not represent symbols of elements.)



(i) With reference to the above graph, deduce the chemical equation for the reaction in terms of P(g), Q(g) and R(g).

(2 marks)

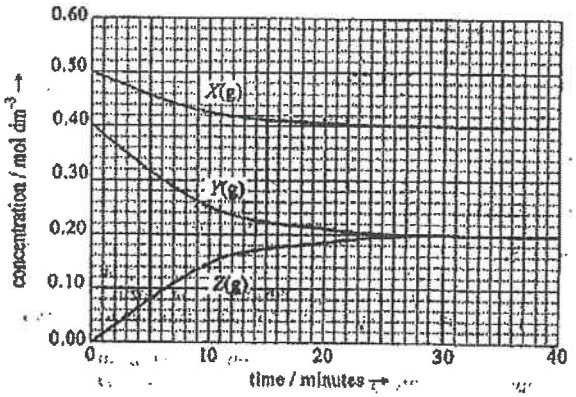
(ii) If the mixture of P(g) and Q(g) is allowed to react at the same temperature but in a closed container of volume 2 dm^3 instead, will the time required for the reaction to complete remain the same? Explain.

(2 marks)

(iii) Explain why the collision between molecules of P(g) and Q(g) will not necessarily lead to a reaction.

(1 mark)

(b) $X(g)$ reacts with $Y(g)$ reversibly to give $Z(g)$. A mixture of $X(g)$ and $Y(g)$ is allowed to react in a closed container of volume 1 dm^3 kept at a constant temperature. The graph below shows the changes in concentrations of $X(g)$, $Y(g)$ and $Z(g)$ in the container with time. (X, Y, Z do not represent symbols of elements.)



(i) With reference to the above graph, deduce an expression for the equilibrium constant, K_c, for the reaction.

(2 marks)

(ii) Compare the rate of forward reaction and that of the backward reaction

(1) at the 5th minutes after X(g) and Y(g) are mixed.

(1 mark)

(2) at the 3th minutes after X(g) and Y(g) are mixed.

(1 mark)

(You are not required to perform any calculation.)

(iii) if the mixture X(g) and Y(g) is allowed to react at the same temperature but in a closed container of volume 2 dm^3 instead, will the yield of Z(g) be the same? Explain.

(2 marks)

AL05(I)_03b [Similar to DSE17_11]

Cyanidin (Cy) is a water-soluble plant pigment which can be found in blackberry, and is responsible for its purple color. The following equilibrium exists in an aqueous solution of cyanidin:

$$\underset{\text{red}}{CyH^+(aq)} \rightleftharpoons \underset{\text{purple}}{Cy(aq)} + H^+(aq)$$

(i) Write an expression for the acid dissociation constant K_a of $CyH^+(aq)$.

(1 mark)

(ii) In a sample of blackberry juice buffered at pH 3.0 at 298 K, the concentration ratio of CyH^+ to Cy(aq) was found to be 20 to 1. Calculate K_a of $CyH^+(aq)$ at 298 K.

(2 marks)

(iii) Blackberry juice is often preserved by adding small amount of $SO_2(g)$, which reacts with $CyH^+(aq)$ to give colourless product, $CySO_3H_2(aq)$. The reaction can be represented by the equation below:

$$CyH^+(aq) + SO_2(aq) + H_2O(l) \rightleftharpoons CySO_3H_2(aq) + H^+(aq) \quad (1)$$

(I) Write an expression for the equilibrium constant K_c in reaction (1).

(1 mark)

(II) When sufficient $SO_2(g)$ is added to a blackberry juice buffered at pH = 3.00 at 298 K so that concentration of $SO_2(aq)$ at equilibrium is 1.0×10^{-2} mol dm^{-3}, the concentration of $CyH^+(aq)$ drops to one tenth of its original value.

Assuming that $SO_2(aq)$ does not react with Cy(aq), calculate K_c in reaction (1) at 298 K.

(2 marks)

ASL05(II)_08 [Similar to DSE13_12]

$Y_2(g)$ undergoes decomposition according to the following equation:

$$Y_2(g) \rightleftharpoons 2Y(g) \qquad \Delta H > 0$$

Two experiments were carried out to study the decomposition of $Y_2(g)$. In these experiments, different amounts of $Y_2(g)$ and Y(g) were charged into a closed container of volume 2 dm^3 kept at a constant temperature. The table below lists the initial numbers of moles of $Y_2(g)$ and Y(g) in the container, as well as the number of moles of Y(g) present in the container after one day.

Experiment	Initial number of moles		Number of moles of Y(g) after one day
	$Y_2(g)$	Y(g)	
I	4	0	2
II	0	4	$^4/_3$

(a) The reaction quotient Q of the system can be represented by the following expression:

$$Q = \frac{[Y(g)]^2}{[Y_2(g)]}$$

For each experiment, calculate Q of the system after one day. Hence, deduce whether the system had attained equilibrium after one day.

(5 marks)

(b) Consider experiment I

(1) will the yield of Y(g) be affected if the volume of the container is decreased from 2 dm^3 to 1 dm^3? Explain.

(2 marks)

(2) State the effect of an increase in temperature on the yield of Y(g). Explain.

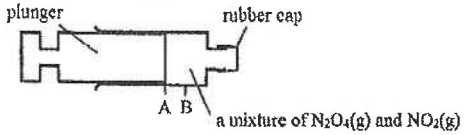
(2 marks)

ASL06(I)_04 [Similar to DSE13_12c]

The diagram below shows a gas syringe containing a pale brown mixture of $N_2O_4(g)$ and $NO_2(g)$ at equilibrium at room temperature.

$N_2O_4(g)$ ⟷ $2NO_2(g)$

Colorless Dark brown



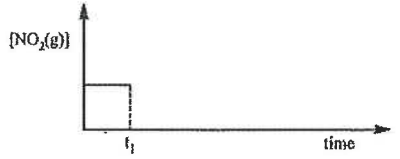
In each of the following cases, state the expected observation, with reason(s). Sketch on the given graph to show the expected variation in the concentration of $NO_2(g)$ in the mixture until the attainment of a new equilibrium.

(a) The plunger is quickly pushed from position A to position B at time t_1, while the temperature of the mixture is kept constant.

Expected observation:

Reason:

Graph:



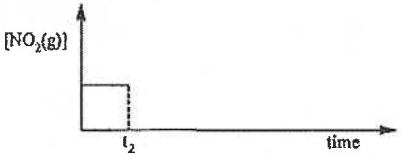
(5 marks)

(b) Some $N_2O_4(g)$ is introduced into the gas syringe at time t_2, while the volume and the temperature of the mixture are both kept constant.

Expected observation:

Reason:

Graph:



(3 marks)

ASL06(II)_12 (modified)

Propanoic acid is a week acid

(a) Explain what is meant by the term 'weak acid'.

(1 marks)

(b) Calculate the pH of 0.20 M propanoic acid at 298 K.

Given that

$$K_a \text{ of acid dissociation} = \frac{[H^+(aq)][CH_3CH_2COO^-(aq)]}{[CH_3CH_2COOH(aq)]} = 1.35 \times 10^{-5} \text{ mol dm}^{-3}$$

(3 marks)

(c) Sketch a graph showing the change in pH of the solution mixture when 25.0 cm^3 of 0.20 M propanoic acid is titrated against 0.20 M aqueous sodium hydroxide.

(2 marks)

(d) When sodium propanoate is dissolved in water, the following chemical equilibrium is established:

$$CH_3CH_2COO^-(aq) + H_2O(l) \rightleftharpoons CH_3CH_2COOH(aq) + OH^-(aq)$$

(i) If K_c is the equilibrium constant of the above system, while K_a and K_w are the equilibrium constants of the following reactions:

$$CH_3CH_2COOH(aq) \rightleftharpoons CH_3CH_2COO^-(aq) + H^+(aq)$$
$$K_a = \frac{[H^+(aq)][CH_3CH_2COO^-(aq)]}{[CH_3CH_2COOH(aq)]}$$

$$H_2O(aq) \rightleftharpoons H^+(aq) + OH^-(aq)$$
$$K_w = [H^+(aq)][OH^-(aq)]$$

Show that $K_c = \frac{K_w}{K_a}$.

(1 mark)

(ii) For a 0.20 M aqueous solution of sodium propanoate, calculate

(1) The concentration of $OH^-(aq)$

(3 marks)

(2) The pH value

(1 mark)

At 298 K, ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6};
K_a of propanoic acid = 1.35×10^{-5} mol dm^{-3})

ASL07(II)_04 [Similar to DSE13_12]

The equilibrium constant K_c for the following reaction is 0.20 mol^{-1} dm^3 at 873 K.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

A mixture of 2.0 mol of CO(g), 1.0 mol of $Cl_2(g)$ and 0.5 mol of $COCl_2(g)$ is introduced into an evacuated vessel of 4.0 dm^3 kept at 873 K.

(a) Calculate the reaction quotient of the system at the start of the reaction. Then, decide the direction in which the reaction will proceed to achieve equilibrium.

(3 marks)

(b) Calculate the concentration of $COCl_2(g)$ when equilibrium is attained at 873 K.

(3 marks)

(c) Discuss the effect on K_c, if the volume of the vessel is decreased while keeping the temperature of the system at 873 K.

(1 mark)

ASL08(I)_04

Consider the reaction of $H_2(g)$ with $I_2(g)$ at elevated temperature:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

4.0 mol of $H_2(g)$ and 2.0 mol of $I_2(g)$ were introduced into an evacuated 5.0 dm^3 closed container kept at 713 K.

(a) Given that the equilibrium constant K_c for the reaction is 50 at 713 K, calculate the concentration of $H_2(g)$, $I_2(g)$ and HI(g), in mol dm^{-3}, respectively in the equilibrium mixture.

(4 marks)

(b) Deduce the effect on the number of moles of HI(g) in the equilibrium mixture

(I) If the volume of the container is reduced to 2.5 dm^3;

(1.5 marks)

(II) If the initial number of moles of $H_2(g)$ and $I_2(g)$ used are both 4.0.

(1.5 marks)

(You may assume all other conditions to be the same in each case, and are not required to carry out calculations.)

ASL09(II)_02

The equilibrium constant K_c for the thermal decomposition of calcium carbonate is 2.7×10^{-3} mol dm^{-3} at 1000 K.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad \Delta H > 0$$

25.0 g of $CaCO_3(s)$ is introduced into a 5.0 dm^3 evacuated vessel, and the system is allowed to attain equilibrium at 1000 K.

(a) Write an expression of K_c for the decomposition.

(1 mark)

(b) Calculation the percentage of decomposition of $CaCO_3(s)$ in the above equilibrium system.

(3 marks)

(c) Will the percentage of decomposition of $CaCO_3(s)$ increase, decrease or remain unchanged if the temperature of the above equilibrium system is decreased? Explain your answer.

(2 marks)

(d) If more $CaCO_3(s)$ is added to the equilibrium system at 1000 K, will the equilibrium concentration of $CO_2(g)$ change? Explain your answer.

(1 mark)

AL10(I)_02 (modified)

From a saturated aqueous solution of calcium hydroxide, several 20.0 cm^3 aliquots of the solution were withdrawn. Each aliquot was titrated with 0.100 mol dm^{-3} hydrochloric acid using a suitable indicator. The mean titre were 9.10 cm^3. Calculate

(a) the concentration of hydroxide ions in the saturated solutions, and

(1 mark)

(b) the solubility of calcium hydroxide at the temperature of the experiment.

(2 marks)

(c) the equilibrium constant (solubility product) of calcium hydroxide at the temperature of experiment.

(3 marks)

AL10(I)_03

State the expected observation(s) in each of the following experiments, and account for the observation with the aid of chemical equation(s).

Adding excess $H_2SO_4(aq)$ to $K_2CrO_4(aq)$, and then excess $FeSO_4(aq)$ to the resulting solution.

(3 marks)

AL10(II)_03

Ammonia is manufactured by Haber process:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

(a) In a simulation of the process, a mixture of 10 mole $N_2(g)$ and 30 mol $H_2(g)$ is introduced into a 50 dm^3 closed vessel, which is kept at 673 K and contains the iron catalyst. When the system attains equilibrium, the mole percent of ammonia is 39. Calculate

(I) The equilibrium concentration of each gas, and

(3 marks)

(II) The equilibrium constant, K_c, of the above reaction at 673 K.

(2 marks)

(b) Suggest TWO ways to increase the yield of ammonia when the process is put into industrial practice.

(2 marks)

AL11(II)_06

State the expected observation(s) in each of the following experiments, and write the chemical equation(s) of the reaction(s) involved.

(a) HCl(aq) is added to K_2CrO_4(aq)

(2 marks)

ASL11(II)_06

Ammonia is manufactured by the Haber process:

$$N_2(g) + 3H_2(g) \overset{Fe(s)}{\rightleftharpoons} 2NH_3(g) \qquad \Delta H^\ominus_{298} = -92 \text{ kJ mol}^{-1}$$

In a simulation study of the process, mixture of N_2(g) and H_2(g) were allowed to attain equilibrium under five sets of reaction conditions, and the mole percent of NH_3(g) in each equilibrium mixture was recorded. The table below lists the results obtained in the five trials:

Trial	Initial mole ratio of N_2(g) to H_2(g)	Reaction conditions			mole percent of NH_3(g) in equilibrium mixture
		Temperature / K	Pressure / atm	catalyst	
1	1 : 3	473	10	Fe(s)	51
2	1 : 3	773	1000	Fe(s)	58
3	1 : 3	473	1000	Fe(s)	*a*
4	1 : 3	773	10	--	*b*
5	1 : 3	773	1000	--	*c*

(No catalyst was used in trials 4 and 5; *a*, *b* and *c* represent the mole percent of NH_3(g) in the equilibrium mixture in trials 3, 4 and 5 respectively.)

(a) In which TWO trials would the mole percent of NH_3(g) in the equilibrium mixture be the same? Explain your answer.

(2 marks)

(b) In which trial would the mole percent of NH_3(g) in the equilibrium mixture be the highest? Explain your answer.

(2 marks)

(c) The industrial operating conditions for the Haber process are as follows:

Mole ratio of N_2(g) to H_2(g)	1 : 3
Temperature	673 K
Pressure	200 atm
Catalyst	Fe(s)

Explain why this set of conditions is used.

(2 marks)

AL11(II)_07 (modified) [Similar to DSE16_10]

For the reaction below,

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

The equilibrium constant K_c is 11.73 mol^{-1} dm^3 at 1100 K.

(a) A mixture of 0.20 mol of SO_2(g) and 0.20 mol of O_2(g) is introduced into an evacuated closed container. Calculate the volume of the system in order to achieve an 80% conversion of SO_2 to SO_3(g) at 1100 K.

(4 marks)

(b) If the above system is subjected to each of the following changes, will the percentage conversion of SO_2(g) to SO_3(g) increases, decrease or remain unchanged? Explain you answer in each case.

(i) Increasing the volume of the container

(1 mark)

(ii) Decreasing the temperature

(1 mark)

(iii) Introducing a catalyst

(1 mark)

ASL12(I)_01

(b) Account for the following observations and give the relevant chemical equation(s):

Word written on a paper using KSCN(aq) are invisible. When the paper is sprayed with Fe^{3+}(aq), the words appear blood-red. If the words are written with alkaline KSCN(aq) they will turn orange-brown when sprayed with Fe^{3+}(aq).

(3 marks)

ASL12(I)_07

The equilibrium constant K_c for the following reaction can be determined by finding the concentration of I^-(aq) and that of SO_4^{2-}(aq) in the solution phase of the equilibrium mixture:

$$PbSO_4(s) + 2I^-(aq) \rightleftharpoons PbI_2(s) + SO_4^{2-}(aq)$$

(a) Write an expression of K_c for this reaction.

(1 mark)

(b) You are provided with $PbSO_4$(s) and standard KI(aq). Outline how you would prepare, in a school laboratory, an equilibrium mixture for determining K_c at 313K.

(2 marks)

(c) The concentration of I^-(aq) in the solution phase can be found by titration using standard $AgNO_3$(aq). What treatment(s) on the equilibrium mixture is/are necessary before carrying out the titrations?

(2 marks)

(d) Given that the concentration of the standard KI(aq) used is 0.100 mol dm^{-3} and the concentration of I^-(aq) in the solution phase of the equilibrium mixture is 0.072 mol dm^{-3}, calculate K_c at 313 K.

(2 marks)

ASL12(II)_01 (modified)

At 298 K, the dissociation constant K_c for $NH_3(aq)$ is 1.8×10^{-5} mol dm^{-3}.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(a) Calculate the pH of 0.10 mol dm^{-3} $NH_3(aq)$ at 298 K.

(3 marks)

(b) Calculate the molarity ratio of $NH_3(aq)$ to $NH_4Cl(aq)$ required for preparing a pH 10 solution at 298 K.

(2 marks)

(c) Briefly explain how the solution in (b) can resist pH change upon addition of a small amount of acid or alkali.

(2 marks)

ASL13(I)_04

Consider the following reversible reaction:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H < 0$$

0.10 mol of CO(g) and 0.10 mol of $H_2O(g)$ were introduced into a fixed-volume closed container maintained at 700 K. When equilibrium was attained, 74.0% of CO(g) was found to have reacted.

(a) Calculate the equilibrium constant K_c for this reaction at 700 K.

(2 marks)

(b) State and explain the effect of each of the following changes on the equilibrium concentration of $H_2(g)$.

(i) Increasing temperature

(1 mark)

(ii) Introducing extra CO(g) into the container.

(1 mark)

AL13(I)_01

(c) Blue cobalt(II) chloride paper is commonly used to test for the presence of water. The addition of water turns the blue paper pink. The pink paper turns back to blue when it is heated in an oven.

With the aid of a chemical equation, explain the above observations.

(2 marks)

ASL13(II)_03

You are provided with the equilibrium constants, K_c, at 298 K for reactions (1) and (2) below:

		K_c at 298 K
(1)	$Mg(OH)_2(s) + aq \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$	2.0×10^{-11} mol^3 dm^{-9}
(2)	$Ni(OH)_2(s) + aq \rightleftharpoons Ni^{2+}(aq) + 2OH^-(aq)$	6.3×10^{-18} mol^3 dm^{-9}

(a) Write the K_c expression for reaction (1) and that for reaction (2).

(1 mark)

(b) At 298 K, a mixture of $Mg(OH)_2(s)$ and 0.010 mol dm^{-3} $NiSO_4(aq)$ was stirred until the following equilibrium was attained:

$$Mg(OH)_2(s) + Ni^{2+}(aq) \rightleftharpoons Ni(OH)_2(s) + Mg^{2+}(aq) \qquad (\alpha)$$

(i) Write the K_c expression for reaction (α) and calculate the K_c at 298 K.

(3 marks)

(ii) Calculate the concentration of $Ni^{2+}(aq)$ ions in this equilibrium mixture.

(2 marks)

DSE11SP_11 [Similar to DSE14_13]

The table below lists the equilibrium constants, K_c, for the reversible reaction

$$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

at three different temperatures.

Temperature / K	500	700	900
K_c	7.76×10^{-3}	1.23×10^{-1}	6.03×10^{-1}

(a) Based on the above information, deduce whether the forward reaction is exothermic or endothermic.

(2 marks)

(b) 2.0 mol of $H_2(g)$ and 2.0 mol of $CO_2(g)$ are allowed to react in a 4.0 dm^3 closed container. Calculate the concentration of CO(g), in mol dm^{-3}, in the equilibrium mixture at 700 K..

(2 marks)

(c) State the effect of an increase in temperature on the rate of the backward reaction.

(1 marks)

DSE12PP_13

In an experiment, excess aqueous ammonia is added to an aqueous solution of copper(II) sulphate. The following equilibrium is established and the resulting solution is deep blue in color.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$$

(a) Write an expression of K_c for this reaction.

(1 mark)

(b) If the above equilibrium mixture contains 0.0020 mol dm^{-3} of $Cu^{2+}(aq)$ ions, 0.0014 mol dm^{-3} of $NH_3(aq)$ and 0.0800 mol dm^{-3} $Cu(NH_3)_4^{2+}(aq)$ ions, calculate K_c under the conditions of the experiment.

(2 marks)

(c) When $H_2SO_4(aq)$ is added slowly to the equilibrium mixture until in excess, a blue precipitate is formed and the precipitate subsequently dissolves in the excess acid forming a blue solution. Account for these observations with the help of relevant chemical equation(s).

(5 marks)

DSE12_13

Consider the reaction represented by the equation below:

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$$

In an experiment, 25.0 cm^3 of 0.010 M $Fe_2(SO_4)_3(aq)$ and 25.0 cm^3 of 0.010 M KSCN(aq) were mixed in a conical flask at room temperature, and equilibrium was attained.

(a) The concentration of $Fe(SCN)^{2+}(aq)$ in the mixture was 0.0043 M when equilibrium was attained. Calculate the equilibrium constant K_c for the above reaction at room temperature.

(3 marks)

(b) It is known that $FePO_4(s)$ is insoluble in water. Suggest what would be the effect on the equilibrium position if $Na_3PO_4(s)$ is added to the equilibrium mixture.

(1 mark)

DSE13_12 [Similar to ASL06(I)_04b, ASL07(II)_04a, b]

At 250 °C, the equilibrium constant K_c for the following reaction is 25 mol^{-1} dm^3.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

A 10 dm^3 sealed container, which is maintained at 250 °C, initially contains 0.50 mol of $PCl_3(g)$, 0.20 mol of $Cl_2(g)$ and 0.40 mol of $PCl_5(g)$.

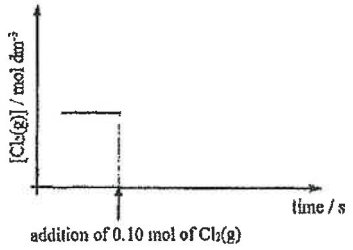
(a) For this system under the initial conditions, calculate its reaction quotient. Predict and explain, under the initial conditions, whether the forward reaction rate or the backward reaction rate would be greater.

(2 marks)

(b) Calculate the concentration of $Cl_2(g)$ when the system attains equilibrium at 250 °C.

(2 marks)

(c) 0.10 mol of $Cl_2(g)$ is added to the equilibrium mixture in (b). Sketch in the graph below, the variation of the concentration of $Cl_2(g)$ with time until a new equilibrium is attained. (Assume that the temperature of the system remains at 250 °C throughout the whole process.)



(1 mark)

DSE14_13 [Similar to DSE11SP_11]

Consider the reaction represented by the equation below:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

(a) In an experiment, 1.02 mol of NO(g) and 1.29 mol of $O_2(g)$ are mixed in a 50.0 dm^3 closed container maintained at 980 K. When equilibrium is attained, 61.0% of NO(g) is consumed.

(i) Calculate the equilibrium constant K_c for the above reaction under the experimental conditions.

(2 marks)

(ii) Discuss whether K_c would change if additional NO(g) is introduced into the above equilibrium mixture.

(2 marks)

(b) The values of K_c (in appropriate unit) for this reaction at different temperatures are shown below:

Temperature / K	600	700	800	900
K_c	6.88×10^6	2.97×10^5	2.89×10^3	4.68×10^2

Based on the above data, deduce whether the forward reaction is exothermic or endothermic.

(1 mark)

DSE15_11

Refer to the following chemical equation:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H > 0$$

Under fixed conditions, $[H_2O(l)]$ is considered as a constant. In consideration of the definition of K_c, $[H^+(aq)][OH^-(aq)]$ would also be a constant.

(a) The pH of an aqueous solution is defined as $-\log[H^+(aq)]$. The pH of water equals 7.0 at 298 K. Find, at this temperature, the:

(i) $[H^+(aq)]$

(1 mark)

(ii) $[H^+(aq)][OH^-(aq)]$

(2 marks)

(b) $[H_2O(l)]$ equals 55.6 mol dm^{-3} at 298 K. Suggest why $[H_2O(l)]$ is considered as a constant with reference to the values of $[H^+(aq)]$ and $[OH^-(aq)]$.

(1 mark)

(c) Explain whether the pH of water at 328 K would be less than 7.0, equal to 7.0, or greater than 7.0.

(2 marks)

DSE16_10 [Similar to AL11(II)_07]

In an experiment, 2.0 mol of $SO_2(g)$ and 2.0 mol of $O_2(g)$ are allowed to react in a closed container maintained at 950 K. The chemical equation for the reaction is shown below:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198 \text{ kJ mol}^{-1}$$

When the reaction attains dynamic equilibrium, 1.8 mol of $SO_3(g)$ is obtained.

(a) What is meant by the term 'dynamic equilibrium'?

(1 mark)

(b) At 950 K, the equilibrium constant K_c for the above reaction is 878 $dm^3\ mol^{-1}$. Calculate the volume of the container.

(3 marks)

(c) If the above equilibrium mixture is subjected to each of the following changes, will the number of moles of $SO_3(g)$ obtained increase, decrease or remain unchanged? Explain your answer in each case.

(i) Increasing the temperature

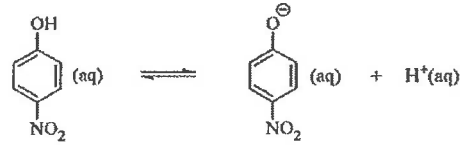
(1 mark)

(ii) Adding a suitable catalyst

(1 mark)

DSE17_11 [Similar to ASL04(II)_08, AL05(I)_03b]

The equation below shows the ionization of 4-nitrophenol in water:



4-nitrophenol (colorless) — 4-nitrophenoxide ion (yellow)

At 25°C, the equilibrium constant K_c for the ionization is 8.0×10^{-8} mol dm^{-3}.

(a) Write an expression for K_c.

(You may use HA to present 4-nitrophenol and A^- to represent 4-nitrophenoxide ion.)

(1 mark)

(b) When the above ionization attains equilibrium at 25°C, the pH of an aqueous of 4-nitrophenol is 2.4. Calculate the ratio of the concentration of 4-nitrophenol to the concentration of 4-nitrophenoxide ions in this solution.

(2 marks)

(c) Suggest if there is any color change when NaOH(aq) is added gradually into the solution in (b). Explain your answer.

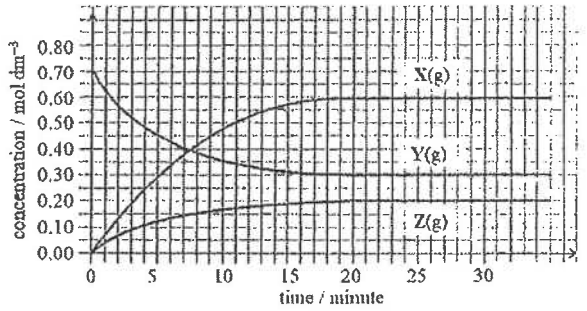
(2 marks)

(d) Suggest one possible use of 4-nitrophenol is acid-base titration experiment.

(1 mark)

DSE18_13 [Similar to ASL04(II)_09]

An experiment was performed for a reversible reaction involving X(g), Y(g) and Z(g) in a closed container of 2.0 dm^3 at a constant temperature. The graph below shows the relevant experimental data.



(a) According to the graph, how do you know that the reaction is reversible?

(1 mark)

(b) Calculate the equilibrium constant K_c for the reaction at the temperature of the experiment.

(3 marks)

(c) Comment on the following statement:

'*The rate of the forward reaction is zero at the 25th minute after the start of the reaction.*'

(1 mark)

DSE19_12 [Similar as DSE12_13]

Consider an equilibrium mixture of the following chemical reaction:

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$$

yellow colourless deep red

(a) Write an expression for the equilibrium constant K_c for the reaction.

(1 mark)

(b) At a certain temperature, the equilibrium constant K_c for the reaction is 1.08×10^3 $dm^3\ mol^{-1}$. The equilibrium mixture is prepared by mixing 20.0 cm^3 of 0.030 M $Fe(NO_3)_3(aq)$ with 10.0 cm^3 of 0.030 M KSCN(aq) in an acidic medium. Calculate the concentration of $Fe(SCN)^{2+}(aq)$ in the equilibrium mixture at that temperature.

(3 marks)

(c) It is known that the equilibrium constant K_c increases when temperature increases. Suggest and explain whether the enthalpy change of the reaction is positive, negative or zero.

(1 mark)

(d) When a little amount of $Na_2SO_3(s)$ is added to the equilibrium mixture, the colour of the mixture becomes paler. Explain this observation.

(2 marks)

DSE20_09

9. Consider the following reaction mixture at 25°C in a closed container of fixed volume :

$$\underset{\text{brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)}$$

(a) With reference to the table below, calculate **a**. Hence, determine the equilibrium constant K_c for the reaction at 25°C.

	$NO_2(g)$	$N_2O_4(g)$
Concentration at start / mol dm^{-3}	0.0400	0.0010
Concentration at equilibrium / mol dm^{-3}	0.0323	**a**

(3 marks)

(b) The temperature of the mixture is increased to 55 °C and its colour eventually turns darker. Deduce whether the reaction above is endothermic or exothermic.

DSE21_09

9. An experiment was performed for a reversible reaction involving $CH_4(g)$, $H_2S(g)$, $H_2(g)$ and $CS_2(g)$ in a closed container of a fixed volume of 2.0 dm^3 at a constant temperature. The equation for the reaction is shown below :

$$CH_4(g) + 2H_2S(g) \rightleftharpoons 4H_2(g) + CS_2(g)$$

(a) Write an expression for the equilibrium constant K_c for the reaction.

(b) The number of moles of each species at different times at that temperature are given in the table below :

	$CH_4(g)$	$H_2S(g)$	$H_2(g)$	$CS_2(g)$
Initial number of moles	0.04	0.08	0.08	0.04
Number of moles at equilibrium		0.11	0.02	0.025

(i) Fill in the number of moles at equilibrium for $CH_4(g)$ in the above table.

(ii) Calculate the equilibrium constant K_c for the reaction at that temperature.

(iii) If the volume of the closed container changes to 3.0 dm^3 while all other experimental conditions remain unchanged, explain whether K_c would increase, decrease or remain unchanged.

32. Consider the following equilibrium system :

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

Which of the following statements can demonstrate that chromium exhibits the characteristic(s) of transition metals ?

(1) $Cr_2O_7^{2-}(aq)$ ions are orange in colour.
(2) Adding HCl(aq) would shift the equilibrium position to the right.
(3) The oxidation states of chromium in CrO_4^{2-} and $Cr_2O_7^{2-}$ are the same.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

36. Consider the following statements and choose the best answer :

1st statement	**2nd statement**
At chemical equilibrium, the concentration of reactants must be equal to the concentration of products.	At chemical equilibrium, both forward reaction rate and backward reaction rate are equal to zero.

A. Both statements are true and the 2nd statement is a correct explanation of the 1st statement.
B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.
C. The 1st statement is false but the 2nd statement is true.
D. Both statements are false.

Marking Scheme

MCQ

ASL05(1)_01	D	DSE11SP_29	C	DSE11SP_35	B	DSE12PP_26	D
DSE12PP_31	D	DSE12_26	D (88%)	DSE12_27	A (60%)	DSE13_35	C (60%)
DSE13_27	D (61%)	DSE13_28	A (79%)	DSE14_26	B (68%)	DSE14_31	D (28%)
DSE14_35	D (80%)	DSE15_27	A (60%)	DSE15_31	B (61%)	DSE15_33	C
DSE16_26	B (60%)	DSE16_27	D (67%)	DSE17_31	B (56%)	DSE17_32	C (72%)
DSE17_34	D (42%)	DSE18_26	B (71%)	DSE18_29	B (48%)	DSE19_26	B
DSE19_27	D	DSE19_25	C	DSE20_26	B	DSE20_33	D

Structural Questions

ASL99(I)_03

(a) The reaction is endothermic since the value of K_c increases with increasing temperature. [1]

(a)

	$H_2(g)$	+	$CO_2(g)$	⟷	$CO(g)$	+	$H_2O(g)$
Before / mol	2		2				
At equil. / mol	$2-y$		$2-y$		y		y

[1]

$$K_c = \frac{[CO(g)][H_2O(g)]}{[H_2(g)][CO_2(g)]}$$

$$1.23 \times 10^{-1} = \frac{\left(\frac{y}{4}\right)^2}{\left(\frac{2-y}{4}\right)^2} \Rightarrow y = 0.520 \text{ mol}$$ [1]

$$[CO(g)] = \frac{0.520}{4} = 0.130 \text{ mol dm}^{-3}$$ [1]

(b) No change. [1]

Percentage yield only depends on the temperature. [1]

AL99(II)_04a

(i) When equilibrium is attained

$[N_2(g)] = 0.5 \times 0.75 = 0.375$ mol dm^{-3} [1]

$[H_2(g)] = 1.5 - 3 \times (0.5 \times 0.25) = 1.125$ mol dm^{-3} [1]

$[NH_3(g)] = 2 \times 0.5 \times 0.25 = 0.25$ mol dm^{-3} [1]

(ii) $$K_c = \frac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3} = \frac{(0.25)^2}{(0.375)(1.125)^3} = 0.117 \text{ mol}^{-2}\text{dm}^6$$ [2]

(iii) (I) K_c decreases with increasing temperature. [½]

The reaction is exothermic. ∴ increase in temperature will cause the equilibrium position to shift to the left. [½]

(II) The reaction proceeds slowly at low temperature. The yield of NH_3 is low at high temperature. [½]

[½]

∴ The procee is operated at around 723K.

ASL00(I)_04

(a) $CH_3COOH(l) + CH_3CH(OH)CH_3(l) \rightleftharpoons CH_3COOCH(CH_3)_2(l) + H_2O(l)$ [1]

(b) As catalyst to speed up the reaction. [1]

(c) (i) To prevent the disturbance of equilibrium position due to the removal of reactant / to prevent the equilibrium state of reaction shifts to the left due to the removal of reactant. [1]

(ii) Phenolphthalein [1]

(d) As the anti-bumping granule to ensure the smooth boiling process. [1]

(e) No. of mole of $CH_3COOH(l)$ in 1 cm^3 of mixture = $36.80 \times 10^{-3} \times 0.30 = 0.011$

$[CH_3COOH(l)] = [CH_3CH(OH)CH_3(l)] = 0.011 \div 1 \times 10^{-3} = 11.04$ mol dm^{-3} [1]

[No. of mole of $CH_3COOH(l)$ in 1 cm^3 of mixture after equilibrium

$= [17.15 - (36.90 - 36.8)] \times 10^{-3} \times 0.30 = 5.12 \times 10^{-3}$

$[CH_3COOH(l)] = [CH_3CH(OH)CH_3(l)]$ at equilibrium

$= 5.12 \times 10^{-3} \div 1 \times 10^{-3} = 5.12$ mol dm^{-3} [1]

	$CH_3COOH(l)$	+	$CH_3CH(OH)CH_3(l)$	⟷	$CH_3COOCH(CH_3)_2(l)$	+	$H_2O(l)$
Initial	11.04		11.04				
At equil.	$11.04-y$		$11.04-y$		5.92		5.92
	$= 5.12$		$= 5.12$				

$$K_c = \frac{[CH_3COOCH(CH_3)_2(l)][H_2O(l)]}{[CH_3COOH(l)][CH_3CH(OH)CH_3(l)]}$$ [1]

$$= \frac{(5.92)(5.92)}{(5.12)(5.12)} = 1.34$$ [1]

(f) Allow the mixture heating reflux for another hour and repeat the titration. If the volume of titrant used / amount of CH_3COOH remained is unchanged, the equilibrium has been attained. [1]

ASL01(I)_02

	(i) Adding a catalyst to the mixture	(ii) Increasing the temperature of the mixture
Effect on the rate of the forward reaction	Increase in the same extent	Increase in the smaller extent [2]
Effect on the rate of the backward reaction	Increase in the same extent	Increase in the larger extent [2]
Effect on the equilibrium position	remain unchanged	Shift to left (reactant side) [2]

AL02(I)_01a

(i) $H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

At equil. / mol dm^{-3} $\quad y \quad y \quad 10^{-6.10}$

$$K_a = \frac{[HCO_3^-(aq)][H^+(aq)]}{[H_2CO_3(aq)]}$$ [1]

In the solution, $[HCO_3^-(aq)] = [H_2CO_3(aq)]$

∴ $K_a = [H^+(aq)] = 10^{-6.10} = 7.94 \times 10^{-7}$ mol dm^{-3} [1]

(ii) $$K_a = \frac{[HCO_3^-(aq)][H^+(aq)]}{[H_2CO_3(aq)]}$$

$$7.94 \times 10^{-7} = \frac{[HCO_3^-(aq)]10^{-7.40}}{[H_2CO_3(aq)]}$$ [1]

$$\frac{[HCO_3^-(aq)]}{[H_2CO_3(aq)]} = \frac{7.94 \times 10^{-7}}{10^{-7.40}} = 20$$ [1]

(Accept answer from 19.8 to 20.0)

(1 mark for method; 1 mark for answer)

(iii) (I) During physical exertion, the concentration of CO_2 in blood increases. [½]

The equilibrium

$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$ [½]

shifts to the right. ∴ pH of blood will drop. [1]

(II) Blood contains high concentration of $HCO_3^-(aq)$ which reacts with H^+ produced. [1]
∴pH of blood is maintained within the narrow pH range.

AL02(I)_02a

Color of mixture becomes lighter instantaneously because there is an expansion in volume. [1]
As the reaction is endothermic, the color of mixture finally becomes darker because equilibrium shifts to the right. [1]

AL02(II)_03

(a) For reaction (1), $K_{c1} = \dfrac{[Ag(NH_3)_2{}^+(aq)]}{[Ag^+(aq)][NH_3(aq)]^2}$ [1]

For reaction (2), $K_{c2} = [Ag^+(aq)][Cl^-(aq)]$ [1]

(b) For reaction (3), $K_{c3} = \dfrac{[Ag(NH_3)_2{}^+(aq)][Cl^-(aq)]}{[NH_3(aq)]^2}$ [1]

$= \dfrac{[Ag(NH_3)_2{}^+(aq)]}{[Ag^+(aq)][NH_3(aq)]^2} \times [Ag^+(aq)][Cl^-(aq)] = K_{c1}\,K_{c2}$ [1]

$= 1.8\times10^{7} \times 2.0\times10^{-10} = 3.6\times10^{-3}$ [1]

(c) Assuming that $[[Ag(NH_3)_2]^+(aq)] = [Cl^-(aq)]$

$AgCl(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$

$0.1 - 2y \qquad y \qquad y$ mol dm^{-3}

$3.6\times10^{-3} = \dfrac{[Ag(NH_3)_2{}^+(aq)][Cl^-(aq)]}{[NH_3(aq)]^2} = \dfrac{y^2}{0.1-2y}$ [1]

$y = 5.36\times10^{-3}$ mol dm^{-3} [1]

Solubility of AgCl(s) $= 5.36\times10^{-3}$ mol dm^{-3}

(accept 5.3×10^{-3} mol dm^{-3} to 6.3×10^{-3} mol dm^{-3})

ASL02(II)_09 (modified)

(a) $H_2O(l)$ and $CH_3(CH_2)_3NH_3^+(aq)$ [1]

(b) $CH_3(CH_2)_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3(CH_2)_3NH_3^+(aq) + OH^-(aq)$

Initial / M 0.10

At equil. / M $0.10-y \qquad y \qquad y$

$K_c = 5.9\times10^{-4} = \dfrac{[CH_3(CH_2)_3NH_3{}^+(aq)][OH^-(aq)]}{[CH_3(CH_2)_3NH_2(aq)]} = \dfrac{y^2}{0.10-y}$ [1]

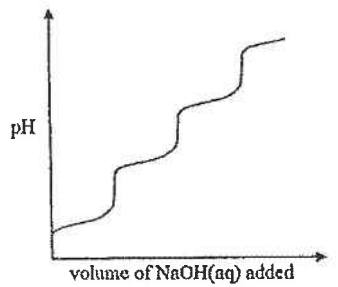
$y = [OH^-(aq)] = 7.68\times10^{-3}$ [1]

$pH = 14 - pOH = 14 - \log(7.68\times10^{-3}) = 11.9$ [1]

ASL03(I)_01

(a) After the removal of a hydrogen ion, the remaining species has an addition negative charge that attracts the remaining hydrogen atoms more strongly. [1]

(b)



[3]

(2 marks for a curve showing the neutralization of $H_3PO_4(aq)$, $H_2PO_4^-(aq)$ and $HPO_4^{2-}(aq)$ + 1 mark for labeling the axes)

ASL03(I)_05

(a) (i) ∵ pH = 2.9, ∴ $[H^+(aq)] = 10^{-2.9}$ M [1]

$C_3H_7COOH(aq) \rightleftharpoons C_3H_7COO^-(aq) + H^+(aq)$

At equil $0.1\text{ M} - y \qquad y \qquad y$

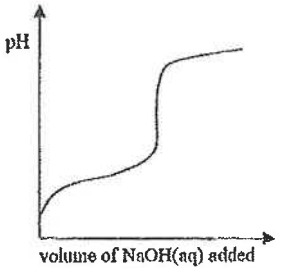
$y = 10^{-2.9}$ M

degree of dissociation $= 10^{-2.9} \div 0.1 = 0.0126$ [1]

(ii) $K_c = \dfrac{[H^+(aq)][C_3H_7COO^-(aq)]}{[C_3H_7COOH(aq)]} = \dfrac{(10^{-2.9})^2}{0.10-10^{-2.9}}$ [1]

$= 1.6\times10^{-5}$ mol dm^{-3} [1]

(b)



[3]

ASL03(II)_11

(a) Backward rate will decrease. [1]

Kinetic energy of the molecules decreases with decrease in temperature. [1]

Hence, the fraction of colliding molecules with K.E. greater than the activation energy becomes smaller. [1]

(b) (i) When the temperature of the mixture is lowered, the equilibrium position shifts to the left. The reaction is endothermic. [1] [1]

(ii) The dissociation of N_2O_4 requires breaking of covalent bond. [1]
∴ the reaction is endothermic.

(c) Treat the gas in the syringe with NaOH. [1]

ASL04(I)_04 (modified)

(a) $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ [1]

(b) $K_c = [H^+(aq)][OH^-(aq)]$ [1]

(c) (i) $[H^+(aq)] = \sqrt{K_c} = \sqrt{5.5 \times 10^{-14}}$ mol dm^{-3} $= 2.35 \times 10^{-7}$ mol dm^{-3} [1]

$pH = -\log(2.35 \times 10^{-7}) = 6.63$ [1]

(ii) Neutral because $[H^+(aq)] = [OH^-(aq)]$ [1]

(iii) **The value of K_w increases with temperature. That is, energy is absorbed when water undergoes auto-ionization. The process is endothermic.** [1]

ASL04(II)_08

(a) $ClO^-(aq) + H_2O(l) \rightleftharpoons HClO(aq) + OH^-(aq)$ [1]

(b) (i) $HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$

$$K_c = \frac{[H^+(aq)][ClO^-(aq)]}{[HClO(aq)]}$$

$$\frac{K_c}{[H^+(aq)]} = \frac{[ClO^-(aq)]}{[HClO(aq)]}$$

$pH = 7.50$, $\therefore [H^+(aq)] = 10^{-7.5}$ mol dm^{-3} [1]

$$\frac{[ClO^-(aq)]}{[HClO(aq)]} = \frac{2.95 \times 10^{-8}}{10^{-7.5}} = 0.933$$ [1]

(ii) The low pH of pool water would cause eye irritation of swimmers. [1]

(c) (i) $HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$ [1]

(ii) The equilibrium position will shift to the right. [1]

There is a greater number of aqueous species on the right. Dilution leads to a decrease in concentration of the aqueous species and the equilibrium position will shift to the right to counteract the effect of the change. [1]

ASL04(II)_09

(a) (i) From the curve, 1 mole of P(g) reacts with 2 moles of Q(g) to give 1 mole of R(g). [1]

Equation: $P(g) + 2Q(g) \longrightarrow R(g)$ [1]

(ii) The time required will become longer. [1]

In a larger container, the concentrations of reactants become smaller and hence the collision frequency decreases. [1]

(iii) **Colliding molecules will undergo reaction only if they possess an energy greater than the activation energy and collide in the right orientation.** [1]

(b) (i) From the curve, 1 mole of X(g) reacts with 2 molecules of Y(g) to give 2 moles of Z(g). [1]

Equation: $X(g) + 2Y(g) \rightleftharpoons 2Z(g)$

$$K_c = \frac{[Z(g)]^2}{[X(g)][Y(g)]^2}$$ [1]

(ii) (1) At the 5th minute, forward rate is greater than backward rate. [1]

(2) At the 35th minute, forward rate is equal to backward rate. [1]

(iii) The yield of product decreases. [1]

With an increase in volume, the total pressure decreases. The equilibrium position will shifts to the side with a greater number of moles of gases. [1]

AL05(I)_03b

(i) $$K_c = \frac{[Cy(aq)][H^+(aq)]}{[CyH^+(aq)]}$$ [1]

(ii) $pH = 3.00$, $[H^+] = 10^{-3}$ M [½]

$$\frac{[CyH^+(aq)]}{[Cy(aq)]} = 20$$

$$\frac{[CyH^+(aq)]}{[Cy(aq)]} = \frac{10^{-3}}{K_c} = 20$$ [½]

$K_c = 5 \times 10^{-5}$ M [1]

(iii) (I) $$K_c = \frac{[CySO_3H_2(aq)][H^+(aq)]}{[CyH^+(aq)][SO_2(aq)]}$$ [1]

(II)

	CyH^+	+ SO_2 + H_2O $\rightleftharpoons$	$CySO_3H_2$	+ H^+
At equil / M	0.1y	0.01	0.9y	10^{-3}

[1]

$$K_c = \frac{[CySO_3H_2(aq)][H^+(aq)]}{[CyH^+(aq)][SO_2(aq)]} = \frac{(0.9y)(10^{-3})}{(0.1y)(0.01)} = 0.9$$ [1]

ASL05(II)_08

(a) Experiment 1

	$Y_2(g)$ $\rightleftharpoons$	$2Y(g)$
Before / mole	4	0
After 1 day / mol	3	2
After 1 day / mol dm^{-3}	1.5	1

[1]

$$Q = \frac{[Y(g)]^2}{[Y_2(g)]} = \frac{(1)^2}{1.5} = \frac{2}{3} \text{ mol dm}^{-3}$$ [1]

Experiment 2

	$Y_2(g)$ $\rightleftharpoons$	$2Y(g)$
Before / mole	0	4
After 1 day / mol	$^4/_3$	$^4/_3$
After 1 day / mol dm^{-3}	$^2/_3$	$^2/_3$

[1]

$$Q = \frac{[Y(g)]^2}{[Y_2(g)]} = \frac{(^2/_3)^2}{^2/_3} = \frac{2}{3} \text{ mol dm}^{-3}$$ [1]

The system had already attained an equilibrium state because the two reaction quotients are the same. [1]

(b) (1) Yield of Y(g) will decrease.

When the volume of the container decreases, the pressure of the system will increase. [1]

The total number of moles of gaseous products is greater than that of gaseous reactants. [1]

∴ Increase in pressure will cause the equilibrium position to shift to the left.

∴ Less Y(g) will be formed.

(2) The yield of Y(g) will increase. [1]

For an endothermic reaction, increase in temperature will cause the equilibrium position to shift to the right / will lead to an increase in the value of K_c. ∴ more Y(g) will be formed. [1]

ASL06(I)_04

(a) Expected observation:

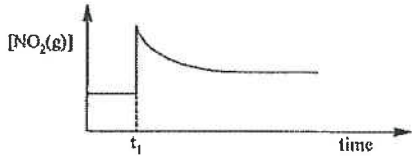
The brown color of the mixture turns deeper for a moment and then gets pater gradually. [2]

Reason:

When the plunger is moved from A to B, there is a decrease in volume and so an increase in the concentration of brown $NO_2(g)$. [1]

A decrease in volume will lead to a shift in the equilibrium position to the left, to produce a smaller number of moles of gaseous molecules, so that $[NO_2(g)]$ decreases. [1]

Graph



[1]

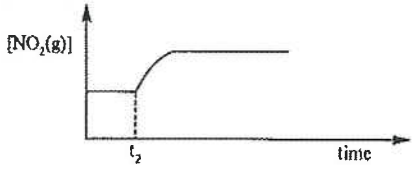
(b) Expected observation:

The brown color of the mixture gradually gets darker. [1]

Reason:

An increase in the concentration of N_2O_4 will shifts the equilibrium position to the right, so that $[NO_2(g)]$ increases. [1]

Graph



[1]

ASL06(II)_12 (modified)

(a) A weak acid is an acid that only partially ionize in water. [1]

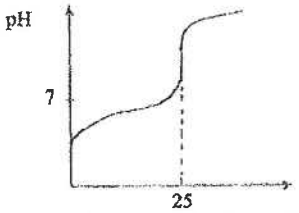
(b) $K_c = \dfrac{[H^+(aq)][CH_3CH_2COO^-(aq)]}{[CH_3CH_2COOH(aq)]}$

$1.35 \times 10^{-5} = \dfrac{y^2}{0.2 - y}$, where $y = [H^+(aq)]$ [1]

$y = 1.636 \times 10^{-3}$ [1]

$pH = -\log(1.636 \times 10^{-3}) = 2.79$ [1]

(c)



[2]

(d) (i) $K_c = \dfrac{[CH_3CH_2COOH(aq)][OH^-(aq)]}{[CH_3CH_2COO^-(aq)]}$

$= [H^+(aq)][OH^-(aq)]\dfrac{[CH_3CH_2COOH(aq)]}{[H^+(aq)][CH_3CH_2COO^-(aq)]} = \dfrac{K_w}{K_a}$ [1]

(ii) (1) $K_c = \dfrac{[CH_3CH_2COOH(aq)][OH^-(aq)]}{[CH_3CH_2COO^-(aq)]}$ [1]

$\dfrac{1.0 \times 10^{-14}}{1.35 \times 10^{-5}} = \dfrac{y^2}{0.2 - y}$ [1]

$[OH^-(aq)] = y = 1.217 \times 10^{-5}$ mol dm^{-3} [1]

(2) $pH = 14 - pOH$

$= 14 - \log(1.217 \times 10^{-5})$

$= 9.09$ [1]

ASL07(II)_04

(a) Reaction quotient, $Q = \dfrac{[COCl_2(g)]}{[CO(g)][O_2(g)]} = \dfrac{\frac{0.5}{4}}{\left(\frac{2}{4}\right)\left(\frac{1}{4}\right)}$ [1]

$= 1$ mol^{-1} dm^3 [1]

$Q > K_c$ ∴ Reaction will proceed to the left to achieve equilibrium. [1]

(b)

	$CO(g)$	+	$Cl_2(g)$	⟝	$COCl_2(g)$
Initial / mol	2		1		0.5
At equil / mol	$2+y$		$1+y$		$0.5-y$

[1]

$K_c = \dfrac{[COCl_2(g)]}{[CO(g)][O_2(g)]}$

$0.20 = \frac{(0.5-y)4}{(2+y)(1+y)}$, $\therefore y = 0.343$ [1]

$[COCl_2(g)] = \frac{0.5-0.343}{4} = 0.0339$ mol dm^{-3} [1]

(c) No change. K_c is a constant at a constant temperature. [1]

ASL08(I)_04

(a)

	$H_2(g)$	+	$I_2(g)$	⟹	$2HI(g)$
Initial / mol	4.0		2.0		0
At equil / mol	$4.0-y$		$2.0-y$		$2y$

[½]

$K_c = \frac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$ [1]

$50 = \frac{(2y)^2}{(4-y)(2-y)}$, $\therefore y = 1.87$ [½]

$[H_2(g)] = 0.426$ mol dm^{-3} [1]

$[I_2(g)] = 0.026$ mol dm^{-3} [½]

$[HI(g)] = 0.747$ mol dm^{-3} [½]

(b) (i) No change. [½]

There is no change in the number of moles of gases in the reaction. No shifting of equilibrium position will result. [1]

(ii) Increased [½]

The equilibrium position will shift to the right to give a greater number of moles of HI(g). [1]

ASL09(II)_02

(a) $K_c = [CO_2(g)]$ [1]

(b) Moles of $CO_2(g)$ in the equilibrium mixture = $2.7\times10^{-3} \times 5$ [1]

Moles of $CaCO_3(s)$ originally present = $25 \div (40.1 + 12 + 16\times3) = 0.2498$ [1]

% dissociation of $CaCO_3(s) = \frac{2.7\times10^{-3}\times5}{0.2498} \times 100\% = 5.4\%$ [1]

(c) Decrease [1]

The dissociation is an endothermic process. A decrease in temperature will cause the equilibrium position to shift to the left resulting in a smaller percentage of $CaCO_3(s)$ to undergo dissociation. [1]

(d) No. The equilibrium constant depends only on temperature. Adding $CaCO_3(s)$ to the system will not affect the concentration of $CO_2(g)$. [1]

AL10(I)_02 (modified)

(a) $[OH^-(aq)]$ in the saturated solution.

$= \frac{0.1\times9.0}{20} = 0.0455$ mol dm^{-3} [1]

(b) $Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$ [1]

Solubility of $Ca(OH)_2(s) = \frac{0.0455}{2} = 0.02275$ mol dm^{-3} [1]

(c) $Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$

$[Ca^{2+}(aq)] = \frac{0.0455}{2} = 0.02275$ mol dm^{-3} [1]

$K_c = [Ca^{2+}(aq)][OH^-(aq)]^2$ [1]

$= (0.02275)(0.0455)^2 = 4.71\times10^{-5}$ mol^3 dm^{-9} [1]

AL10(I)_03

Adding $H_2SO_4(aq)$ to $K_2CrO_4(aq)$: the yellow solution turn orange ($Cr_2O_7^{2-}$). [½]

$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$ [1]

Adding $FeSO_4(aq)$ to the orange solution: it turns green (Cr^{3+}). [½]

$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ [1]

AL10(II)_03

(a) (i)

	$N_2(g)$	+	$3H_2(g)$	⟹	$2NH_3(g)$
Before / mol	10		30		--
At equil / mol	$10-y$		$30-3y$		$2y$

Total no. of mole of gaseous species = $(10-y) + (30-3y) + 2y = 40-2y$

∵ mole percentage of $NH_3 = 39\%$

$\therefore \frac{2y}{40-2y} = 0.39$, $y = 5.61$

$\therefore$ concentration of $NH_3(g) = 5.61\times2 \div 50 = 0.2244$ mol dm^{-3} [1]

$\therefore$ concentration of $N_2(aq) = (10-5.61) \div 50 = 0.0878$ mol dm^{-3} [1]

$\therefore$ concentration of $H_2(aq) = (30-3\times5.61) \div 50 = 0.2634$ mol dm^{-3} [1]

(ii) $K_c = \frac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3} = \frac{(0.2244)^2}{(0.0878)(0.2634)^3}$ [1]

$= 31.38$ mol^{-2} dm^6 [1]

(b) Increase the pressure of the system [1]

Remove ammonia by liquefaction and pass the unreacted $N_2(g)$ and $H_2(g)$ back into the reaction chamber. [1]

AL11(II)_06

(a) Observation: solution changes from yellow to orange [1]

Equation: $2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$ [1]

ASL11(II)_06

(a) Trial 2 & 5 [1]

Explanation: The mole ratios of $N_2(g)$ to $H_2(g)$ ar the same in the filve trials. $\therefore$ The equilibrium position of the reaction is affected by temperature and pressure only. In trial 2 and 5, both pressure and temperature are the same, thus they have the same yield of $NH_3(g)$. [1]

(b) Trial 3

Explanation: The reaction is exothermic, low temperature will favour the formation of product. [1]

There is a smaller number of molecules on the product side than on the reactant side. Increase in pressure will favor the formation of product. In trial 3, the pressure is greatest while the temperature is lowest. [1]

(c) Any TWO of the following: [2]

- Under the operation conditions, the percentage conversion of $N_2(g)$ to $NH_3(g)$ is reasonably high and the use of catalyst can speed up the reaction.
- Operating the process at 200 atm (much lower than 1000 atm) can help reduce the maintenance cost of the pipelines.
- Operating the process at 673 K makes the reaction to proceed at a reasonably fast rate without having a great increase on fuel cost.

AL11(II)_07 (modified)

(a) [1]

	$2SO_2(g)$	+	$O_2(g)$	⟛	$2SO_3(g)$
Initial / mol	0.20		0.20		0
At equil. / mol	0.04		0.12		0.16
At equil / mol dm^{-3}	$0.04/V$		$0.12/V$		$0.16/V$

[1]

$$K_c = \frac{[SO_3(g)]^2}{[SO_2(g)]^2[O_2(g)]} = \frac{\left(\frac{0.16}{V}\right)^2}{\left(\frac{0.04}{V}\right)^2\left(\frac{0.12}{V}\right)} = \frac{(0.16)^2}{(0.04)^2(0.12)} = 11.73$$ [1]

$V = 88\ cm^3$ [1]

(b) (i) Decrease. The no. of gas molecules on the product side is smaller than that on the reactant side. [1]

Decrease in pressure will cause the equilibrium position to shift to the left.

(ii) Increase. The reaction is exothermic. Decrease in temperature will cause the equilibrium position to shift to the right. [1]

(iii) No change. A catalyst will increase the rate of the forward reaction and that of the backward reaction to the same extent and has no effect on the equilibrium constant. [1]

ASL12(I)_01

(b) The blood-red color is due to the formation of $[Fe(SCN)]^{2+}$. [1]

$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq)$ [½]

OH^- ion binds more strongly with Fe^{3+} ion than SCN^- ion does.

If the solution is made alkaline, brown $Fe(OH)_3(s)$ will be formed instead. [1]

$Fe^{3+}(aq) + 3OH^-(aq) \rightleftharpoons Fe(OH)_3(s)$ [½]

ASL12(I)_07

(a) $K_c = \frac{[SO_4^{2-}(aq)]}{[I^-(aq)]^2}$ [1]

(b) Add $PbSO_4(s)$ to the standard KI(aq).

Stir the mixture thoroughly, and allow it to stand in a water bath at 313 K for a long period of time. [2]

(c) Collect the supernatant solution by filtering off solids / decantation. [1]

Pipette a known volume of the solution and transfer it to a (conical) flask. [1]

(d)

	$PbSO_4(s)$	+	$2I^-(aq)$	⟛	$PbI_2(s)$	+	$SO_4^{2-}(aq)$
Initial / mol dm^{-3}			0.100				
At equil / mol dm^{-3}			0.072				0.014

$[SO_4^{2-}(aq)]_{eq} = \frac{0.1 - 0.072}{2} = 0.014\ mol\ dm^{-3}$ [1]

$K_c = \frac{[SO_4^{2-}(aq)]}{[I^-(aq)]^2} = \frac{0.014}{(0.072)^2} = 2.7\ (mol\ dm^{-3})^{-1}$ [1]

ASL12(II)_01 (modified)

(a)

	$NH_3(aq)$	+	$H_2O(l)$	⟛	$NH_4^+(aq)$	+	$OH^-(aq)$
Initial / mol dm^{-3}	0.10						
At equil / mol dm^{-3}	$0.10 - y$				y		y

$K_c = \frac{[NH_4^+(aq)][OH^-(aq)]}{[NH_3(aq)]} = \frac{y^2}{0.10 - y} = 1.8 \times 10^{-5}$ [1]

$y^2 = 1.8 \times 10^{-6} - 1.8 \times 10^{-5}y$

$y = [OH^-(aq)] = 1.33 \times 10^{-3}$ [1]

$pH = 14 - pOH = 14 - \log(1.33 \times 10^{-3}) = 11.0$ [1]

(b)

	$NH_3(aq)$	+	$H_2O(l)$	⟛	$NH_4^+(aq)$	+	$OH^-(aq)$
At equil / mol dm^{-3}	x				y		10^{-4}

$K_c = \frac{[NH_4^+(aq)][OH^-(aq)]}{[NH_3(aq)]} = \frac{[NH_4^+(aq)]10^{-4}}{[NH_3(aq)]} = 1.8 \times 10^{-5}$ [1]

$\frac{[NH_4^+(aq)]}{[NH_3(aq)]} = 0.18$

Hence, $[NH_3(aq)] : [NH_4^+(aq)] = 5.56$ [1]

(c) The solution contains both $NH_3(aq)$ and $NH_4^+(aq)$ ions in large amounts. [½]

When a small amount of acid (or alkali) is added to the solution, the $H^+(aq)$ ions (or $OH^-(aq)$ ions) added with be consumed by the $NH_3(aq)$ (or $NH_4^+(aq)$ ions). [½]

The equilibrium position will shift to the left (right_ to counteract the change and the change in pH is small. [1]

ASL13(I)_04

(a)

	$CO(g)$	+	$H_2O(g)$	⟹	$CO_2(g)$	+	$H_2(g)$
Initial / mol	0.10		0.10		--		--
At equil / mol	0.10×(1–74%) = 0.026		0.026		0.074		0.074

$$K_c = \frac{[CO_2(g)][H_2(g)]}{[CO(g)][H_2O(g)]} = \frac{\left(\frac{0.074}{V}\right)^2}{\left(\frac{0.026}{V}\right)^2} = \left(\frac{0.074}{0.026}\right)^2$$ [1]

$= 8.10$ [1]

(b) (i) The forward reaction is exothermic. [½]

Increase in temperature will shift the equilibrium position to the left thus decreasing the concentration of $H_2(g)$. [½]

(ii) K_c is a constant at a fixed temperature. When extra $CO(g)$ is introduced into the container, moe $CO(g)$ will react with $H_2O(g)$ to maintain a constant value of K_c. [½] ∴ Concentration of $H_2(g)$ will increase. [½]

AL13(I)_01

(c) $CoCl_2 \cdot xH_2O(s)$ ⟹ $CoCl_2(s) + xH_2O(l)$ [1]

pink blue

With the addition of water, the equilibrium position shifts to the left to give pink $CoCl_2 \cdot xH_2O(s)$. [½]

Heating $CoCl_2 \cdot xH_2O(s)$ removes water. The equilibrium position shifts to the right to give anhydrous $CoCl_2(s)$ [½]

ASL13(II)_03

(a) Reaction (1)

$K_{c1} = [Mg^{2+}(aq)][OH^-(aq)]^2$ [½]

Reaction (2)

$K_{c2} = [Ni^{2+}(aq)][OH^-(aq)]^2$ [½]

(b) (i) $K_a = \frac{[Mg^{2+}(aq)]}{[Ni^{2+}(aq)]}$ [1]

$K_a = \frac{[Mg^{2+}(aq)]}{[Ni^{2+}(aq)]} = \frac{[Mg^{2+}(aq)][OH^{2-}(aq)]^2}{[Ni^{2+}(aq)][OH^{2-}(aq)]^2} = \frac{K_{c1}}{K_{c2}}$ [1]

$= \frac{2.0 \times 10^{-11}}{6.3 \times 10^{-18}} = 3174603 = 3.17 \times 10^6$ [1]

(ii)

	$Mg(OH)_2(s)$	+	$Ni^{2+}(aq)$	⟹	$Ni(OH)_2(s)$	+	$Mg^{2+}(aq)$
Initial / mol			0.010				
At equil / mol			$0.010 - y$				$+y$

$3.17 \times 10^6 = \frac{[Mg^{2+}(aq)]}{[Ni^{2+}(aq)]} = \frac{y}{0.010 - y}$ [1]

$y = 3.15 \times 10^{-9}$ mol dm^{-3} [1]

DSE11SP_11

(a) K_c increase with temperature. The equilibrium position shifts to the right when temperature is increased. [1]

∴, the forward reaction is endothermic. [1]

(b)

	$H_2(g)$	+	$CO_2(g)$	⟹	$CO(g)$	+	$H_2O(g)$
Initial conc. / mol dm^{-3}	0.5		0.5				
Equil conc. / mol dm^{-3}	$0.5 - y$		$0.5 - y$		y		y

$K_c = \frac{[CO(g)][H_2O(g)]}{[H_2(g)][CO_2(g)]}$

$1.23 \times 10^{-1} = \frac{y^2}{(0.5 - y)(0.5 - y)}$ [1]

$y = 0.130$ mol dm^{-3} [1]

(c) The rate of the backward reaction increases. [1]

DSE12PP_13

(a) $K_c = \frac{[Cu(NH)_4^{2+}(aq)]}{[Cu^{2+}(aq)][NH_3(aq)]^4}$ [1]

(b) $K_c = \frac{0.0800}{(0.0020)(0.0014)^4} = 1.04 \times 10^{13}$ (mol dm^{-3})$^{-4}$ [2]

(1 mark for answer; 1 mark for correct units)

(c) $H_2SO_4(aq)$ reacts with the $NH_3(aq)$ present:

$H^+(aq) + NH_3(aq) \longrightarrow NH_4^+(aq)$ [1]

OR, $H_2SO_4(aq) + 2NH_3(aq) \longrightarrow (NH_4)_2SO_4(aq)$

Removal of $NH_3(aq)$ causes the position of the following equilibrium to shift to the left. [1]

$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$ [1]

$NH_3(aq)$ is a weak base:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ [1]

When $[Cu^{2+}(aq)]$ builds up it will react with the $OH^-(aq)$ ions to give the blue precipitate.

$Cu^{2+}(aq) + OH^-(aq) \longrightarrow Cu(OH)_2(s)$

When excess $H_2SO_4(aq)$ is added, it will react with the $Cu(OH)_2(s)$ formed to give a blue solution.

(3 marks for chemical equations; 1 mark for explanation of the shift in equilibrium position; 1 mark for the formation of blue precipitate.)

DSE12_13

(a) $[Fe^{3+}(aq)]_{\text{initial after mixing}} = 0.010 \times 2 \times 25 \div (25 + 25) = 0.01$ M [1]

$[SCN^-(aq)]_{\text{initial after mixing}} = 0.010 \times 25 \div (25 + 25) = 0.005$ M

	$Fe^{3+}(aq)$	+	$SCN^-(aq)$	⟹	$Fe(SCN)^{2+}(aq)$
Initial / mol dm^{-3}	0.01		0.005		
Reacted / mol dm^{-3}	$0.01 - 0.0043$		$0.005 - 0.0043$		
At eqm / mol dm^{-3}	0.0057		0.0007		0.0043

$$K_c = \frac{[Fe(SCN)^{2+}(aq)]}{[Fe^{3+}(aq)][SCN^-(aq)]} = \frac{0.0043}{(0.0057)(0.0007)}$$ [1]

$= 1078\ mol^{-1}\ dm^3$ (accept $1080\ mol^{-1}\ dm^3$, no mark for wrong unit) [1]

(b) The equilibrium position will shift to the left hand side / reactant side. [1]

DSE13_12

(a) $$\text{Reaction quotient} = \frac{0.04}{(0.05)(0.02)}\ mol^{-1}dm^3$$

$= 40\ mol^{-1}\ dm^3$ [1]

$\because$ Reaction quotation $> K_c$

$\therefore$ Backward reaction rate is greater than the forward reaction rate. [1]

(b) At equilibrium, the concentrations are:

$[PCl_5(g)] = (0.04 - y)\ mol\ dm^{-3}$

$[PCl_3(g)] = (0.05 + y)\ mol\ dm^{-3}$

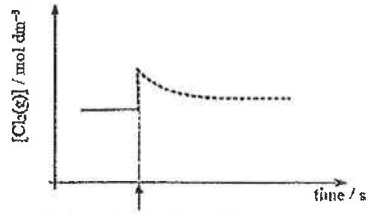
$[Cl_2(g)] = (0.02 + y)\ mol\ dm^{-3}$

$$\frac{0.04 - y}{(0.05 + y)(0.02 + y)} = 25$$ [1]

Solving equation, $y = 0.0052$

$[Cl_2(g)]_{eqm} = (0.02 + 0.0552)\ mol\ dm^{-3} = 0.0252\ mol\ dm^{-3}$ [1]

(c)



[1]

The final equilibrium level of $[Cl_2]$ should lie between the original level and the level when 0.1 mol of Cl_2 was just added.

DSE14_13

(a) (i)

	$2NO(g)$ +	$O_2(g)$ ⇌	$2NO_2(g)$
Initial conc.:	$1.02 \div 50$	$1.29 \div 50$	
	$= 0.0204$	$= 0.0258$	
Equil conc.:	0.0204×0.39	$0.0258 - 0006222$	0.0204×0.61
	$= 0.007956$	$= 0.019578$	$= 0.012444$

$$K_c = \frac{[NO_2(g)]^2}{[NO(g)]^2[O_2(g)]} = \frac{(0.012444)^2}{(0.007956)^2(0.019578)}$$ [1]

$= 125\ dm^3\ mol^{-1}$ (accept 118 – 125) (not accept M^{-1}) [1]

(accept maximum 3 decimal places)

(ii) No change, because K_c is independent of concentration / only depends on temperature. [1]

(b) As revealed from the data, when temperature increases, K_c decreases. Therefore the forward reaction is exothermic. [1]

OR, As higher temperature favors endothermic side of reaction, so the forward reaction is exothermic.

DSE15_11

(a) (i) $-\log[H^+(aq)] = 7.0$

$[H^+(aq)] = 10^{-7}\ mol\ dm^{-3}$ [1]

(ii) $[H^+(aq)] = [OH^-(aq)] = 10^{-7}\ mol\ dm^{-3}$ [1]

$[H^+(aq)][OH^-(aq)] = (10^{-7})(10^{-7}) = 10^{-14}\ mol^2\ dm^{-6}$ [1]

(b) Because $[H_2O(l)] >> [H^+(aq)]$ and $[OH^-(aq)]$ [1]

OR, Only a very small amount of H_2O is ionized to give $H^+(aq)$ and $OH^-(aq)$

(c) The pH of water would be less than 7. [1]

The ionization of $H_2O(l)$ is endothermic. Increasing the temperature will shift the equilibrium position to the right. [1]

DSE16_10

(a) At dynamic equilibrium, the rate of forward reaction is equal to the rate of backward reaction, and not equals zero. [1]

OR, At dynamic equilibrium, reactants are converted to products and products are converted to reactants at equal rate. No net change is observed.

(b)

	$2SO_2(g)$	+ $O_2(s)$ ⇌	$2SO_3(g)$
Initial / mol	2	2.0	
At equil. / mol	$2 - 2y$	$2 - y$	$2y$
At equil. / mol	$2 - 2(0.9) = 0.2$	$2 - 0.9 = 1.1$	1.8

[1]

$$878 = \frac{\left(\frac{1.8}{V}\right)^2}{\left(\frac{0.2}{V}\right)^2\left(\frac{1.1}{V}\right)}$$ [1]

$V = 11.92\ dm^3$ (Accept: 12, 11.9, 11.92, 11.923. Not accept: 12.0, 11.90) [1]

(c) (i) **Decrease. The reaction is exothermic. Increase in temperature will cause the equilibrium position to shift to the left.** [1]

(ii) **No change. A catalyst will increase the rate of forward reaction and that of backward reaction to the same extent.** [1]

A catalyst has no effect on the equilibrium position.

DSE17_11

(a) $$K_c = \frac{[H^+(aq)][A^-(aq)]}{[HA(aq)]}$$ [1]

(Accept no state symbols are given in the expression)

(b) In the solution, $2.4 = -\log [H^+(aq)]$ [1]

$[H^+(aq)] = 4.0 \times 10^{-3}$ mol dm^{-3}

Accept 3.98×10^{-3} to 4.0×10^{-3}

$$8.0\times10^{-8} = \frac{4.0 \times 10^{-3}[A^-(aq)]}{[HA(aq)]}$$

$$\frac{[HA(aq)]}{[A^-(aq)]} = 50000 \quad \text{(Accept 49750 to 50000)}$$ [1]

(c) The equilibrium position will shift to right, when H^+ ions are consumed by NaOH(aq). [1]

(Also accept: The rate of the backward reaction decreases / HA will decompose to compensate for the loss of H^+, forming more A^-)

HA is colorless while A^- is yellow. Increase in $[A^-]$ cause the solution changes from colorless to yellow / the color/yellow color becomes more intense. [1]

(d) Indicator / use to find out the end-point of acid-base titration. [1]

DSE18_13

(a) None of the final concentration of X(g), Y(g) and Z(g) is equal to zero. [1]

OR X, Y, Z co-exist in the system, and their concentrations remain unchanged after a long period of time.

OR The concentration of the reactant, Y, is still not equal to zero after a long period of time.

(b) $2Y(g) \rightleftharpoons 3X(g) + Z(g)$ [1]

$$K_c = \frac{[X(g)]^3[Z(g)]}{[Y(g)]^2} = \frac{(0.60)^3(0.20)}{(0.30)^2} = 0.48 \text{ mol}^2\text{dm}^{-6}$$ [2]

1 mark for correct equation or K_c expression

1 mark for correct final concentrations of X, Y and Z, and substituting the numbers into the expression

1 mark for correct numerical answer with correct unit. Not accept M^2.

(c) The statement is INCORRECT.

At the 25th minute after the reaction has started, the reaction attained dynamic equilibrium. [1]

OR The rate of forward reaction is equal to the rate of backward reaction (and both of rates are not equal to zero).

DSE19_12

(a) $$K_c = \frac{[Fe(SCN)^{2+}(aq)]}{[Fe^{3+}(aq)][SCN^-(aq)]}$$ [1]

(State symbols not required)

(b) $[Fe^{3+}(aq)]_{\text{initial after mixing}} = 0.030 \times 20 \div 30 = 0.020$ M

$[SCN^-(aq)]_{\text{initial after mixing}} = 0.030 \times 10 \div 30 = 0.010$ M

	$Fe^{3+}(aq)$	+	$SCN^-(aq)$	$\rightleftharpoons$	$Fe(SCN)^{2+}(aq)$
At eqm / mol dm^{-3}	$0.020 - y$		$0.010 - y$		y

[1]

$$K_c = \frac{[Fe(SCN)^{2+}(aq)]}{[Fe^{3+}(aq)][SCN^-(aq)]} = \frac{y}{(0.020 - y)(0.010 - y)} = 1.08 \times 10^{-3}$$ [1]

$y = 0.0217$ mol dm^{-3} (rejected since larger than both 0.020 and 0.010)

$y = 9.21 \times 10^{-3}$ mol dm^{-3} [1]

NOT accept 9×10^{-3} / 9.2097×10^{-3} mol dm^{-3}

(Accept max. 4 sig.figs) (Correct unit is required)

(c) Increasing of K_c means that the equilibrium position is shifted to the right /product side, hence the ΔH should be positive. [1]

(d) • $Na_2SO_3(s)$ added reacts with $Fe^{3+}(aq)$ so as to decrease the concentration of $Fe^{3+}(aq)$. [1]

• The equilibrium position shifts to the left / reactant side. The concentration of $Fe(SCN)^{2+}$ decreases, the colour of the mixture becomes paler. [1]

DSE20_09

9. (a) $K_c = [N_2O_4(g)] / [NO_2(g)]^2$ 1*

$[NO_2(g)]_{eqm} = 0.0323$ mol dm^{-3}

$a = [N_2O_4(g)]_{eqm} = 0.001 + (0.04 - 0.0323) / 2 = 0.00485$ mol dm^{-3} 1*

$K_c = 0.00485 / (0.0323)^2 = 4.649$ mol^{-1}dm^3 (Accept 4.65 – 4.66) 1

(Correct unit is required) (Not Accept M^{-1} or (mol dm^{-3})$^{-1}$)

(Accept answer with maximum 4 decimal places)

(b) • More NO_2 is formed and the equilibrium position shifts to left / shifts to reactant side when the temperature increases. 1

• Increase temperature shifts equilibrium position to endothermic direction. Therefore, the forward reaction is exothermic. 1

(No 2nd mark if no deduction is given, or the deduction is incorrect. e.g. The reaction is exothermic as the equilibrium position shifts to right when the temperature increases.)

SECTION 11 Chemistry of Carbon Compounds

Multiple-Choice Questions

Part 1: Organic reaction and Part 2: Plastic

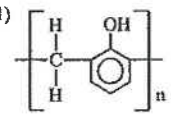
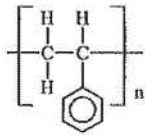
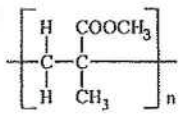
CE90_39

A glass of sweet wine is left on a dinning table. After two days, the wine becomes sour. Which of the following type of reactions accounts for this change?

A. oxidation
B. hydrolysis
C. fermentation
D. esterification

CE90_41

Which of the following polymers is/are made by condensation polymerization?

(1) 
(2) 
(3) 

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

CE91_30

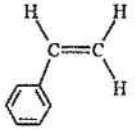
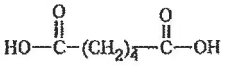
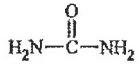
Propan-1-ol is refluxed with acidified potassium permanganate solution for a long time. Which of the following descriptions is/are correct?

(1) The reactants undergo esterification.
(2) Propanoic acid is formed.
(3) The permanganate is reduced.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE91_40

Which of the following compounds would react with each other to form a condensation polymer?

(1) 
(2) 
(3) 

A. (1) and (2)
B. (1) and (3)
C. (2) and (4)
D. (3) and (4)

CE92_06

0.01 mol of C_2H_5OH is burnt completely in oxygen. What are the numbers of moles of carbon dioxide and water formed respectively?

	carbon dioxide	water
A.	0.01	0.03
B.	0.02	0.03
C.	0.02	0.06
D.	0.04	0.06

CE92_20

Which of the following compounds does NOT react with propan-1-ol?

A. sodium
B. bromine water
C. acidified potassium permanganate solution
D. ethanoic acid

CE92_41

A compound, $C_2H_4O_2$, react with ethanol in the presence of concentrated sulphuric acid to form a product with a fruity smell.

Which of the following statements about this compound is/are correct?

(1) It can liberate carbon dioxide from sodium carbonate solution.
(2) It can decolourize acidified potassium permanganate solution.
(3) Its aqueous solution is an electrolyte.

A. (3) only
B. (1) and (2) only
C. (1) and (3) only
D. (1), (2) and (3)

CE92_47

1st statement	2nd statement
Polyester is a thermoplastic.	Polyester is formed by condensation polymerization.

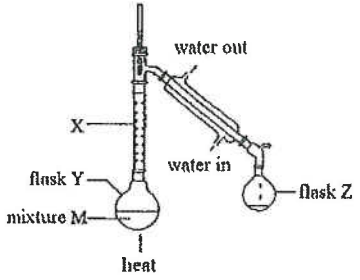
CE93_30

Directions: CE93_30 and CE93_31 refer to the following experiment:

A mixture of methyl propanoate and sulphuric acid was allowed to react by heating under reflux for some time until equilibrium was reached. The resulting mixture M was then transferred to flask Y and heated as shown below:

What is the function of the piece of apparatus labelled X?

A. to condense the products in M
B. to separate the products in M
C. to prevent the loss of the products in M due to evaporation
D. to prevent the loss of the reactants in M due to evaporation



CE93_31

The first fraction of the distillate collected in flask Z is mainly

A. methanol.
B. propan-1-ol.
C. methanoic acid.
D. propanoic acid.

CE93_43

Which of the following reagents can be used to distinguish between aluminium sulphate solution and lead(II) ethanoate solution?

A. barium chloride solution
B. sodium hydroxide solution
C. nitric acid
D. hydrochloric acid

CE94_19

Which of the following substances can turn an acidified solution of potassium permanganate colourless?

A. ethane
B. ethanol
C. ethanoic acid
D. ethyl ethanoate

CE94_42

Which of the following substances can be fermented to give an alcoholic drink?

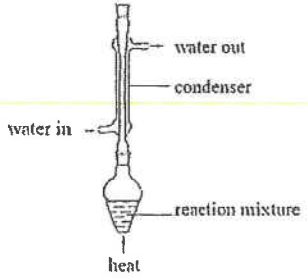
(1) grapes
(2) wheat
(3) potatoes

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE96_23

Directions: Q.23 and Q. 24 refer to the following experiment.

A reaction mixture containing acidified potassium dichromate solution and ethanol is heated using the set-up shown below:



In this experiment, the reaction mixture is undergoing

A. reflux.
B. distillation.
C. emulsification.
D. fractional distillation.

CE96_24

Which of the following statements concerning this experiment is correct?

A. The acidified potassium dichromate solution acts as a catalyst.
B. The reaction mixture gradually becomes brown.
C. Ethanol is reduced during the experiment.
D. Ethanoic acid is formed during the experiment.

CE96_41

Which of the following statements concerning propan-1-ol are correct?

(1) propan-1-ol can be used as a solvent.
(2) propan-1-ol can undergo polymerization.
(3) propan-1-ol can undergo esterification with ethanoic acid in the presence of concentration sulphuric acid.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE97_15

Which of the following substances, when mixed, would produce a precipitate?

A. chlorine water and potassium bromide solution
B. ethyl ethanoate and ethanol
C. iron(III) sulphate solution and aqueous ammonia
D. nitric acid and potassium hydroxide solution

CE97_20

When a glass of wine is left overnight, it becomes sour. Which of the following reactions is responsible for this change?

A. fermentation
B. oxidation
C. dehydration
D. esterification

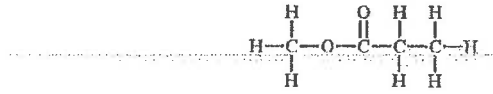
CE98_48

1st statement	2nd statement
The ethanol content of beer is less than that of red wine.	Beer is made by fermentation of barley while red wine is made by fermentation of grapes.

CE99_26

Directions: Q.26 and Q.27 refer to the following experiment:

Some concentrated sulphuric acid and pumice stones were added to an alkanol and an alkanoic acid. The mixture was heated under reflux for some time and the following compound was obtained:



Which of the following combinations is correct?

	Alkanol	Alkanoic acid
A.	methanol	ethanoic acid
B.	methanol	propanoic acid
C.	ethanol	ethanoic acid
D.	ethanol	propanoic acid

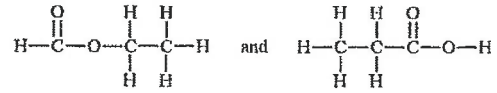
CE99_27

Which of the following statements concerning the experiment is correct?

A. Concentrated sulphuric acid acts as an oxidizing agent in the reaction.
B. The purpose of using pumice stones is to speed up the reaction.
C. A fractionating column should be used in the experimental set-up.
D. Heating under reflux can prevent the loss of reactants and products.

CE00_13

Consider the compounds represented by the two structures below:

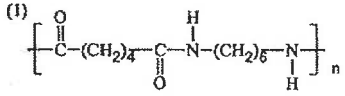
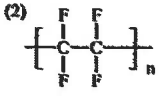
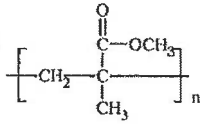

and

Which of the following statements concerning these compounds is correct?

A. Both compounds can turn wet blue litmus paper red.
B. Both compounds have the same odour.
C. Both compounds have the same molecular formula.
D. Both compounds have the same boiling point.

CE00_36

Which of the following polymers is/are made by condensation polymerization?

(1)

(2)

(3)


A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE01_21

Which of the following statements concerning ethanol and butan-2-ol is INCORRECT?

A. Both compounds can dissolve iodine.
B. Both compounds can be represented by the same general formula.
C. The boiling point of ethanol is higher than that of butan-2-ol.
D. Each compound can be obtained by catalytic hydration of the corresponding alkene.

CE01_25

The reaction involved in the preparation of ethanoic acid from ethanol is

A. an addition.
B. a condensation.
C. a redox.
D. a dehydration.

CE01_50

1st statement	2nd statement
The reaction of ethanoic acid with ethanol is a neutralization.	Water is one of the products formed in the reaction of ethanoic acid with ethanol.

CE04_17

The following paragraph was extracted from the laboratory report of a student on the preparation of an organic compound.

> $CH_3CH_2CO_2H$ and CH_3CH_2OH were heated with a small amount of concentrated H_2SO_4 in a test tube for a few minutes. The resultant mixture was then added to a beaker of cold water.

Which of the following statements concerning the experiment is correct?

A. The compound prepared was ethyl ethanoate.
B. Concentrated H_2SO_4 acted as an oxidizing agent.
C. The preparation involved a condensation.
D. When the resultant mixture was added to the cold water, a white precipitate was formed.

CE04_27

Ethane can be prepared by heating ethanol with excess concentrated sulphuric acid. The reaction involved can be represented by the equation:

$$CH_3CH_2OH \xrightarrow{\text{conc. } H_2SO_4} CH_2{=}CH_2 + H_2O$$

The type of reaction involved in the preparation is

A. cracking.
B. condensation.
C. addition.
D. dehydration.

CE04_33

Which of the following processes is/are involved in the production of whisky?

(1) heating under reflux
(2) distillation
(3) fermentation

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE05_24

Which of the following health hazards are related to excessive drinking of spirits?

(1) liver damage
(2) stomach damage
(3) lung damage

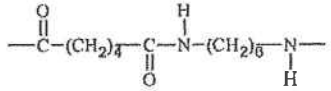
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE05_49

1st statement	2nd statement
Polyester is an addition polymer.	Polyester softens on heating.

CE06_43

The repeating unit of polymer X is shown below:



Which of the following statements about X is/are correct?

(1) X is an addition polymer.
(2) X is formed from two different monomers.
(3) X is a thermosetting plastic. [OUT]

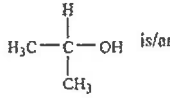
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

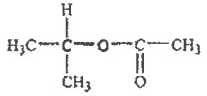
CE07_16

A mixture containing 25 cm^3 of $CH_3CH_2CH_2OH$, 25 cm^3 of CH_3COOH and 1 cm^3 of concentrated H_2SO_4 is heated under reflux. After some time, a pleasant smell is detected. Which of the following statements concerning this experiment is correct?

A. A redox reaction is involved.
B. The reaction cannot go to completion.
C. Concentrated H_2SO_4 acts as a reactant.
D. One of the products is ethyl propanoate.

CE07_23

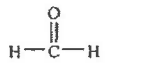
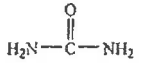
Which of the following statements concerning  is/are correct?

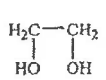
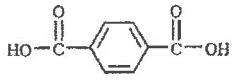
(1) It is neutral to litmus solution.
(2) Its systematic name is propanol.
(3) When it reacts with ethanoic acid, the ester formed is 

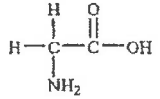
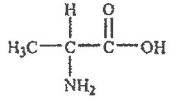
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE07_42

Which of the following pairs of compound can form condensation polymers?

(1)  

(2)  

(3)  

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE08_47

The empirical formula of an organic compound T is CH_2O. Effervescence occurs when T is added to sodium carbonate solution. T may be

(1) $HCOOCH_3$.
(2) $CH_3CH(OH)COOH$.
(3) $CH_3CH_2CH_2COOH$.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE09_12

An organic compound X has the molecular formula $C_3H_4F_2$. Which of the following statements concerning X is correct?

A. X has at least four possible structures.
B. X must be a saturated compound.
C. X turns acidified potassium dichromate solution from orange to green.
D. X can be used to make a thermosetting plastic by addition polymerization.

CE09_24

Which of the following substances can react with acidified potassium permanganate solution?

(1) propene
(2) potassium iodide solution
(3) sodium sulphite solution

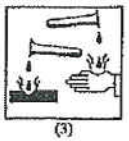
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE09_25

Which of the following hazard warning labels should be displayed on the reagent bottle of methanol?


(1)


(2)


(3)

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE09_27

Esters can be used to make

(1) perfumes,
(2) food additives,
(3) solvent for paint.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

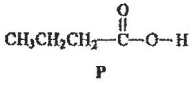
CE10_07

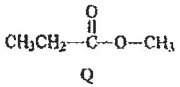
In an experiment, a mixture of ethanol and acidified potassium permanganate solution is heated under reflux to obtain ethanoic acid. Which of the following apparatus should be used in the experiment?

A. stopper
B. thermometer
C. fractionating column
D. water condenser

CE10_18

The structures of compounds P and Q are shown below:


P

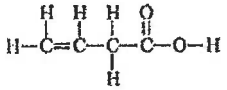

Q

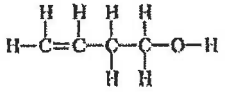
Which of the following statements is correct?

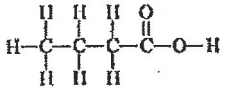
A. P and Q are both acids.
B. P is more volatile than Q.
C. P dissolves in water readily but Q does not.
D. P and Q both decolourlise bromine water rapidly.

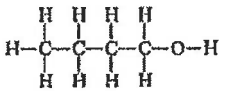
CE10_38

Compound E rapidly decolourises cold acidified potassium permanganate solution. When E is added to sodium hydrogencarbonate solution, effervescence occurs. Which of the following compounds may E be?

A. 

B. 

C. 

D. 

CE11_13

Propene reacts with bromine dissolved in organic solvent to give

A. 1-bromopropane.
B. 2-bromopropane.
C. 1,2-dibromopropane.
D. 1-bromopropane and 2-bromopropane.

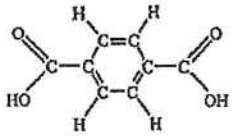
CE11_15

What is the chemical formula of the organic product formed from the reaction between ethanol and propanoic acid under suitable conditions?

A. $CH_3COOC_3H_7$
B. $C_2H_5COOCH_3$
C. $C_2H_5COOC_2H_5$
D. $C_3H_7COOC_2H_5$

CE11_34

The two compounds shown below undergo condensation polymerization under suitable conditions.


and $HO-CH_2-CH_2-OH$

What small molecule would be eliminated in this condensation polymerization?

A. H_2O
B. H_2O_2
C. CH_3OH
D. HCOOH

CE11_48

1st statement	2nd statement
Nylon has cross-links among the polymer chains.	Nylon is a condensation polymer.

CE11_39

In an experiment, a mixture of coconut oil and excess concentrated sodium hydroxide solution is heated for some time. Then a small amount of concentrated sodium chloride solution is added to the reaction mixture with stirring. A solid product is eventually formed. Which of the following statements concerning this experiment is correct?

A. The solid formed is glycerol.
B. This experiment involves emulsification.
C. The purpose of this experiment is to prepare a soapless detergent.
D. The purpose of adding concentrated sodium chloride solution is to salt out the product formed.

CE11_50

1st statement	2nd statement
Propane can change acidified potassium permanganate solution from purple to colourless.	Substitution reaction occurs when propane is added to acidified potassium permanganate solution.

Part 3: Soaps and Soapless detergents

CE90_37

Clothes stained with grease can be cleaned by detergents because detergents can

(1) decrease the surface tension of water.
(2) dissolve in both water and grease.
(3) emulsify greasy particles.

Which of the following combinations is correct?

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE90_38

Which of the following statements concerning the production of soap from vegetable oils and sodium hydroxide solution is/are correct?

(1) Sodium hydroxide acts as a catalyst.
(2) Glycerol is formed at the end of the reaction.
(3) The reaction between vegetable oils and sodium hydroxide solution is reversible.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE91_33

Which of the following statements is/are true for soapless detergents?

(1) All soapless detergents are not biodegradable.
(2) Soapless detergents form a scum with sea water.
(3) Soapless detergents are mainly manufactured from products of the petroleum industry.

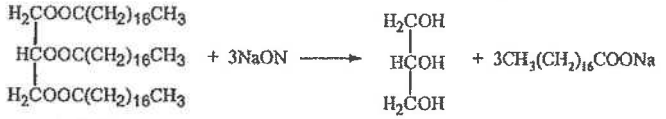
A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

CE91_49

1st statement	2nd statement
In the preparation of soap, sodium chloride is added after the reaction between oil and sodium hydroxide has been completed.	Sodium chloride can increase the solubility of soap.

CE92_23

Direction Q.22 and Q.23 refer to the making of soap as represented by the following reaction:



animal fat soap

Soap has a hydrophilic head and hydrophobic tail. Which of the following combination is correct?

	Hydrophilic head	Hydrophobic tail
A.	Na^+	$CH_3(CH_2)_{16}-$
B.	$-COO^-$	$CH_3(CH_2)_{16}-$
C.	Na^+	$CH_3(CH_2)_{16}COO^-$
D.	$CH_3(CH_2)_{16}COO^-$	Na^+

CE93_44

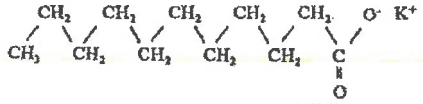
Which of the following statements is INCORRECT?

A. Tin is used for making food cans.
B. Sulphuric acid is used for making soap.
C. Ammonium chloride is used for making dry cells.
D. Chlorine is used for sterilizing drinking water.

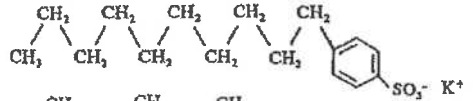
CE94_24

Directions: Q.24 and Q.25 refer to the structural formulae of the following three detergents:

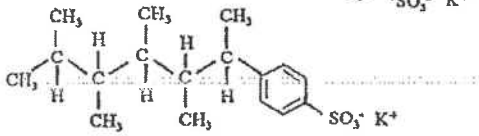
detergent I



detergent II



detergent III



Which of the above is/are soapless detergent(s)?

A. detergent I only
B. detergent III only
C. detergents I and II only
D. detergents II and III only

CE94_25

Which of the following statements concerning these detergents is correct?

A. The hydrocarbon tail of detergent III is hydrophilic.
B. Both detergents I and II form scum with seawater.
C. Detergent III causes more serious pollution problems than detergent I when discharged into rivers.
D. Both detergents II and III are made from fats.

CE96_28

Directions: Q.28 and Q.29 refer to the following experiment used to study the causes of hardness of water.

A student added some soap solution to four test tubes containing the same volume of different aqueous solutions of the same molarity. He shook the tubes and measured the minimum volume of soap solution needed to form a permanent lather. The results are tabulated below:

Aqueous solution	Minimum volume of soap solution needed to form a permanent lather / cm^3
Sodium chloride	0.6
Calcium chloride	9.3
Potassium chloride	0.9
Magnesium chloride	8.5

Which of the following apparatus would be most suitable for measuring the volume of soap solution?

A. 50 cm^3 burette
B. 50 cm^3 measuring cylinder
C. 25 cm^3 pipette
D. 10 cm^3 beaker

CE96_29

Which of the following substances is/are responsible for the hardness of water?

(1) sodium chloride
(2) calcium chloride
(3) potassium chloride
(4) magnesium chloride

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (4) only

CE97_35

Dilute ammonia solution is used in domestic glass cleaners because

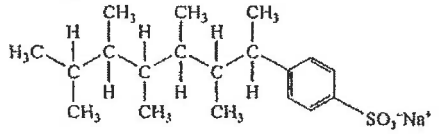
(1) it can saponify grease.
(2) it is non-corrosive.
(3) it contains ammonium ions which can emulsify grease.

Which of the above statements is/are correct?

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE98_15

A detergent has the following structure:



Which of the following statements concerning the detergent is correct?

A. Its hydrocarbon chain is hydrophilic.
B. It can be manufactured from vegetable oil.
C. It is readily degraded by micro-organisms.
D. It acts as an emulsifier in the cleaning process.

CE98_41

Which of the following problems are associated with the excessive use of soapless detergents?

(1) They can cause skin allergies.
(2) They form foam when discharged into rivers and lakes.
(3) They form scum when discharged into the sea.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE99_43

Which of the following statements concerning a soapless detergent are correct?

(1) It can be prepared by heating a cooking oil with sodium hydroxide solution.
(2) It acts as a wetting agent by reducing the surface tension of water.
(3) It acts as n emulsifying agent in the cleaning process.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE99_48

1st statement	2nd statement
Local tap water produces a scum with soap.	Water containing calcium ions can form an insoluble compound with soap.

CE00_18

Some potassium carbonate solution is added to a sample of tap water. The mixture then appears cloudy. Which of the following ions is probably present in the sample?

A. NH_4^+
B. Mg^{2+}
C. Br^-
D. SO_4^{2-}

CE00_41

Which of the following statements concerning soaps are correct?

(1) They are esters.
(2) They can reduce the surface tension of water.
(3) Their aqueous solutions are alkaline.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE01_16

Which of the following statements is correct for a soapy detergent but incorrect for a soapless detergent?

A. Its structure consists of a hydrophilic part and a hydrophobic part.
B. It forms a lather when shaken with distilled water.
C. It can be made by reacting a vegetable oil with an alkali.
D. It acts as an emulsifier in the cleaning process.

CE01_21

In a boiler using hard water, scale is deposited on its interior after a period of time. The scale consists mainly of metal carbonates. Which of the following substances can be used to remove the boiler scale?

A. soapless detergent
B. chlorine bleach
C. sodium hydroxide solution
D. vinegar

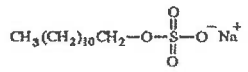
CE03_19

Soap was prepared by heating fat with sodium hydroxide solution for some time. Concentrated sodium chloride solution was then added to the resulting mixture. The purpose of adding concentrated sodium chloride solution is

A. to help the precipitation of soap.
B. to enhance the cleansing power of the soap.
C. to reduce the alkalinity of the soap.
D. to act as a preservative for the soap.

CE03_29

A detergent has the structure shown below:



Which of the following statements concerning this detergent is correct?

A. It is non-biodegradable.
B. It functions well in hard water.
C. It can be manufactured from vegetable oils.
D. The portion, $CH_3(CH_2)_{10}CH_2-$, is hydrophilic.

CE03_49

1st statement	2nd statement
Sodium carbonate can be used to soften hard water which contains calcium ions.	Sodium carbonate reacts with calcium ions in hard water to form a precipitate.

CE04_04

Which of the following substances is the poorest electrical conductor?

A. vinegar
B. household bleach
C. soap solution
D. antiseptic alcohol

CE04_22

The main chemical constituent of bleaching power is calcium hypochlorite. Which of the following statements concerning bleaching power is INCORRECT?

A. It works effectively with soaps in cleaning processes.
B. It can be used as a domestic sterilizing agent.
C. It reacts with acids readily to give chlorine.
D. It bleaches by oxidation.

CE04_49

1st statement	2nd statement
Sodium chloride is used in the manufacture of soap.	Sodium chloride helps the precipitation of soap from soap solution.

CE05_32

Which of the following substances is NOT used for the preparation of soaps?

A. vegetable oil
B. sodium hydroxide solution
C. concentrated sodium chloride solution
D. concentrated sulphuric acid

CE05_42

Which of the following statements concerning soaps are correct?

(1) Soaps are biodegradable.
(2) Soaps have good cleaning power in hard water.
(3) The structure of a soap particle consists of a hydrophilic part and a hydrophobic part.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE06_26

Which of the following statements concerning the cleansing actin of a detergent are correct?

(1) It reduces the surface tension of water.
(2) It acts as an emulsifying agent.
(3) It reacts with grease to form soluble products.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE06_42

Which of the following materials is/are used in the production of soap?

(1) petroleum fractions
(2) sodium hydroxide
(3) sulphuric acid

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE07_50

1st statement	2nd statement
Soapy detergent can be used to treat oil spillage on sea surface.	Soapy detergent can act as an emulsifying agent for oil.

CE08_35

Which of the following statements concerning a soapy detergent is correct?

A. It can increase the surface tension of water.
B. It contains a hydrophobic hydrocarbon chain.
C. It can be manufactured from petroleum products.
D. It contains a positive ionic part for carrying out emulsification.

CE09_45

Which of the following statements concerning soapy and soapless detergents are correct?

(1) They both are emulsifying agents.
(2) They both contain hydrophobic and hydrophilic parts.
(3) Soapy detergent is biodegradable while soapless detergent is non-biodegradable.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

CE09_50

1st statement	2nd statement
Discharge of synthetic detergents into rivers may cause rapid growth of algae.	Synthetic detergents may contain nutrients for the growth of algae.

CE10_41

The structure of a detergent is shown below:

$CH_3(CH_2)_{15}COO^-Na^+$

Which of the following statements concerning this detergent is correct?

A. It is non-biodegradable.
B. It forms scum in sea water.
C. It is manufactured from petroleum.
D. The hydrophilic part responsible for its cleansing action is Na^+.

CE11_47

Which of the following statements concerning soapy detergents and soapless detergents are correct?

(1) Soapy detergents can be made from fats whereas soapless detergents cannot.
(2) Soapy detergents form scum with sea water whereas soapless detergents do not.
(3) All soapy detergents are biodegradable whereas all soapless detergents are not.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

ASL08(I)_05

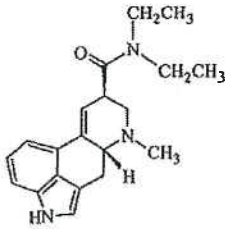
Which of the following compounds can be oxidized by acidified $Na_2Cr_2O_7(aq)$ at room temperature?

(1) CH_3CH_2OH
(2) CH_3COCH_3
(3) $(CH_3)_3COH$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

ASL09(I)_03

Lysergic acid diethylamide (LSD) is a stimulant drug with the following structure:



Which one of the following statements about LSD is correct?

A. It has one chiral centre and possesses an amine functional group.
B. It has one chiral centre and possesses an alkene functional group.
C. It has two chiral centres and possesses an amide functional group.
D. It has two chiral centres and possesses a ketone functional group.

ASL13(I)_03

Which of the following pairs of substances react to give ammonia?

(1) $(NH_4)_2SO_4(s)$ and $Ca(OH)_2(s)$
(2) $NaNH_2(s)$ and $H_2O(l)$
(3) $CH_3CONH_2(aq)$ and $KOH(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE11SP_26

Which of the following conversions is a substitution reaction?

A. $CH_3CH_2CH{=}CH_2 \longrightarrow CH_3Ch_2CHBrCH_3$
B. $CH_3CH_2CH_2CH_2OH \longrightarrow CH_3CH_2CH_2CHO$
C. $CH_3CH_2CHOHCH_3 \longrightarrow CH_3CH_2CHBrCH_3$
D. $CH_3CH_2CH_2CO_2H \longrightarrow CH_3CH_2CH_2CH_2OH$

DSE11SP_27

A compound with an ester functional group has a molecular formula of $C_4H_8O_2$. What is the number of possible structures of the compound?

A. 3
B. 4
C. 5
D. 6

DSE11SP_28

Which type of reaction is involved in converting propan-2-ol to propene?

A. Addition
B. Oxidation
C. Dehydration
D. Substitution

DSE11SP_30

Hydrogen, methane and butane are commonly used fuels. Which of the following statements is correct?

A. Hydrogen is a more environmental friendly fuel than butane.
B. Methane burns with a more sooty flame than butane.
C. Hydrogen, methane and butane all belong to the same homologous series.
D. On complete combustion, one mole of methane releases more carbon dioxide than one mole of butane.

DSE11SP_31

The following is a series of reactions starting from ethanol:

$$\text{ethanol} \xrightarrow{\text{reagent A}} \text{P} \xrightarrow{Na_2CO_3(aq)} CO_2(g) + \text{Q}$$

Which of the following correctly describes the reagent A and the product Q?

	Reagent A	Product Q
A.	Dehydrating agent	Ethene
B.	Dehydrating agent	Ethane
C.	Oxidizing agent	Sodium ethanoate
D.	Oxidizing agent	Ethanoic acid

DSE11SP_34

Which of the following statements is/are correct concerning the numbers of the homologous series of alkenes?

(1) Members of higher molecular mass are often used to make soap.
(2) The first few members are often used to make polymers.
(3) The members can commonly react with hydrogen halides to give halohydrocarbons.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12PP_27

Consider the isomeric compounds shown below:

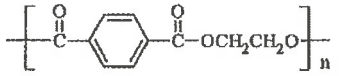
CH_3COCH_3 and CH_3CH_2CHO

Which of the following reagents can be used to distinguish between the two compounds?

A. Acidified potassium dichromate solution
B. Lithium aluminium hydride
C. Dilute sulphuric acid
D. pH indicator

DSE12PP_28

The structure of polymer X is shown below:



Which of the following statements about X is correct?

A. It possesses a ketone functional group.
B. It can undergo degradation in an acidic environment.
C. It has a giant covalent network structure.
D. It has a sharp melting point.

DSE12PP_33

Consider the following organic conversion:

$$(CH_3)_3COH \xrightarrow{X} (CH_3)_3Cl$$

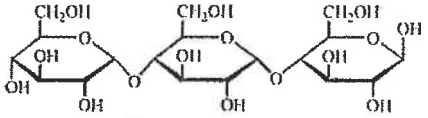
Which of the following reagents can X be?

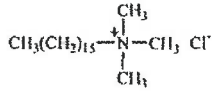
(1) $Cl_2(g)$
(2) $PCl_3(l)$
(3) Concentrated HCl(aq)

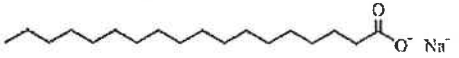
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12PP_34

Consider the following compounds: Which of these compounds can be used as active ingredients of detergents?

(1) 

(2) 

(3) 

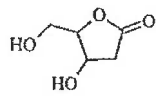
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE12PP_36

1st statement	2nd statement
The structural formula $H_2C=CF_2$ can represent two different compounds.	The rotation of the CF_2 group relative to the CH_2 group in $H_2C=CF_2$ is restricted by the C=C bond.

DSE12_28

The structure of an organic compound is shown below:



Which of the following statements is correct?

A. The compound does NOT show enantiomerism.
B. The molecular formula of the compound is $C_5H_6O_4$.
C. The compound contains a ketone group.
D. The compound can be oxidized by acidified $K_2Cr_2O_7$(aq).

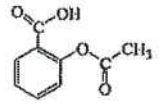
DSE12_29

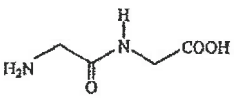
Which of the following statements concerning compound U ($CH_3CH_2CH=CHCH_2CH_2OH$) is correct?

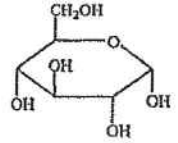
A. The empirical formula of U is C_5H_8O.
B. The systemic name of U is hex-4-en-ol.
C. U reacts with HCl to give a single product.
D. U can separately turn Br_2(aq) and acidified $KMnO_4$(aq) colorless.

DSE12_32

Which of the following structures represent(s) the active ingredient(s) in aspirin tablets?

(1) 

(2) 

(3) 

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12_33

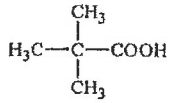
Which of the following compounds can be formed when $(CH_3)_2C(OH)CH_2CH_3$ is dehydrated?

(1) $(CH_3)_2C=CHCH_3$
(2) $(CH_3)_2CHCH=CH_2$
(3) $CH_2=C(CH_3)CH_2CH_3$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE12_34

The structure of a compound is shown below:



Which of the following statements concerning the compound are correct?

(1) It can form a salt with aqueous ammonia.
(2) It can be reduced to an alkanol by using $LiAlH_4$.
(3) It can form an ester with methanol under suitable conditions.

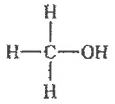
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE12_36

1st statement	2nd statement
2-Chlorobut-1-ene shows geometrical isomerism	2-Chlorobut-1-ene has a double bond.

DSE13_20

An organic compound has the following structure:



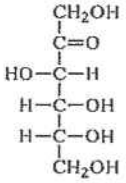
Which of the following statements about this compound is/are correct?

(1) It is immiscible with water.
(2) It is neutral to litmus solution.
(3) It burns with a non-luminous flame.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE13_29

The structure of fructose is shown on the right:

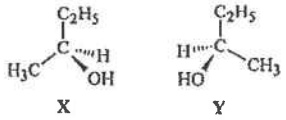


Which of the following statements about fructose is correct?

A. Its empirical formula is $C_6H_{12}O_6$.
B. It can turn acidified potassium dichromate solution from orange to green.
C. It is insoluble in water.
D. Its molecule has five chiral carbon centres.

DSE13_30

The three-dimensional structure of a molecule of compound X and that of compound Y are shown below:



X Y

Which of the following statements about X and Y is correct?

A. X and Y are identical.
B. X and Y are a pair of structural isomers.
C. A mixture of X and Y can be separated by fractional distillation.
D. X and Y have the same standard enthalpy change of combustion.

DSE13_31

Consider the compounds X and Y shown below:

X Y

Which of the following statements about X and Y is correct?

A. X and Y are a pair of geometrical isomers.
B. Both X and Y react with $H_2(g)$ in the presence of Ni(s).
C. X and Y react separately with Br_2 in CH_3CCl_3 to give the same organic product.
D. Both the polymerization of X and that of Y give the same addition polymer.

DSE13_32

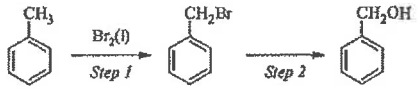
Which of the following statements about the action of sodium hydroxide solution on ethanamide is/are correct?

(1) Sodium ethanoate is formed in the reaction.
(2) In the reaction, sodium hydroxide act as catalyst.
(3) The reaction attains equilibrium if the reaction mixture is heated under reflex.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE13_34

Consider the following conversion of organic compounds:



Which of the following statements about the above conversion are correct?

(1) Excess $Br_2(l)$ should be used in *Step 1*.
(2) Light is needed in *Step 1*.
(3) The reagent used in *Step 2* can be KOH(aq).

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE13_35

In order to prepare 2-chloro-2-methylpropane, a mixture of 2-methylpropan-2-ol and concentrated hydrochloric acid is shaken vigorously.

$$(CH_3)COH \xrightarrow{\text{conc. HCl}} (CH)_3CCl$$

Which of the following statements about this preparation are correct?

(1) Two layers of liquids can be observed in the reaction mixture after shaking.
(2) The crude product should be washed with sodium carbonate solution.
(3) The unreacted 2-methylpropan-2-ol can be removed by simple distillation.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE14_27

Which of the following combinations concerning $CH_3CH{=}CHCH_2CH(C_2H_5)_2$ is correct?

	Number of geometrical isomers	Number of enantiomers
A.	2	4
B.	2	2
C.	0	2
D.	2	0

DSE14_28

Consider the following organic reactions where P, Q and R are the major organic products formed.

$$CH_3CH_2CH{=}CH_2 \xrightarrow{HBr(g)} P \xrightarrow{NaOH(aq)} Q \xrightarrow{K_2Cr_2O_7(aq)\,/\,H^+(aq)} R$$

Which of the following combinations is correct?

	P	Q	R
A.	$CH_3CH_2CHBrCH_3$	$CH_3CH_2CH(OH)CH_3$	$CH_3CH_2COCH_3$
B.	$CH_3CH_2CH_2CH_2Br$	$CH_3CH_2CH_2CH_2OH$	$CH_3CH_2CH_2CHO$
C.	$CH_3CH_2CH_2CH_2Br$	$CH_3CH_2CH{=}CH_2$	$CH_3CH_2CH(OH)CH_2OH$
D.	$CH_3CH_2CHBrCH_3$	$CH_3CH_2CH(OH)CH_3$	$CH_3CH_2CO_2H$

DSE14_32

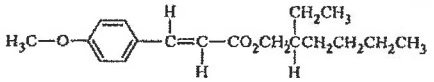
Which of the following statements concerning aspirin is/are correct?

(1) It undergoes esterification with ethanoic acid in the presence of an acid catalyst.
(2) It reacts with sodium carbonate solution to give a colorless gas.
(3) It can be used to reduce inflammation.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE14_33

A sunblock cream contains the compound below as the active ingredient:



Which of the following reagents can react with this compound?

(1) NaOH(aq)
(2) $PCl_3(l)$
(3) acidified $KMnO_4(aq)$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE14_34

The structure of a detergent is shown below:

Which of the following statements concerning the detergent are correct?

(1) It has a cleaning function in hard water.
(2) Vigorous shaking it with oil and water can form a stable emulsion.
(3) It can be formed by reacting a certain vegetable oil with NaOH(aq).

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE15_26

How many geometrical isomers does $H_3C{-}CH{=}CH{-}CH{=}CH{-}CH_3$ have?

A. 0
B. 2
C. 3
D. 4

DSE15_29

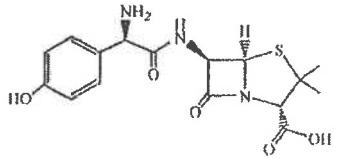
Consider the following conversion:

Which of the following combinations of reagents can achieve the above conversion?

A. NaOH(aq) and $CH_3OH(l)$
B. $CH_3OH(l)$ and $CH_3COOH(l)$
C. NaOH(aq), $H_2SO_4(aq)$ and $CH_3OH(l)$
D. $H_2SO_4(aq)$, NaOH(aq) and $CH_3COOH(l)$

DSE15_30

The structure of the antibiotic 'amoxicillin' is shown below:



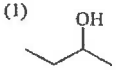
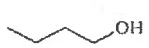
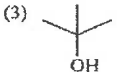
Which of the following functional groups is / are present in amoxicillin?

(1) ester
(2) amide
(3) hydroxyl

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE15_32

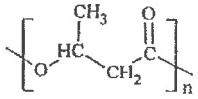
Which of the following compounds can react with acidified potassium dichromate solution to form a ketone?

(1) 
(2) 
(3) 

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE15_34

A polymer has the structure shown below:



Which of the following statements concerning the polymer is correct?

(1) Its intermolecular attraction is predominately hydrogen bond.
(2) The polymer chains can be broken in the presence of dilute hydrochloric acid.
(3) The polymer chains can be broken in the presence of dilute sodium hydroxide solution.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE16_28

Which of the following statements concerning but-1-ene and butan-1-ol is INCORRECT?

A. Both of the them can decolorize acidified $KMnO_4(aq)$.
B. Butan-1-ol can react with $PBr_3(l)$ while but-1-ene cannot.
C. Both of them can react with $H_2(g)$ in the presence of platinum.
D. But-1-ene can be obtained from heating butan-1-ol with $Al_2O_3(s)$

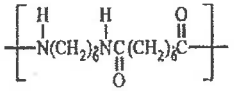
DSE16_29

The molecular formula of compound X is $C_4H_4O_4$. It has two –COOH groups. How many isomers may X have?

A. 5
B. 4
C. 3
D. 2

DSE16_31

Which of the following statements concerning nylon-6,6 is/are correct?

(1) It can be used to make ropes.
(2) The polymerization in forming it is a hydrolysis process.
(3) Its repeating unit is 

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE16_35

Soap can

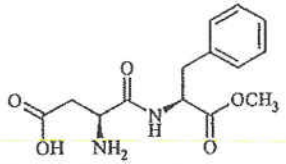
(1) be made from fats.
(2) emulsify oil particles.
(3) increase the surface tension of water.

Which of the following combinations is correct?

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE16_32

Aspartame is an artificial sweetener. The structure of it is shown below:



Which of the following statements concerning an aspartame molecule is/are correct?

(1) It has two ester groups.
(2) It has two chiral centres.
(3) It has two amide groups.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE17_18

The structures of organic compound A and B are shown below:

A B

Which of the following statements concerning the two compounds is/are correct?

(1) A and B belong to the same homologous series.

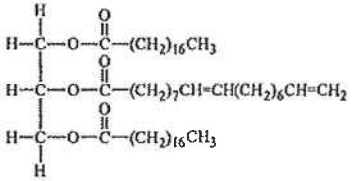
(2) A and B can be distinguished by acidified $KMnO_4$(aq).

(3) Complete combustion of 1.0 g of A and complete combustion of 1.0 g of B would form the same mass of CO_2(g).

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

DSE17_26



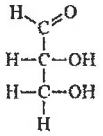
How many *cis-trans* isomers does this compound have?

A. 0 B. 2

C. 4 D. 8

DSE17_29

A compound has the following structure:



Which of the following statements concerning the compound is correct?

A. It can react with PCl_3.

B. It is insoluble in water.

C. It is optically inactive.

D. It has a ketone functional group.

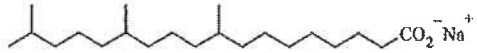
DSE17_33

The structures of three compounds are shown below:

(1)

(2)

(3)



Which of them can form a stable emulsion when shaken with oil and water vigorously?

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

DSE17_35

Which of the following processes can form ethanol?

(1) Heating ethanoic acid with $NaBH_4$

(2) Heating bromoethane with KOH(aq)

(3) Heating ethyl butanoate with NaOH(aq) under reflux

A. (1) and (2) only B. (1) and (3) only

C. (2) and (3) only D. (1), (2) and (3)

DSE17_36

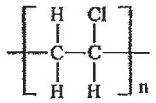
Consider the following statements and choose the best answer:

1st statement	2nd statement
Both $CH_3(CH_2)_3OH$ and $(CH_3)_3COH$ can react with acidified $K_2Cr_2O_7$(aq).	Both $CH_3(CH_2)_3OH$ and $(CH_3)_3COH$ have the same functional group.

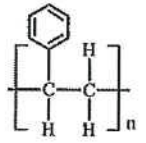
DSE18_27

Which of the following polymers is commonly used to make drainage pipes?

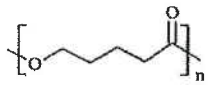
A.



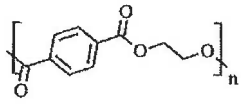
B.



C.



D.



DSE18_30

Consider the following conversion:

Which of the following combinations can achieve the above conversion?

	Reagent used in Step (I)	Reagent used in Step (II)
A.	Aqueous ammonia	Dilute sulphuric acid
B.	Aqueous potassium hydroxide	Dilute sulphuric acid
C.	Aqueous ammonia	Concentrated sulphuric acid
D.	Aqueous potassium hydroxide	Concentrated sulphuric acid

DSE18_31

Which of the following compounds CANNOT form condensation polymers?

(1) $H_2N(CH_2)_5CO_2H$
(2) $CH_3CO_2CH{=}CH_2$
(3) $CH_3CH(OH)CO_2H$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE18_34

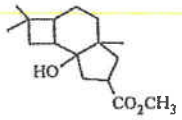
Which of the following statements concerning soap are correct?

(1) Soap is an ester.
(2) Soap can reduce the surface tension of water.
(3) Soap particles consists of both hydrophobic and hydrophilic parts.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE18_35

An organic compound has the following structure:



Which of the following statements concerning this compound are correct?

(1) It has an ester group.
(2) It contains at least one chiral centre.
(3) It reacts with acidified sodium dichromate solution to form a ketone.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE19_23

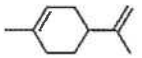
Which of the following statements concerning ethanol are correct ?

(1) It is flammable.
(2) It is soluble in water.
(3) It is more volatile than water.

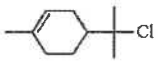
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

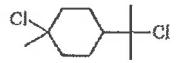
DSE19_29

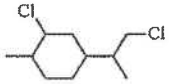
The structure of limonene is shown below :

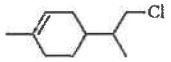


It reacts with excess HCl(g) to give Z as the major product. Which of the following is Z ?

A. 

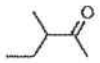
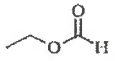
B. 

C. 

D. 

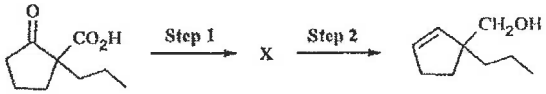
DSE19_31

Which of the following combinations is correct ?

	Structure	Systematic name
A.		3-ethylbutanone
B.		pentane-1,5-diamide
C.		ethyl methanoate
D.		pent-1-enal

DSE19_32

Consider the following conversion of organic compounds :



Which of the following combinations of steps is correct ?

	Step 1	Step 2
A.	$LiAlH_4$, dry ether; then $H^+(aq)$	NaOH(aq), heat
B.	$NaBH_4$, ethanol; then $H^+(aq)$	NaOH(aq), heat
C.	$LiAlH_4$, dry ether; then $H^+(aq)$	concentrated $H_2SO_4(l)$, heat
D.	$NaBH_4$, ethanol; then $H^+(aq)$	concentrated $H_2SO_4(l)$, heat

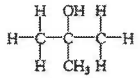
DSE19_36

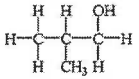
Consider the following statements and choose the best answer:

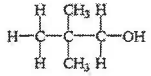
1st statement	2nd statement
CH_2=CHCH(CH_3)C_2H_5 can exhibit optical activity.	CH_2=CHCH(CH_3)C_2H_5 has one chiral centre.

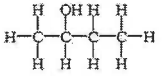
DSE2020:

27. Which of the following alkanols can form a ketone by warming with acidified sodium dichromate solution ?

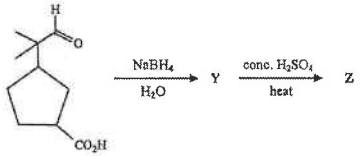
A. 

B. 

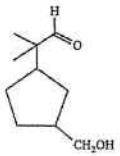
C. 

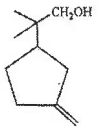
D. 

29. Refer to the following conversions :



Which of the following is a possible structure of Z ?

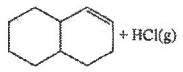
A. 

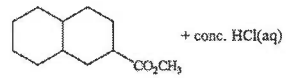
B. 

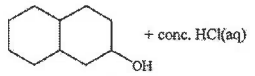
C. 

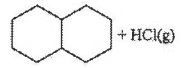
D. 

31. Which of the following pairs of reagents would NOT react with each other ?

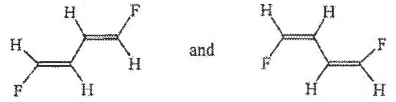
A. 

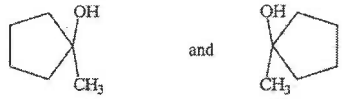
B. 

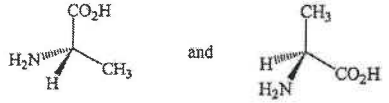
C. 

D. 

32. Which of the following pairs of compounds are isomers ?

(1) 

(2) 

(3) 

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

34. Which of the following statements concerning nylon-6,6 are correct ?

(1) Fishing net can be made from nylon-6,6.
(2) $H_2N(CH_2)_6NH_2$ is one of the monomers of nylon-6,6.
(3) The intermolecular attractions in nylon-6,6 are covalent bonds.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

36. Consider the following statements and choose the best answer :

1st statement	2nd statement
The rate of conversion from glucose to ethanol is increased by adding yeast.	The conversion from glucose to ethanol is catalysed by enzymes in yeast.

A. Both statements are true and the 2nd statement is a correct explanation of the 1st statement.
B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.
C. The 1st statement is false but the 2nd statement is true.
D. Both statements are false.

DSE2021:

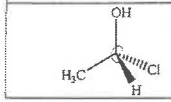
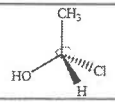
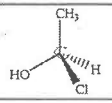
29. Consider the following reaction :

$HOOCCH_2COCH_2CHO \xrightarrow{NaBH_4(aq)} Y$

What is Y ?

A. $HOOCCH_2COCH_2CH_2OH$
B. $HOOCCH_2CH(OH)CH_2CHO$
C. $HOOCCH_2CH(OH)CH_2CH_2OH$
D. $HOCH_2CH_2CH(OH)CH_2CH_2OH$

30. Consider the information shown in the table below :

Structure of the molecules of the liquid in		
bottle A	bottle B	bottle C
		

Which of the following liquids have identical boiling point ?

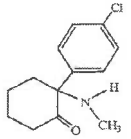
A. liquids in bottle **A** and bottle **B** only
B. liquids in bottle **A** and bottle **C** only
C. liquids in bottle **B** and bottle **C** only
D. liquids in bottle **A**, bottle **B** and bottle **C**

34. Which of the following mixtures would NOT separate into two liquid layers after heating under reflux for a period of time ?

(1) $HCOOCH_2CH_3(l)$ and excess NaOH(aq)
(2) $CH_3CH_2CH_2Cl(l)$ and excess concentrated NaOH(aq)
(3) $CH_3CH_2CHO(l)$ and excess acidified $K_2Cr_2O_7(aq)$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

35. The diagram below shows the structure of a compound.



Which of the following statements concerning the compound are correct ?

(1) It has an amide group.
(2) Its structure has only one chiral carbon.
(3) It can be converted to an alcohol by using an appropriate reducing agent.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

36. Consider the following statements and choose the best answer :

1st statement	2nd statement
Methyl ethanoate and ethyl methanoate have similar chemical properties.	Methyl ethanoate and ethyl methanoate are isomers.

A. Both statements are true and the 2nd statement is a correct explanation of the 1st statement.
B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.
C. The 1st statement is false but the 2nd statement is true.
D. Both statements are false.

Structural Questions

Part 1: Organic reaction

CE90_01a

The table below describes some reactions of liquid propan-1-ol:

EXPERIMENT	RESULT
1. Propan-1-ol is heated with acidified potassium permanganate solution.	Substance X is formed. X produces effervescence with sodium carbonate solution.
2. A mixture of propan-1-ol and substance X is heated with concentrated sulphuric acid.	A sweet smelling liquid Y is formed.
3. Propan-1-ol is heated and the vapour passes over heated broken porcelain.	Gas Z is produced.

(i) Name X.
Write an ionic equation for the reaction of X with sodium carbonate solution.
(ii) Write an equation for the formation of Y.
Suggest TWO functions of the concentrated sulphuric acid in experiment 2.

(4 marks)

CE90_03b

The formula of a weak alkanoic acid can be represented by
$C_nH_{2n+1}CO_2H$ (where n is an interger).

A sample of the alkanoic acid weighing 0.355 g was dissolved in about 20 cm^3 of water in a conical flask. The solution was then titrated against a 0.180 M sodium hydroxide solution. A total of 22.40cm^3 of the alkali was required for complete neutralization.

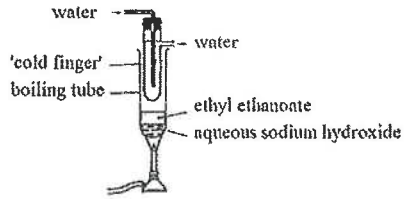
(i) Explain the meaning of the term 'weak acid'.
(ii) Describe how the end-point in this titration can be determined.
(iii) Calculate
(1) the number of moles of sodium hydroxide used for the titration.
(2) the relative molecular mass of the alkanoic acid.
(iv) (1) Deduce the molecular formula of the alkanoic acid.
(2) Draw TWO molecular structures for the alkanoic acid.

(Relative atomic masses: H = 1.0, C =12.0, O = 16.0)

(12 marks)

CE90_05b

A student heated a mixture of aqueous sodium hydroxide and ethyl ethanoate for some time using the following set-up:



(i) (1) Name the type of reaction that took place. Write an appropriate equation for the reaction.

(2) What would be observed when the reaction was complete?

(3) Give an industrial application of this type of reaction.

(ii) What is the function of the 'cold finger'?

(iii) State a potential hazard in the set-up shown above.

(iv) The quantity of the products obtained in this experiment was much less than that expected.

(1) Give an explanation for this.

(2) Draw a labelled diagram of a completely different set-up to illustrate how the quantity of the products can be increased by using the *same quantities of reactants*.

(9 marks)

CE92_03a

Fermentation of cooked rice produced an alcoholic drink which contains about 8% of ethanol.

(i) Describe briefly how such fermentation can be carried out in the laboratory.

(ii) How can the alcoholic drink be concentrated so as to raise its ethanol content to about 30%?

(iii) Some alcoholic drinks become sour when exposed to air for some time. Suggest a reason for this.

(iv) State one health hazard and one social problem associated with the excessive taking of alcoholic drinks.

(8 marks)

CE94_06b

The following paragraph was taken from a student's laboratory report:

'A mixture if ethanol, ethanoic acid and several drops of concentrated sulphuric acid was heated under reflux form some time. The resulting mixture was then cooled and poured into a beaker containing some saturated sodium chloride solution.'

(i) Draw a labelled diagram of the experimental set-up used for heating the mixture under reflux.

(ii) Why is it necessary

(1) to use concentrated sulphuric acid in the above experiment?

(2) to heat the mixture under reflux?

(iii) What would be observed when the resulting mixture was poured into the saturated sodium chloride solution?

(7 marks)

CE95_07b

The following flow diagram shows the conversion of a compound X to an acid Y.

$$X \longrightarrow \text{Ethanol} \xrightarrow{\text{oxidation}} Y$$

X can rapidly decolourize a solution of bromine in 1,1,1-trichloroethane.

(i) What is X? Name the industrial process by which X is converted to ethanol.

(ii) Write a chemical equation for the reaction between X and bromine.

(iii) (1) Give the systematic name of Y.

(2) Draw a labelled diagram of the laboratory set-up for the conversion of ethanol to Y.

(iv) Ethanol can be detected in the breath of a drunken driver. Suggest ONE chemical test to show the presence of ethanol in his breath and state the observable change produced by the test.

(9 marks)

CE96_02

The relative molecular mass of an alkanol X is 60.0. X contains 60% of carbon by mass.

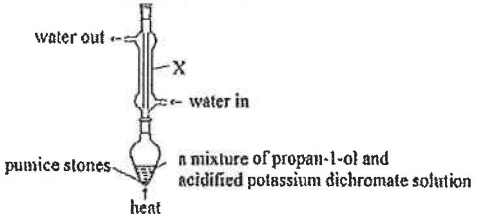
(a) Calculate the number of moles of carbon in one mole of X and hence deduce the molecular formula of X.

(b) Draw ONE possible structure of X and give its systematic name.

5 marks)

CE98_09a

A student used the following set-up to prepare propanoic acid:



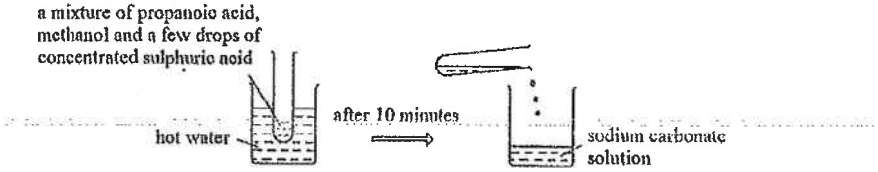
(i) Name apparatus X.

(ii) Explain why some pumice stones were added to the reaction mixture before heating.

(iii) Write the chemical equation for the reaction involved.

(iv) Suggest a method to obtain propanoic acid from the reaction mixture.

The student used the propanoic acid obtained to carry out the following experiment:



(v) Why is a water bath, instead of a naked flame, used for heating the test tube and its contents?

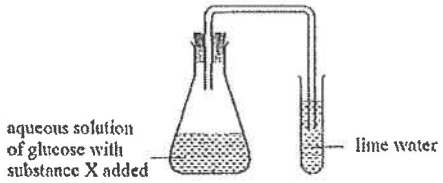
(vi) (1) State TWO observable changes when the contents of the test tube were added to the sodium carbonate solution.

(2) Give the systematic name of the carbon compound formed in the experiment.

(8 marks)

CE99_06b

(i) A teacher prepared an ethanol solution by fermentation of glucose using the following set-up.

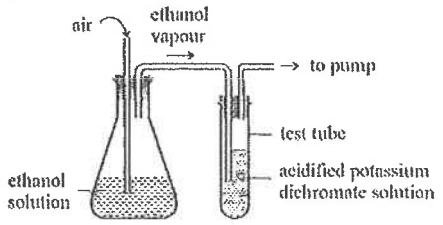


(1) Suggest what X may be.

(2) Explain why the lime water turned milky during the fermentation process.

(3) Write the chemical equation for the fermentation of glucose.

(ii) The teacher used the ethanol solution obtained in (i) to carry out the following experiment on a redox reaction:



(1) State the observable change in the test tube.

(2) Explain, in terms of oxidation number, whether potassium dichromate was oxidized or reduced.

(3) Give the structural formula of the product formed from ethanol in the reaction.

(iii) Suggest ONE reason for each of the following statements:

(1) Drinking a small quantity of wine may be good for health.

(2) Excessive drinking of alcoholic beverages may cause health problems.

(10 marks)

CE02_03c

Consider the substances listed below:

ammonia, manganese(IV) oxide, potassium hydroxide,
sodium benzoate, sodium dichromate, sodium nitrate

(c) Which substance is used in breathalysers to detect the presence of ethanol in the breath of suspected drunk drivers? State the expected observation in the breathalyser if a positive result is obtained.

(2 marks)

CE02_06c

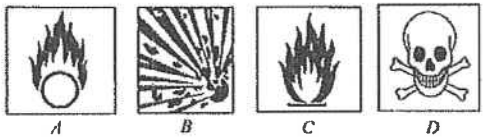
Ethyl ethanoate is an ester. It can be prepared by heating mixture of ethanoic acid and ethanol under reflux in the presence of a catalyst.

(i) What is the catalyst used in the preparation?

(ii) Draw a labelled diagram of the set-up used for heating the mixture under reflux.

(iii) Ethyl ethanoate is commonly used as a solvent. Explain why ethyl ethanoate can dissolve iodine but cannot dissolve sodium iodide.

(iv) Which ONE of following hazard warning labels should be displayed on a bottle of ethyl ethanoate?

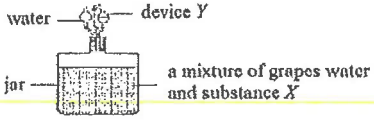


(v) Draw the structure of another ester which has the same molecular formula as ethyl ethanoate, and give its systematic name.

(9 marks)

CE03_08a

A mixture of grapes, water and substance *X* is used to produce wine in the set-up shown below:



(i) The wine contains ethanol.

(1) State ONE substance in grapes that can be converted to ethanol. Write the chemical equation for the reaction involved.

(2) Suggest what *X* may be. State its function in the production of ethanol.

(ii) State TWO functions of device *Y*.

(iii) (1) Explain why the concentration of ethanol in the wine cannot exceed a certain level (about 18% by volume).

(2) Suggest a reason to increase the concentration of ethanol in the wine to a level higher than 18% by volume.

(iv) Explain why a glass of wine turns sour upon standing in air.

(9 marks)

CE04_08c

A policeman suspected a car driver to have drunk an excessive amount of alcoholic drinks, and used a dichromate breathalyser to conduct a test on the driver's breath. The result was positive.

(i) State the principle underlying the test of ethanol using a dichromate breathalyser.

(ii) The driver claimed that he had just rinsed his mouth using ethanol-containing mouthwash. Without using other instruments, suggest how the policeman could check whether the driver's claim was valid or not. Explain your answer.

(4 marks)

CE04_09b

An ester can be prepared by heating an alkanol with an alkanoic acid under reflux in the presence of concentrated sulphuric acid.

(i) Draw a labelled diagram to show the set-up used in heating the reaction mixture under reflux.

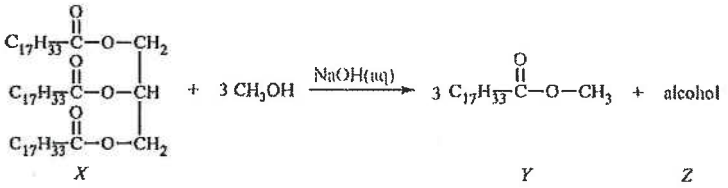
(ii) Suggest ONE reason why it is necessary to heat the mixture under reflux.

(3 marks)

CE05_11

Vegetables oils are esters formed from carboxylic acids with long carbon chains. Although vegetable oils have high calorific values comparable to diesel, they are not used directly as fuel in cars. One of the reasons is due to their high viscosity. By heating with methanol in the presence of sodium hydroxide solution, vegetable oils can be converted to less viscous esters, methyl carboxylates. These methyl carboxylates can be used to substitute diesel as fuel in cars.

(a) The equation below shows the conversion of vegetable oil X to methyl carboxylate Y and alcohol Z:



X Y Z

(i) Draw the structure of Z.

(ii) Suggest why Y is less viscous than X.

(iii) Sodium hydroxide solution acts as a catalyst in this conversion. What is the meaning of the term 'catalyst'?

(iv) Y and Z are immiscible liquids. Suggest a method to separate Y and Z from their mixture.

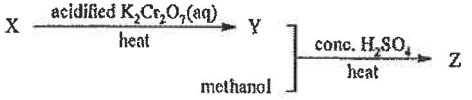
(5 marks)

(b) The term 'biodiesel' refers to the methyl carboxylates obtained from vegetable oils. Suggest TWO reasons why biodiesel is considered a more environmentally-friendly fuel than diesel.

(2 marks)

CE06_02

X, Y and Z are organic compounds. The flow diagram below shows the conversion of X to Z.



(a) Z has a pleasant smell and its molecular formula is $C_4H_8O_2$. Draw the structure of Z.

(1 mark)

(b) To which homologous series does Y belong?

(1 mark)

(c) Give the systematic name of X.

(1 mark)

(d) State the expected observation when X reacts with acidified potassium dichromate solution.

(1 mark)

(e) State the function of concentrated sulphuric acid in the reaction of Y with methanol.

(1 mark)

CE07_12

Organic compound Z contains carbon, hydrogen and oxygen only. Analysis of Z gives the following results:

(I) 1.0 g of Z contains 0.401 g of carbon, 0.068 g of hydrogen and 0.531 g of oxygen.

(II) 1.0 g of Z, upon complete vapourisation, occupies 400 cm^3 at room temperature and pressure.

(III) There are no observable changes when potassium carbonate solution is added to Z.

(IV) Brown colour of bromine remains unchanged when several drops of bromine in organic solvent are added to Z.

(Molar volume of gas at room temperature and pressure = 24 dm^3)

(a) Calculate the empirical formula of Z.

(2 marks)

(b) Deduce the molecular formula of Z.

(2 marks)

(c) (i) Suggest a possible structure of Z. Explain your answer.

(ii) Give the systematic name for the compound represented by the structure you suggested in (i).

(4 marks)

CE11_10b

A type of breathalyser for investigating drink-driving consists of a chemical cell. The breath of the driver is allowed to get into contact with one of the electrodes of the cell. If the breath contains ethanol, the ethanol would be converted to ethanoic acid at this electrode and an electric current would be produced.

(i) Explain whether the above mentioned electrode acts as the anode or cathode of the chemical cell.

(ii) Write a half equation for the change occurring at this electrode.

(iii) Explain how this type of breathalyser could estimate the amount of ethanol in the breath of the driver.

(3 marks)

CE11_12

The chemical properties of hexane (C_6H_{14}) and hex-1-ene (C_6H_{12}) are different. Design experiments to show how they differ in their reactions with oxygen in air and their reactions with bromine. Explain the differences concerned.

(6 + 3 marks)

Part 2: Plastic

CE94_03

The following diagrams show some items made of synthetic polymers.

Electric switch Plastic bag Shirt

(b) Name one synthetic polymer which is suitable for making the plastic bag.

(d) Terylene, the polyester fibre used for making the shirt is synthesized from ethane-1,2-diol, $HOCH_2CH_2OH$ and benzene-1,4-dicarboxylic acid, $HOOCC_6H_4COOH$.

(i) Name the type of polymerization involved in the synthsis of terylene.

(ii) Write a repeating unit of terylene.

(6 marks)

CE07_08

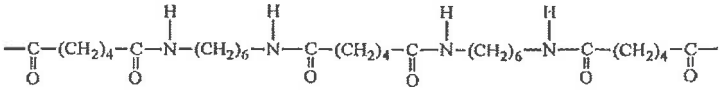
(a) Teflon is a plastic that can be used to make artificial hip joints. Teflon is an addition polymer of linear structure consisting of carbon and fluorine only. The ratio of the number of carbon atoms to the number of fluorine atoms in the polymer is 1 : 2.

(i) Draw a portion of the teflon structure with 10 carbon atoms.

(ii) Write the repeating unit of teflon, and suggest a possible monomer of teflon.

(3 marks)

(b) Nylon is a polymer that can be used to make carpets. A portion of the nylon structure is shown below:



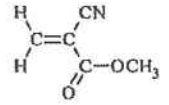
(ii) Suggest one reason why recycling of used carpets to recover nylon is difficult.

(iii) State one disadvantage of disposing of nylon carpets by incineration.

(3 marks)

CE08_08

The active ingredient of a superglue has the following structure:



Superglue can join objects together quickly through the polymerization of the active ingredient in the presence of water vapour.

(a) Name the type of polymerization that the active ingredient undergoes.

(1 mark)

(b) Write a chemical equation for the polymerization involved.

(1 mark)

(c) Assuming that the active ingredient comes from esterification of two compounds, write the structural formulae of these two compounds.

(2 marks)

(d) In addition to putting back the cap for the superglue that remains after use, what storage method could help extend the lifetime of the superglue?

(1 mark)

CE08_09

Outline the steps showing how a sample of ethyl ethanoate ($CH_3COOCH_2CH_3$) can be prepared and isolated in the laboratory by using ethanol, concentrated sulphuric acid, 0.1 M potassium dichromate solution, quickfit apparatus, heating source, and other common apparatus.

(Diagrams, chemical equations, and detailed descriptions in setting up of apparatus are NOT required.)

(6 + 3 marks)

CE09_05

Motor vehicles in some countries use gasohol as fuel. Gasohol is a mixture of ethanol and petrol. Two methods of obtaining ethanol are shown below.

Method 1: heavy oil $\xrightarrow{\text{Process A}}$ ethene $\xrightarrow{\text{Process B}}$ ethanol

Method 2: cane sugar $\xrightarrow{\text{Fermentation}}$ ethanol

(a) Name Process A and state its principle.

(2 marks)

(b) Process B can be represented by the following word equation.

ethene + steam ⟶ ethanol

Name the type of reaction involved.

(1 mark)

(c) The concentration of the ethanol obtained from Method 2 is quite low. Suggest how the concentration of the ethanol obtained from this method can be increased.

(1 mark)

(d) State one advantage of using gasohol over using each of the following substances as a fuel in motor vehicles.

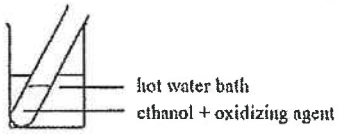
(i) ethanol

(ii) petrol

(2 marks)

CE09_08

A student attempted to oxidize ethanol to ethanoic acid using the set-up shown below.



(a) Suggest an oxidizing agent that can be used.

(1 mark)

(b) State one advantage of using a hot water bath over direct heating with a Bunsen burner carrying out the experiment.

(1 mark)

(c) The student failed to obtain ethanoic acid even after a long period of time. The student then used Quickfit apparatus to perform the experiment. After some time, ethanoic acid was finally obtained.

(i) Draw a labelled diagram to show how to set up Quickfit apparatus for carrying out the experiment.

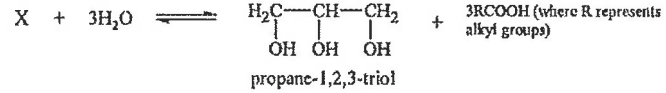
(ii) Explain why ethanoic acid could finally be obtained.

(4 marks)

Part 3: Soaps and Soapless detergents

CE91_01b

A vegetable oil, X, can undergo reversible hydrolysis in the presence of sulphuric acid as given by the following equation:



propane-1,2,3-triol

(i) Write the structural formula of X.

(ii) What is the function of sulphuric acid in this reaction?

X can be hydrolysed more effectively by using sodium hydroxide solution instead of sulphuric acid, and the products are propane-1,2,3-triol and Y.

(iii) Name this process.

(iv) Write the structural formula of Y.

When a solution of Y is slowly added, with stirring, to a mixture of peanut oil and water, a milky solution is obtained.

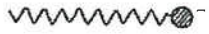
(vi) Based on the structural formula of Y, explain why a milky solution is formed.

(vii) Name the process leading to the formation of the milky solution and suggest one domestic application of this process.

(10 marks)

CE93_01c [Same as DSE12_14, DSE19_15]

(i) The structure of a typical anionic detergent can be represented by:



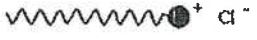
where ∿∿∿ represents a hydrocarbon tail

and ● $^-$ represents an anionic part attached to the hydrocarbon tails.

(1) Using the above representation, draw a diagram to show how the detergent can suspend an oil droplet in water.

(2) A table cloth stained with oil can be cleaned using the detergent in water. Explain the cleaning action with reference to your diagram in (1).

(ii) Scientists have also developed cationic detergents for special cleaning purposes. The structure of a typical cationic detergent is shown below:



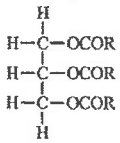
Can anionic and cationic detergents be used together? Explain your answer.

(6 marks)

CE94_05a

A domestic drain cleaner named 'RAINBOW' contains concentrated sulphuric acid as the active ingredient. A student carried out the following experiment to determine the concentration of sulphuric acid in 'RAINBOW'.

(v) If 'RAINBOW' is poured into drains blocked with fat, the fat can be removed. Assuming the formula of fat is



(R represents an alkyl group),

explain how 'RAINBOW' can remove the fat.

(2 marks)

CE95_02

In each of the following groups of substances, there is ONE substance which is different from the others in terms of their properties. In each group, identify the substance which is different from the others and explain your choice.

(c) milk of magnesia, soap, vinegar, window cleaner

(2 marks)

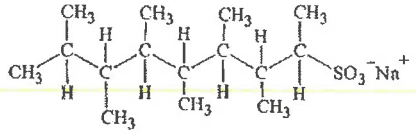
CE95_09a

Sodium hydroxide can be used as a raw material in the manufacture of both soapy and soapless detergents.

(i) Briefly describe how a soapy detergent can be prepared from a vegetable oil in a school laboratory.

(ii) The formula of a certain soapy detergent is C_nH_{2n+1} and its formula mass is between 300 and 310. Calculate the value of n.

(iii) The structure of a certain soapless detergent is shown below:



(1) What other raw materials, apart from sodium hydroxide, are required in the manufacture of this soapless detergent?

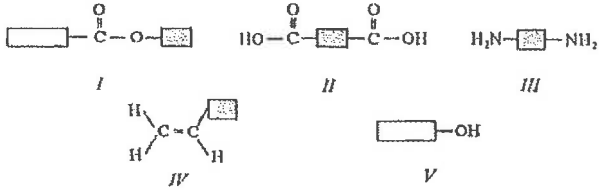
(2) Give ONE advantage and ONE disadvantage of using this soapless detergent for domestic cleaning compared with using a soapy detergent.

(Relative atomic masses: H = 1.0, C = 12.0, O = 16.0, Na = 23.0)

(10 marks)

CE97_07b

The structures of five compounds, I, II, III, IV and V, are shown below:



In the above structures,  represents a saturated hydrocarbon chain containing 1 to 6 carbon atoms and  represents a saturated hydrocarbon chain containing 12 to 20 carbon atoms.

(iii) Upon heating with sodium hydroxide solution, one of these compounds produces a soapy detergent.

(1) What is this compound?

(2) Draw the structure of the soapy detergent produced.

(3) Briefly explain the emulsifying action of the detergent when it is used to remove greasy dirt.

(6 marks)

CE00_06c

Explain the following statements:

(ii) Detergents can be used to clean up oil spillage in the sea.

(2 marks)

CE01_06a

Soap powder usually contains washing soda, a hydrated form of sodium carbonate, which can help reduce the hardness of water.

(i) Explain why soap does not function well in hard water.

(ii) With the help of an ionic equation, explain why washing soda can help reduce the hardness of water.

(4 marks)

CE02_09a

Ammonia is weak alkali. It is used as an active ingredient in domestic glass cleaners.

(i) (1) Write a chemical equation to represent the ionization of ammonia in water.

(2) Explain why an alkaline solution can help remove oily dirt on glass.

(ii) Suggest, with explanation, a precaution necessary when using such glass cleaners.

(4 marks)

CE07_13

Discuss the similarities and differences between soapy detergents and soapless detergents with reference to their raw materials, structures and properties.

(6 + 3 marks)

CE09_12

The procedures in an experiment are summarized below.

A mixture of castor oil and sodium hydroxide solution was heated gently with stirring for 15 minutes. After cooling down the mixture, a white solid X was obtained upon adding a colourless solution Y. X was then separated out and washed with distilled water.

A small amount of X was put in a test tube containing a mixture of water and a few drops of oil. The contents of the test tube were thoroughly shaken and the observation was recorded.

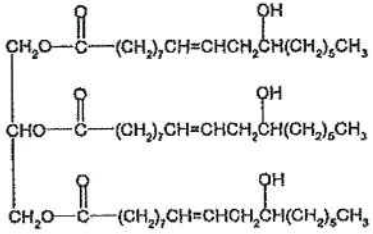
(a) Name the type of reaction involved when the mixture of castor oil and sodium hydroxide solution was heated.

(1 mark)

(b) Suggest what Y would be.

(1 mark)

(c) The structure of a main ingredient of castor oil is shown below.



Suggest a structure of X.

(1 mark)

(d) State the expected observation while shaking the test tube. Explain your answer.

(3 marks)

(e) Suggest a title for the experiment that reflects its objectives.

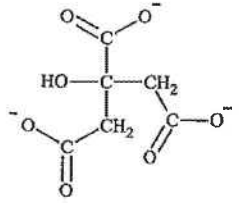
(2 marks)

(f) If X is dissolved in water to form an aqueous solution, what would be observed in shaking a mixture of this solution and lime water?

(1 mark)

CE11_11

(a) Citrate ions can improve the cleaning abilities of soapy detergents in hard water in a way similar to carbonate ions. The structure of a citrate ion is shown below:



(i) Explain why citrate ions can improve the cleaning abilities of soapy detergents in hard water.

(ii) Phosphate ions can also improve the cleaning abilities of soapy detergents in hard water. However, phosphate ions have a negative effect on the environment. What is this negative effect?

(3 marks)

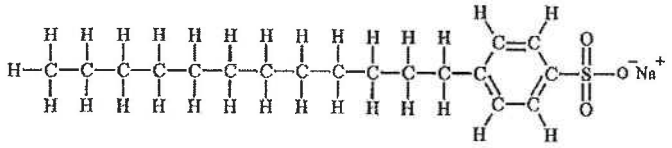
(b) In acidic environments, the soapy detergent $CH_3(CH_2)_{14}COO^-Na^+$ loses its cleaning function because it forms an insoluble organic acid.

(i) Write the structural formula of the organic acid formed.

(ii) With the help of an ionic equation, explain why sodium carbonate can improve the cleaning abilities of soapy detergents in acid environments.

(3 marks)

(c) The structure of a commonly-used detergent is as follows:



Suggest THREE advantages of this detergent.

(3 marks)

AL96(II)_07b

In an experiment, 25 g of $(CH_3)_3COH$ react with 36 g of HCl to give 28 g of $(CH_3)_3CCl$.

(i) Find the limiting reactant of the reaction, showing clearly your calculation.

(1.5 marks)

(ii) Calculate the percentage yield of $(CH_3)_3CCl$.

(1.5 marks)

(iii) Name the type of the reaction.

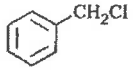
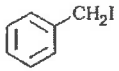
(1 mark)

AL96(II)_07c

Suggest a chemical tet to distinguish one compound from the other in each of the following pairs. Your answer should include the reagents used and the observation expected.

(i)  and

(2 marks)

(ii)  and 

(2 marks)

AL96(II)_08b

The following compounds can exist in isomeric forms:

(i) butenedioic acid, and

(ii) 2-aminopropanoic acid.

In each casem state the type of isomerism and draw suitable representation for the isomers.

(4 marks)

AL98(I)_04

Alcohol **E** has the structure $CH_3CH(OH)C_2H_5$

(a) (i) Draw a three-dimensional representation of **E**.

(1 mark)

(ii) What type of isomerism can be exhibited by **E**?

(1 mark)

(b) (i) Draw the structures of three structural isomers of **E**, all of which are alcohols.

(1.5 marks)

(ii) Describe how the reagent Zn/concentrated HCl can be used to distinguish **E** from the three structural isomers.

(1.5 marks)

(c) On treatment with dilute H_2SO_4(aq), **E** gives mainly two isomeric compounds. **F** and **G**, both of which have the formula C_4H_8. On treatment with bromine, both **F** and **G** give a product **H** with formula $C_4H_8Br_2$.

(i) Draw structures for **F**, **G**, and **H**.

(3 marks)

(ii) What is the isomeric relationship between **F** and **G**?

(1 mark)

AL98(I)_05

Consider the reaction of butanone (C_4H_8O) **J** shown in the reaction scheme below:

$$\text{butanone } (C_4H_8O)\ \mathbf{J} \xrightarrow{2,4\text{-}C_6H_3(NO_2)_2NHNH_2} \mathbf{R}\ \text{(a red precipitate)}$$

(a) Give structure for compound **R**.

(1 mark)

(b) (i) **S** is a structural isomer of **J**. **S** also reacts with $2,4\text{-}C_6H_3(NO_2)_2NHNH_2$ to give a red precipitate. Draw the structure of **S**.

(1 mark)

(ii) How may **J** and **S** be identified by making use of their reacts with $2,4\text{-}C_6H_3(NO_2)_2NHNH_2$?

(1 mark)

AL98(I)_08a

Show how you would

(i) determine whether a sample of $C_2H_5CH(OH)CH_3$ is in the (+) form or (±) form.

(1 mark)

(ii) distinguish between C_6H_5COCl and C_6H_5COBr using a chemical test.

(1 mark)

ASL99(I)_05

Consider the compounds **V**, **W**, **X**, **Y** and **Z** below.

$CH_3CH_2CH_2CH_2OH$	$CH_3CH(OH)CH_2CH_3$	$(CH_3)_3COH$
V	**W**	**X**
$CH_3CH_2CH_2CHO$	$CH_3CH_2CH_2CO_2H$	
Y	**Z**	

(a) Which compound can be converted to butanone in one step? Give the reagent(s) used in the conversion.

(2 marks)

(b) Suggest a chemical test to distinguish between **V** and **Y**.

(2 marks)

(c) Under suitable conditions, **W** and **Z** react to give a product with a pleasant smell. State the conditions for the reaction and give the structure of the product.

(2 marks)

ASL99(II)_11 (modified)

Compound **R** has the following structure:

$$(CH_3)_2CHCH{=}CHCH_3$$

(a) Give the systematic name of **R**.

(1 mark)

(b) **R** exists in two isomeric forms.

(i) Draw the structure of each isomer.

(2 marks)

(ii) State the type of isomerism involved.

(1 mark)

(c) Under suitable conditions, **R** can be converted to cyclic compound **S** with a relative molecular mass of 78.1. **S** has the following composition by mass:

C 92.3% and H 7.7%

(i) Deduce the molecular formula of **S**.

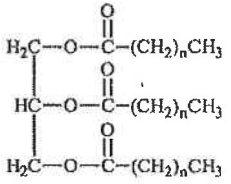
(2 marks)

(ii) Draw a possible structure of **S**.

(1 mark)

ASL99(II)_13 (modified)

Compound **U** is a natural fat. **U** has the following structural formula:



(when n is a positive integer)

(a) State the functional group in **U**.

(1 mark)

(b) In an experiment, 8.51 g of **U** was heated under reflux with 100.0 cm^3 of 2.00 M sodium hydroxide solution until **U** was completely hydrolyzed. The resulting solution was allowed to cool to room temperature.

(i) Draw a labelled diagram of the set-up used for heating **U** and the sodium hydroxide solution under reflux.

(2 marks)

(ii) Write a balanced equation for the hydrolysis reaction.

(1 mark)

(iii) 10.0 cm^3 of the resulting solution was withdrawn with a pipette and titrated against 0.53 M hydrochloric acid with phenolphthalein as indicator. 27.5 cm^3 of the hydrochloric acid was required to reach the titration end point. Calculate the value of n in the structural formula of **U**.

(3 marks)

(iv) The resulting solution after reflux can be used to make soap. The solution was first concentrated by heating and then a saturated sodium chloride solution was added.

(I) State the observable change upon the addition of the saturated sodium chloride solution.

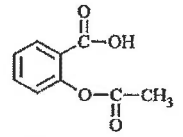
(1 mark)

(II) Explain why a saturated sodium chloride solution was used.

(1 mark)

ASL00(I)_06

Aspirin, a painkiller, has the following structure:



(a) Name all functional groups in aspirin.

(2 marks)

(b) Upon heating with sodium hydroxide solution, aspirin gives a mixture containing two organic compounds, **X** and **Y**. When excess hydrochloric acid is added to the mixture, **X** gives a white precipitate, **Z**, while **Y** does not have any apparent reaction. Draw the structures of **X**, **Y** and **Z**.

(3 marks)

(c) Under suitable conditions, **Z** reacts with methanol in a mole ratio of 1:1 to give oil of wintergreen which is an ester. Draw the structure of oil of wintergreen.

(1 mark)

AL01(I)_08

In an experiment to prepare propanal from propan-1-ol,

$$CH_3CH_2CH_2OH \xrightarrow[\text{heat}]{Cr_2O_7^{2-}/H_3O^+} CH_3CH_2CHO$$

a side-product *N* ($C_6H_{12}O_2$) was formed.

(a) What is *N*? Suggest how N is formed.

(2 marks)

(b) Suggest one method to separate propanal from a mixture of propanal and *N*.

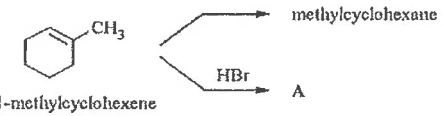
(1 mark)

(c) Suggest two methods to confirm the identity of propanal.

(2 marks)

ASL01(II)_10

Consider the reactions of 1-methylcyclohexene shown below:



(a) (i) Give the reagent(s) and conditions for the conversion of 1-methylcyclohexene to methylcyclohexane.

(2 marks)

(ii) Suggest a chemical test to distinguish between 1-methylcyclohexene and methylcyclohexane.

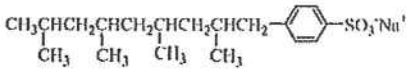
(2 marks)

(b) For the reaction of 1-methylcyclohexene with HBr, draw the structure of the major product A.

(1 mark)

ASL01(II)_12

A synthetic detergent has the following structure:



With reference to its structure, explain why

(a) the detergent can be used to remove oily dirt,

(3 marks)

(b) the detergent is not environmentally friendly.

(2 marks)

ASL02(I)_03

Compound X has the following composition by mass:

C 55.8%, H 7.0%, O 37.2%

(a) Deduce the empirical formula of X.

(2 marks)

(b) The relative molecular mass of X lies between 82 and 90. What is the molecular formula of X?

(2 marks)

(c) X reacts with sodium carbonate solution to give carbon dioxide. Draw all possible structures of X.

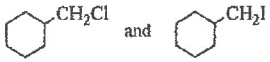
(3 marks)

ASL02(II)_11

For each of the following pairs of compounds, suggest a chemical test to distinguish one compound from the other. In each case, state the expected observation and write the relevant chemical equation(s).

(a) $CH_3(CH_2)_3OH$ and $(CH_3)_3COH$

(2 marks)

(b) 

(4 marks)

ASL03(I)_02

Arrange the following compounds in order of increasing boiling point. Explain your answer.

$CH_3(CH_2)_2CH_3$, $CH_3(CH_2)_3Cl$, $CH_3(CH_2)_3OH$, $CH_3(CH_2)_3CH_3$

(5 marks)

ASL03(II)_09

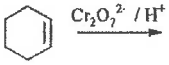
Outline a synthetic route, in not more than three steps, to accomplish each of the following conversions. For each step, give the reagent(s), the conditions and the structure of the organic product.

(a) $CH_3CH_2CH_2Cl \longrightarrow CH_3CH_2-\overset{O}{\overset{\|}{C}}-OH$ (3 marks)

(b) $CH_3CH{=}CH_2 \longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-CH_3$ (3 marks)

ASL03(II)_12

Hexanedioic acid, also known as adipic acid, is used in the manufacture of nylon-6,6. The acid is commonly synthesized from cyclohexene using method (I) or method (II) outlined below:

(I) 

(II) 

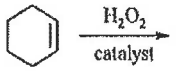
(a) Draw the structure of adipic acid.

(1 mark)

(b) Both methods, (I) and (II), are considered as environmentally unfriendly. Explain.

(2 marks)

(c) Nowadays, some chemists recommend using method (III) below to synthesize adipic acid.

(III)  $\xrightarrow[\text{catalyst}]{H_2O_2}$ adipic acid

Suggest two advantages of using this method to synthesize adipic acid.

(2 marks)

(d) Nylon-6,6 is a polymer of adipic acid and hexane-1,6-diamine. Draw the repeating unit of nylon-6,6.

(1 mark)

ASL04(II)_10

Preparation of benzoic acid ($C_6H_5CO_2H$) involves heating methyl benzoate ($C_6H_5CO_2CH_3$) with excess sodium hydroxide solution under reflux for some time. The resultant mixture contains sodium benzoate and methanol.

(a) Draw a labelled diagram for the set-up used for heating methyl benzoate with sodium hydroxide solution under reflux.

(2 marks)

(b) Suggest how a crude sample of benzoic acid can be obtained from the resultant mixture.

(2 marks)

(c) The crude sample of benzoic acid can be purified by recrystallization from hot water. Outline the procedures in the recrystallization process.

(2 marks)

(d) In an experiment, 3.0 g of methyl benzoate gave 1.9 g of benzoic acid. Calculate the percentage yield of benzoic acid.

(2 marks)

ASL05(I)_03

The reaction of ethanoic acid with methanol gives an ester.

(a) Write the chemical equation for the above reaction.

(1 mark)

(b) Account for the following observation:

'The reaction of ethanoic acid (CH_3CO_2H) with methanol labelled with oxygen-18 ($CH_3{}^{18}OH$) always gives ester molecules with a mass of 76, compared with $^{12}C = 12$.'

(2 marks)

ASL05(I)_06

Compound A has the following composition by mass:

C 81.8%, H 6.1% and O 12.1%

Its relative molecular mass is in the range of 130 to 140.

(a) Calculate the molecular formula of A.

(3 marks)

(b) A is an aromatic compound. It gives positive results when treated with Tollen's reagent. Deduce all functional groups present in A.

(3 marks)

(c) State a type of isomerism that A can exhibit. Illustrate your answer with the appropriate structures.

(2 marks)

ASL05(I)_07

A brand of baby diaper uses polyacrylamide and sodium polyacrylate as water absorbing materials. The structure of the two polymers are shown below:

polyacrylamide sodium polyacrylate

(a) Draw the structure of monomer of polyacrylamide.

(1 mark)

(b) Suggest a synthetic route, with not more than three steps, for the transformation of propenoic acid to sodium polyacrylate.

(2 marks)

(c) Account for the water absorbing property of the following materials:

(i) Polyacrylamide

(2 marks)

(ii) Sodium polyacrylate

(2 marks)

(d) Apart from their use in diapers, suggest one other application of such water absorbing materials in daily life.

(1 mark)

ASL05(II)_09

Arrange the following compounds B, C and D in order of increasing boiling point, and explain your answer.

$CH_3(CH_2)_3CH_3$, $CH_3(CH_2)_3OH$ and $CH_3CH_2COCH_3$
B C D

(3 marks)

ASL05(II)_09

You are provided with four unlabeled bottles each containing one of the following colorless liquids:

1-bromopropane, butan-1-amine, cyclohexene, propanone

Outline a scheme of tests to distinguish the four liquids from one another.

(6 marks)

ASL05(II)_10

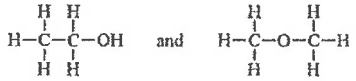
Explain why each of the following methods of preparation are NOT appropriate. In each case, suggest an appropriate method for the preparation.

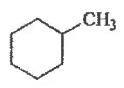
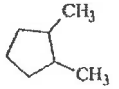
(c) Prepare CH_3CHO by heating CH_3CH_2OH with acidified $Na_2Cr_2O_7(aq)$ under reflux.

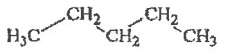
(3 marks)

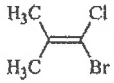
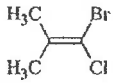
ASL06(I)_01

For each pair of molecules shown below, classify their relationship as 'identical molecule', 'structural isomers' or 'geometrical isomers'.

(a)  and

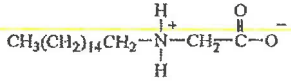
(b)  and 

(c)  and $CH_3-CH_2-CH_2-CH_2-CH_3$

(d)  and 

ASL06(I)_08 (modified)

Some baby shampoos contain a detergent with the following structure:



(a) Explain the cleaning principle of the detergent.

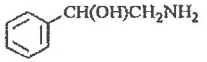
(3 marks)

(b) With the help of chemical equations, explain why the detergent shows both acidic and alkaline properties.

(3 marks)

AL06(II)_05b

Compound B is a strong stimulant. Its structural formula is as follows:



(i) In fact, the above structural formula can represent two stereoisomers.

(I) Draw three-dimensional structures of the two stereoisomers.

(2 marks)

(II) State a physical property which is different for two stereoisomers.

(1 mark)

(ii) It is known that among the two stereoisomers, only B has stimulant activity while the other one does not. Why?

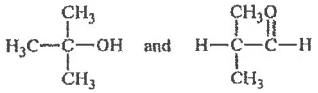
(1 mark)

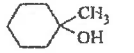
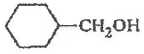
(iii) A person is suspected to have taken stimulant B. A urine sample of the person is sent for analysis. Suggest a method to establish whether B is present in the urine sample.

(2 marks)

ASL06(II)_09

Suggest a chemical test to distinguish one compound from the other in the following pairs. Explain why the test is suitable.

(a)  and (3 marks)

(b)  and  (3 marks)

ASL06(II)_10

Aromatic compounds P, Q and R are esters with the same molecular formula $C_8H_8O_2$.

(a) A mixture of P and aqueous NaOH was heated under reflux for an hour. Excess dilute H_2SO_4 was then added to the resulting mixture and a white precipitate ($C_7H_6O_2$) was formed. Suggest the structure of P and write an equation for the reaction of P with aqueous NaOH.

(2 marks)

(b) A mixture of Q and aqueous NaOH was heated under reflux for an hour. Excess dilute H_2SO_4 was then added to the resulting mixture. Upon warming, a smell of vinegar was detected. Deduce the structure of Q with the help of chemical equations.

(4 marks)

(c) Propose one possible structure of R.

(1 mark)

ASL07(I)_07

Oseltamivir is an antiviral drug against the avian virus H5N1. It is also known by the brand name Tamiflu.

(a) Mark each chiral centre with an asterisk on the structure of oseltamivir shown on the right.

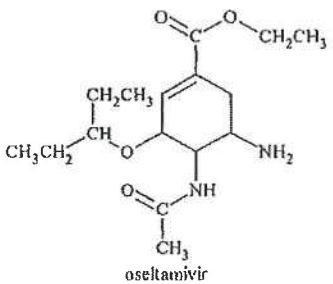
(1 mark)

(b) Besides the ether linkage, how many functional groups are there in oseltamivir? Name two of these functional groups.

(2 marks)

(c) Given that ether linkage are not affected by alkalis, write the structure of the organic products formed when oseltamivir is heated with excess NaOH(aq).

(2 marks)



oseltamivir

ASL07(II)_02

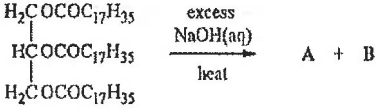
Outline a synthetic route, with no more than three steps, to accomplish each of the following transformation. For each step, give the reagent(s), conditions and structure of the organic product.

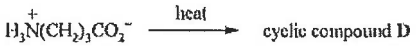
$$CH_3CHO \longrightarrow CH_3CONH_2$$

(2 marks)

ASL08(I)_06

Give the structure of the organic products A, B and D in the following reactions:

(a) 

(b) 

ASL08(II)_01

Deduce the structure of isomeric compounds A and B, with formula C_6H_{12}, that have the following characteristics:

Compound	Characteristics
A	It has a pair of enantiomers. It loses its chiral centre after hydrogenation over Pt.
B	It reacts with Br_2 to give a single compound. It reacts with HBr to give a single achiral compound.

(6 marks)

ASL08(II)_02 (modified)

Upon irradiation of visible light, 0.450 g of 2,4-dimethylpentane undergoes monochloro-substitution to give 0.200 g of 1-chloro-2,4-dimethypentane (**D**), 0.167 g of 2-chloro-2,4-dimethypentane (**E**) and 0.117 g of 3-chloro-2,4-dimethypentane (**F**).

(a) Draw the structure of 2,4-dimethylpentane.

(1 mark)

(b) Calculate

(i) the overall percentage yield for the monochlorinated products formed, and

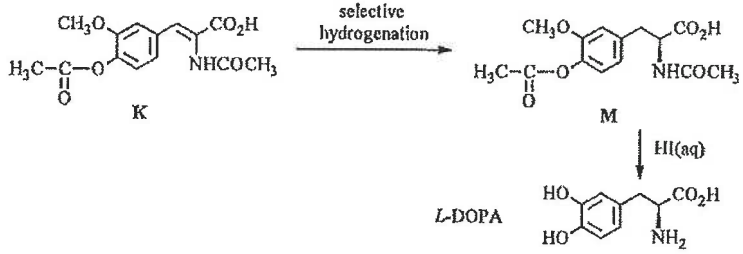
(1 mark)

(ii) the mole ratio of **D**, **E** and **F** formed. (Assign a value of 1.0 to the monochlorinated product which has the lowest yield.)

(2 marks)

AL09(II)_05b (modified)

L-DOPA is an effective drug for Parkinson's disease. The synthesis of *L*-DOPA involves the selective hydrogenation of compound K to compound M, which is then hydrolyzed to give *L*-DOPA.



(i) M has a stereoisomer, N. N is not used to synthesize *L*-DOPA.

(I) Draw the structure of N.

(1 mark)

(II) Name the type of stereoisomerism.

(1 mark)

(III) State ONE difference in physical property between M and N.

(1 mark)

(ii) (I) Explain why the hydrogenation of K over platinum gives M and N in a mole ratio of 1 : 1. [For reference only]

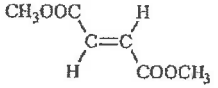
(2 marks)

(II) Suggest a way to achieve the above selective hydrogenation.

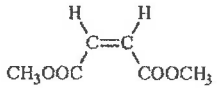
(1 mark)

ASL10(I)_06

Dimethyl fumarate can be found in most leather products since it is commonly used as a mould inhibitor. However, it was banned in Europe for all kinds of consumer goods in March 2009 because it was found to cause skin allergies. Compound A is an isomer of dimethyl fumarate. The structures and melting points of these two compounds are given below:



dimethyl fumarate
m.p. 102 °C



A
m.p. −19 °C

(a) Name the type of isomerism involved.

(1 mark)

(b) Explain why the melting point of A is lower than that of dimethyl fumarate.

(2 marks)

ASL10(II)_04

(a) At room temperature, acyclic organic compound D (relative molecular mass: 58) is a volatile liquid. It has the following composition by mass:

C, 62.1%; H, 10.3%; O, 27.6%

Calculate the empirical formula of D.

(3 marks)

(b) D does not react with cold acidified $K_2Cr_2O_7$(aq). Deduce ONE possible structure of D.

(1 mark)

ASL11(I)_06

Consider compounds F and G as shown below:

F G

(a) Give the systematic name of F.

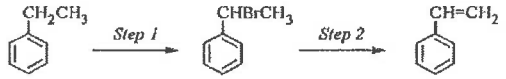
(1 mark)

(b) Suggest a synthetic route with *no more than three steps* to convert F to G.

(2 marks)

ASL11(II)_07

Ethylbenzene can be converted to phenylethene, which is also known as styrene, via the following synthetic route:



(a) Suggest reagent(s) and reaction conditions for *Step 1*.

(1 mark)

(b) *Step 2* is carried out by heating the (1-bromo)ethylbenzene from *Step 1* with a mixture of $(CH_3)_3CO^-K^+$ and $(CH_3)_3COH$. Name the type of reaction involved.

(1 mark)

(c) Styrene undergoes polymerization to give polystyrene (PS).

(i) Draw the repeating unit of PS.

(1 mark)

(ii) Suggest reagent(s) and reaction conditions for the polymerization.

(1 mark)

ASL12(I)_06

Based on the information given below, deduce the possible structure of compounds B and D:

(1) Compound B ($C_6H_{10}O_2$) is optically active.

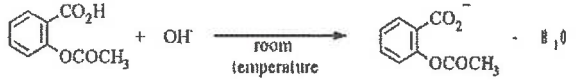
(2) B reacts with H_2(g), in the presence of Ni(s), to give an optically inactive compound D.

(3) When treated with excess $NaHCO_3$(aq), 1 mol of D gives 1 mol of CO_2(g).

(5 marks)

ASL12(I)_10

A commercial aspirin sample E was known to contain about 90% by mass of aspirin, while the rest was an inert binder. Based on the following reaction, a student designed an experiment and performed it at room temperature to determine the percentage by mass of aspirin in E.



The student added 2.25 g of E to 25.00 cm^3 of 3.05 mol dm^{-3} NaOH(aq), and then back titrated the excess NaOH(aq) with 2.50 mol dm^{-3} HCl(aq). The volume of HCl(aq) used was 23.10 cm^3.

(a) Suggest an indicator for the titration.

(1 mark)

(b) From the students' experimental results, calculate the percentage by mass of aspirin in E. Suggest why the calculated percentage by mass of aspirin deivates grealy from 90%.
(Relative molecular mass of aspirin = 180.0)

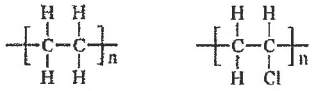
(4 marks)

(c) Suggest ONE improvement to the design of the experiment to find the percentage by mass of aspirin in E.

(1 mark)

ASL12(II)_07 (modified)

Polyethene (PE) and polyvinyl chloride (PVC) are two of the most commonly used synthetic polymers.



PE PVC

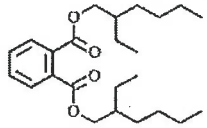
(a) Suggest reaction conditions for the formation of PE from its monomer.

(1 mark)

(b) Explain why PVC is more rigid than PE.

(2 marks)

(c) Plasticiers are often added to PVC to make it more flexible and processable. Bis(2-ethylhexyl)phathalate (DEHP) is one of the commonly used plasticisers.



DEHP

(i) DEHP is an oily liquid. It can be dispered in water by an emulsifying agent to give a stable cloudy mixture. Suggest an explanation for the formation of the cloudy mixture.

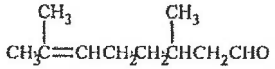
(2 marks)

(ii) It was reported that DEHP had been illegally used in clouding agents for beverages. Suggest ONE method for detecting DEHP in beverage samples.

(1 mark)

ASL12(II)_08

A naturally occurring organic compound has the following structure:



(a) On the above structure, circle the chiral carbon centre(s) in this compound.

(1 mark)

(b) Suggest a systematic name for this compound.

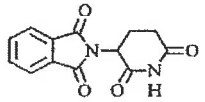
(1 mark)

(c) Give the structure of the major organic product(s) formed when this compound reacts with HCl(g).

(1 mark)

ASL13(I)_06

Thalidomide exhibits enantiomerism. Racemic thalidomide was a drug widely used to prevent morning sickness in pregnant women as one of its enantiomers is an effective sedative. However, by 1962, the other enantiomer of thalidomide was found to have caused more than 10,000 cases of birth defects in babies worldwide.



** Racemic thalidomide = a mixture of pair of enantiomers of thalidomide in mole ratio 1 : 1

(a) Mark, on the above structure of thalidomide, the chiral centre with an asterisk.

(1 mark)

(b) Suggest why the two isomers of thalidomide give different biological effect.

(2 marks)

ASL13(II)_06

The structural formula of $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$ can represent two isomeric compounds.

(a) Draw appropriate structural representations for these two isomers.

(2 marks)

(b) Suggest how these two isomers can be differentiated.

(2 marks)

ASL13(II)_08

From the information given below, deduce ONE possible structure for compound **D**.

(1) **D** has a relative molecular mass of 72.0, and has the following composition by mass:

C, 66.7%; H, 11.1%; O, 22.2%

(2) **D** exhibits optical isomerism.

(3) **D** can turn acidified $K_2Cr_2O_7$(aq) from orange to green.

(7 marks)

DSE11SP_12

Ethyl ethanoate is an ester. It can be prepared by heating a mixture of ethanoic acid and ethanol under reflux in the presence of a catalyst.

(a) What is the catalyst used in the preparation?

(1 mark)

(b) Draw a labelled diagram of the set-up used for heating the mixture under reflux.

(2 marks)

(c) Ethyl ethanoate is commonly used as a solvent. Explain why ethyl ethanoate can dissolve iodine but cannot dissolve sodium iodide.

(3 marks)

(d) Draw the structure of another ester which has the same molecular formula as ethyl ethanoate, and give its systematic name.

(2 marks)

DSE11SP_13

Outline a synthetic route, in not more than three steps, to accomplish each of the following conversions. For each step, give the reagent(s), the conditions and the structure of the organic product.

(a) $CH_3CH_2CH_2Cl \longrightarrow CH_3CH_2\overset{O}{\overset{\|}{C}}-OH$ (3 marks)

(b) $CH_3CH{=}CH_2 \longrightarrow CH_3\overset{O}{\overset{\|}{C}}-CH_3$ (3 marks)

DSE12PP_02

(a) Wine in an opened bottle will become unpalatable if left to stand for some time. Suggest why this is so.

(1 mark)

(b) One common way of preserving wine in an opened bottle is to inject argon, a gas which is chemically unreactive, into the bottle and then stopper the bottle.

(i) Explain why argon is chemically unreactive.

(1 mark)

(ii) State the principle behind the use of argon in preserving wine.

(1 mark)

(iii) Helium gas is also chemically unreactive. Suggest why helium is NOT used for preserving wine in an opened bottle.

(1 mark)

(c) Another way of wine preservation involves pumping air out from an opened bottle of wine and then stoppering the bottle. Suggest ONE possible drawback of preserving wine in this way.

(1 mark)

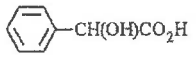
DSE12PP_11

Outline a synthetic route, with *no more than three steps*, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions and structure of the organic product.

(3 marks)

DSE12PP_12

The structural formula shown below can represent two compounds with the same melting point and same solubility in water.



(a) (i) Draw a three-dimensional structure for each of the two compounds.

(2 marks)

(ii) State ONE difference in physical properties of these compounds.

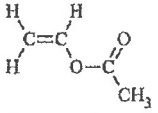
(1 mark)

(b) Both compounds can undergo polymerization under suitable conditions. Draw the repeating unit of the polymer formed from one of these compounds.

(1 mark)

DSE12_02

Poly(ethenyl ethanoate) is a polymer. Its monomer is ethenyl ethanoate with the structure shown below:



(b) Draw the structure of poly(ethenyl ethanoate).

(1 mark)

(c) Ethyl ethanoate is an organic solvent.

(i) Draw the structure of ethyl ethanoate.

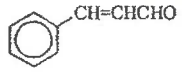
(1 mark)

(ii) Suggest a chemical test to show to distinguish between ethenyl ethanoate and ethyl ethanoate.

(2 marks)

DSE12_12

Cinnamon, which can be used as a flavoring, contains cinnamaldehyde (C_9H_8O). The structure of cinnamaldehyde is shown below:



(a) Draw the *trans*-isomer for the above structure.

(1 mark)

(b) Explain why ethyl ethanoate is a better solvent than water for dissolving cinnamaldehyde.

(1 mark)

(c) In an experiment to extract cinnamaldehyde from cinnamon, a solution containing only ethyl ethanoate and cinnamaldehyde is obtained after a series of steps. In order to separate these two compounds, simple distillation can be carried out. Draw a diagram for the set-up involved, and label the name of the distillate collected.
(Boiling point : cinnamaldehyde = 248 °C, ethyl ethanoate = 77 °C)

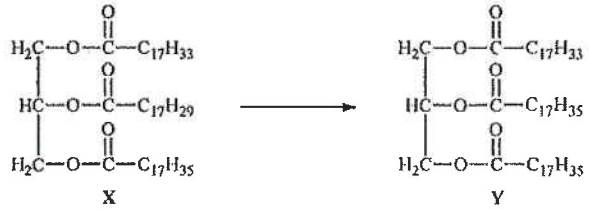
(2 marks)

(d) Outline a synthetic route, with no more than three steps, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of the organic product.

(2 marks)

DSE12_14 [Same as CE93_01]

The diagram below shows the conversion of an oil molecule X to a fat molecule Y.



X Y

(a) (i) Given that all alkyl groups in both X and Y are straight chains, label the chiral carbon(s) by using '*' in the above diagram.

(1 mark)

(ii) With reference to (i), explain whether a change in optical activity is involved in the above conversion.

(1 mark)

(b) One of the products in the alkaline hydrolysis of Y has a cleansing property. Explain the cleaning property of this product.

(4 marks)

DSE12_15 (Similar to ASL03(II)_08a)

Use electron diagrams to illustrate, step by step, how CH_4 reacts with Br_2 under sunlight to form CH_3Br.
(Show electrons in the outermost shells only.)

(3 marks)

DSE13_03

Compound W contains carbon, hydrogen and oxygen only. The relative molecular mass of W is 88.0. Complete combustion of 1.32 g of W gives 2.64 g of carbon dioxide and 1.08 g of water.

(a) Deduce the molecular formula of W.
(relative atomic masses : H = 1.0, C = 12.0, O = 16.0)

(3 marks)

(b) Given that W has only one functional group, draw TWO possible structures of W.

(2 marks)

DSE13_04

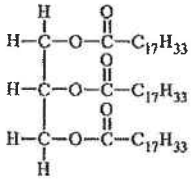
The structure of a dibasic acid with chemical formula $H_2C_2O_4$ is shown below:

(a) Give the systematic name of this dibasic acid.

(1 mark)

DSE13_14

An unsaturated fat F is a component of a vegetable oil. The structure of F is shown below:



(a) State the reagents needed for converting F to a saturated fat.

(1 mark)

(b) Vegetable oils can be used to make soap.

(i) Write the chemical equation involved for the formation of soap from F.

(1 mark)

(ii) In the presence of an acid, the soap formed in (i) can react with methanol to give compound G, which can be used as a biodiesel. Draw the structure of G.

(1 mark)

(c) With reference to their relative molecular masses and physical properties, explain why G can be used as a fuel for cars, but F cannot.

(2 marks)

DSE13_15

Consider the conversions of organic compounds shown below:

$$\underset{\text{X}}{CH_3CH_2COCH_2CH_3} \xrightarrow{R} \underset{\text{Y}}{CH_3CH_2CH(OH)CH_2CH_3} \xrightarrow{\text{dehydrating agent}} \underset{\text{Z}}{\text{a mixture of alkene}}$$

(a) Suggest a chemical test to distinguish between X and Y.

(2 marks)

(b) Suggest what reagent R might be.

(1 mark)

(c) The mixture Z contains two alkene with the same structural formula. Draw the respective structures of these two alkenes, and state their isomeric relationship.

(2 marks)

(d) The alkenes in (c) can react with HCl to form an optically active chloroalkane. Write the structural formula of this chloroalkane.

(1 mark)

DSE13(II)_02a

(ii) Cellulose is a condensation polymer of glucose.
The relative molecular mass of cellulose generally ranges from 2.5×10^5 to 1.0×10^6. Suggest why the relative molecular mass of cellulose falls into a wide range.

(1 mark)

DSE14_02

Draw the structure of ethane-1,2-diol, and suggest whether it is soluble in water.

(3 marks)

DSE14_12

Benzamide, benzoic acid and benzyl bromide are commonly used organic compounds. Their structures are shown below:

(a) In an experiment, benzoic acid is prepared from benzamide in two step:

Step 1: Benzamide is added to excess 1M NaOH(aq) and then mixture is heated gently. An organic compound X is formed.

Step 2: The resulting mixture is then treated with reagent Y until no more solid benzoic acid is given out.

(i) Name the type of reaction involved in Step 1.

(1 mark)

(ii) Draw the structure of X.

(1 mark)

(iii) Suggest what Y would be.

(1 mark)

(iv) Suggest why X is more soluble than benzoic acid in water.

(1 mark)

(v) Describe briefly how a dry benzoic acid sample can be obtained after Step 2.

(1 mark)

(b) Outline a synthetic route, with no more than three steps, to accomplish the conversion of benzoic acid to benzyl bromide. For each step, given the reagent(s), reaction conditions (as appropriate) and structure of the organic product.

(3 marks)

DSE14_14

Butter contains a small amount of triglyceride of butanoic acid.

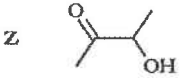
(a) Draw the structure of triglyceride of butanoic acid.

(1 mark)

(b) An organic acid Q is an isomer of butanoic acid. State the systematic name of Q.

(1 mark)

(c) The structure of Z, another isomer of butanoic acid, is shown below:



(i) Using '*', label ALL chiral centre(s) in the above structure of Z.

(1 mark)

(ii) Suggest a chemical test to show how to distinguish between Q and Z.

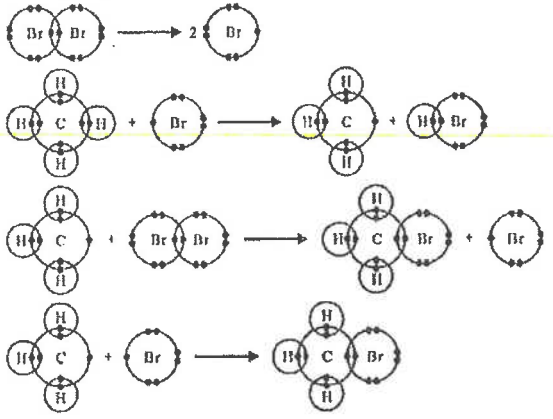
(2 marks)

(d) Margarine, a butter substitute, can be made from vegetable oils. What chemical reaction is involved in the production of margarine from vegetable oils?

(1 mark)

DSE15_06

The steps involved in the reaction of methane with bromine forming CH_3Br can be shown by the following diagram. Only electrons in the outermost shells are shown.



(a) Name the type of the reaction for the formation of CH_3Br from methane and bromine.

(1 mark)

(b) State the condition needed for the reaction to occur.

(1 mark)

(c) State the expected observation for the reaction.

(1 mark)

(d) With reference to its electronic structure, explain why the species 

has a high reactivity.

(1 mark)

(e) The reaction of methane with bromine can also form other single-carbon-containing organic compounds.

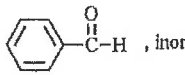
(i) Suggest one such compound.

(1 mark)

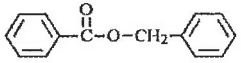
(ii) Suggest a condition so that the reaction of methane with bromine can form more CH_3Br but less other organic compounds.

(1 mark)

DSE15_12

You are provided with  , inorganic reagents and organic solvents.

Outline a synthetic route, with no more than three steps, to obtain the following compound:



For each step, give the reagent(s), reaction conditions (as appropriate) and structure of the organic product.

(3 marks)

DSE15_13

Using $C_2H_5CH(OH)CH_3$ as an example, write a paragraph to illustrate 'enantiomerism'. Suitable diagram(s) should be included in your answer.

(4 marks + 1 mark)

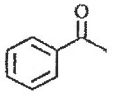
DSE16_12

Outline a synthetic route, with *no more than three steps*, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of the organic product.

(3 marks)

DSE16_13

The structure of acetophenone is shown below:



Heating a mixture of acetophenone and $NaBH_4$ in methanol solvent under reflux can give two isomeric compounds **P** and **Q**. **P** and **Q** have the same melting point and same solubility in methanol.

(a) Draw a labelled diagram of the set-up for heating the mixture under reflux.

(2 marks)

(b) Suggest another reagent that can also react with acetophenone in a suitable solvent to give **P** and **Q**.

(1 mark)

(c) What kind of isomers are **P** and **Q**?

(1 mark)

(d) State one different physical property between **P** and **Q**.

(1 mark)

(e) Suggest a chemical test to show how acetophenone and **P** can be distinguished.

(2 marks)

DSE17_03

Answer the following questions.

(a) Explain why propene can form a polymer, but propane cannot.

(1 mark)

(b) Explain why $HO_2C(CH_2)_4CO_2H$ can form a polymer with $H_2N(CH_2)_6NH_2$, but $CH_3(CH_2)_4CO_2H$ cannot.

(2 marks)

DSE17_09

Four unlabeled reagent bottles each contains one of the colorless liquids listed below:

$HOCH_2CH_2CH_2OH$ $CH_3CO_2CH_3$ $CH_3CH_2CO_2H$ $CH_2{=}CHCO_2H$

Suggest chemical tests to distinguish the four liquids.

(4 marks + 1 mark)

DSE17_12

Consider the following conversions:

$$C_5H_{10}O \xrightarrow{} C_5H_{12}O \xrightarrow{HBr} \text{3-bromopentane}$$

A: optically active

B: optically inactive

C

(a) Write the structural formula of C.

(1 mark)

(b) (i) Deduce the structural formula of B.

(2 marks)

(ii) Name the type of reaction for the conversion of B to C.

(1 mark)

(c) (i) Deduce the structural formula of A. Label on this structural formula all chiral centre(s), if any, by using '*'.

(2 marks)

(ii) State the reagent(s) required for the conversion of A to B.

(1 mark)

DSE17_13

Outline a synthetic route, with *no more than three steps*, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and the structure of the organic product.

(3 marks)

DSE18_04

Petroleum is an important source of hydrocarbons.

(b) D, E and F are isomeric alkene containing four carbon atoms. D and E are *cis-trans* isomers.

(i) Draw the structure of E (*trans*-isomer).

(1 mark)

(ii) State the systematic name of one possible structure of F.

(1 mark)

(c) Ethene and ethane are hydrocarbons.

(i) Suggest how ethene can be converted to ethane.

(1 mark)

(ii) Suggest a chemical test to distinguish between ethane and ethene.

(2 marks)

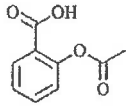
DSE18_10

Outline a synthetic route, with no more than three steps, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of the organic product.

(3 marks)

DSE18_12

Aspirin is a pain-killer. Its structure is shown below:



(a) State one medical application of aspirin other than pain-killing.

(1 mark)

(b) Explain why a suspension of aspirin and water can become clear when sodium hydrogencarbonate powder is added.

(2 marks)

(c) Heating aspirin with excess dilute aqueous acid under reflux will give two organic products.

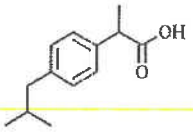
(i) Draw the structures of these two organic products.

(2 marks)

(ii) Explain why the conversion of aspirin to thee two organic products can hardly reach 100% even though the mixture of aspirin and dilute acid is heated under reflux for a long time.

(1 mark)

(d) Ibuprofen is also a pain-killer. Its structure is shown below:

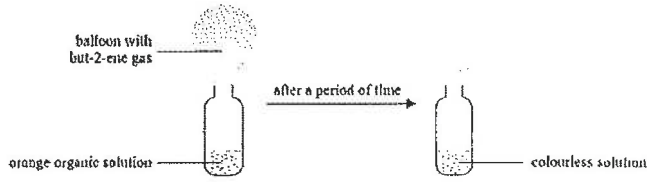


There exists enantiomerism in ibuprofen. Draw the three-dimensional structures for the pair of enantiomers.

(2 marks)

DSE19_03a

An experiment was carried out as shown below:



(i) Suggest what the orange organic solution may be.

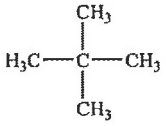
(1 mark)

(ii) With the help of a chemical equation, explain the colour change in the solution.

(2 marks)

DSE19_05

The structure of a compound is shown below :



Reacting with a reagent under certain conditions, it can give two compounds with the same molecular formula $C_5H_{10}Cl_2$ but different structures.

(a) Suggest what the reagent is.

(1 mark)

(b) State the condition needed for the reaction to occur at room temperature.

(1 mark)

(c) Name the type of the reaction involved.

(1 mark)

(d) (i) Draw the structure of ONE of these two compounds and give its systematic name.

(2 marks)

(ii) Draw the structure of the other compound.

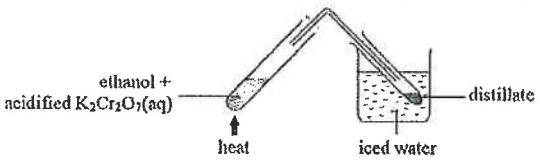
(1 mark)

(iii) These two compounds are isomers. State the type of isomerism exhibited by them.

(1 mark)

DSE19_13

(a) It was intended to prepare ethanoic acid from ethanol by the following set-up. However, the distillate collected mainly contained another organic product X but not ethanoic acid.



(i) What is X ?

(1 mark)

(ii) Explain why the distillate collected mainly contained X but not ethanoic acid.

(1 mark)

(b) Ethanoic acid can be converted to an unsubstituted amide.

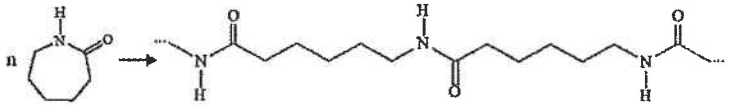
(i) Give the systematic name of this amide.

(1 mark)

(ii) Suggest what reagent and condition are needed for this conversion.

(1 mark)

(c) The following shows the formation of a polymer from an amide:



a portion of the polymer formed

(i) Draw the repeating unit of the polymer formed.

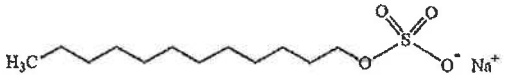
(1 mark)

(ii) There is a view which suggests that the above polymerisation does not involve condensation. Give a reason to support this view.

(1 mark)

DSE19_15 [Same as CE93_01, DSE12_14]

With reference to the structure of sodium lauryl sulphate (SLS) below, explain why it has cleansing properties.



(4 marks + 1 mark)

DSE20_05bi

5. The molecular formula of an organic compound W is $C_4H_6O_4$. It is soluble in water.

(a) When a piece of magnesium ribbon is placed into an aqueous solution of W, hydrogen gas evolves. According to this observation, suggest a functional group that W may contain. (1 mark)

(b) It is known that one mole of W can completely react with two moles of NaOH.

(i) Draw TWO possible structures of W.

b(i)+(ii)+(iii) = 6 marks

DSE20_10

10. The structure of a compound **Y** is shown below :

$H_2C{=}CHCH_2OH$

(a) **Y** can be prepared from reacting 3-chloropropene with an appropriate reagent.

(i) Write a chemical equation for this reaction.

(ii) Name this type of reaction. (2 marks)

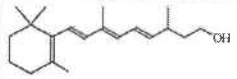
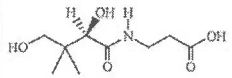
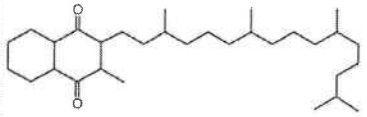
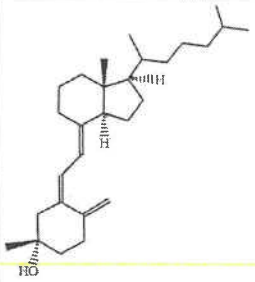
(b) On heating under reflux, a compound **L** reacts with KOH(aq) to give **Y** and $CH_3COO^-K^+$.

(i) Suggest the structural formula of **L**.

(ii) Draw a labelled diagram to show the set-up for this reaction. (3 marks)

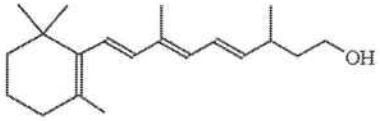
(c) Under suitable conditions, **Y** can form a polymer. Write the repeating unit of the polymer. (1 mark)

DSE20_11 11. The structures of some compounds are shown below :

Compound	Structure
W	
X	
Y	
Z	

(a) Which one of **W**, **X**, **Y** or **Z** is a tertiary alcohol ?

(b) Label all chiral centre(s), if any, by using '*' on the structure of **W** below.



11. (c) Heating **X** under reflux in 2 M NaOH(aq) can form an **optically active** organic compound **U** and an **optically inactive** organic compound **V**. Draw the respective structures of **U** and **V**.

U :

V : (2 marks)

(d) Consider the following reagents :

$Br_2(aq)$ acidified $K_2Cr_2O_7(aq)$ $Na_2CO_3(aq)$

(i) Suggest which one of the reagents can be used to perform a chemical test, in order to distinguish **X** from **W**, **Y** and **Z**.

(ii) State the observation in the test involved in (i). Explain your answer. (3 marks)

DSE21_04(d)

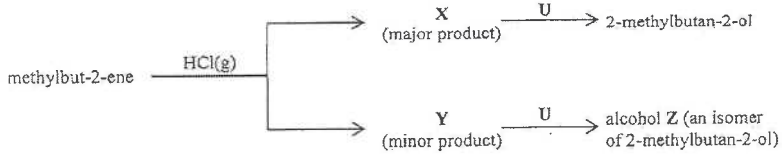
4. (d) Compound **Y** is a structural isomer of butane.

(i) Draw one possible structure of **Y**.

(ii) Which of decane, butane and **Y** would have the highest boiling point ? Explain your answer.

DSE21_11

11. Methylbut-2-ene reacts with HCl(g) to give **X** as the major product as predicted from Markovnikov's rule. During the reaction, another product **Y** (minor product) can also be formed. Refer to the following organic conversions :



(a) State the Markovnikov's rule.

(b) Draw the structure of **X**.

(c) **X** reacts with **U** to give 2-methylbutan-2-ol. What is **U** ?

(d) (i) **Y** has one chiral centre. Draw a three-dimensional diagram for the structure of an enantiomer of **Y**.

11. (d) (ii) **Y** is optically active. What is meant by the term 'optically active' ?

(e) **Y** reacts with **U** to give alcohol **Z**. Suggest a chemical test to show how **Z** and 2-methylbutan-2-ol can be distinguished.

DSE21_13

*13. Using nylon-6,6 as an example, illustrate the meaning of condensation polymerisation. Your answer should also include the structural feature of the monomers.

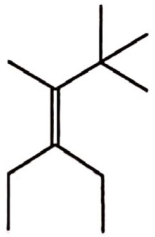
(5 marks)

24. Consider the following statements and choose the best answer :

1st statement	2nd statement
Ethene and but-1-ene have the same standard enthalpy change of combustion.	Ethene and but-1-ene have the same empirical formula.

A. Both statements are true and the 2nd statement is a correct explanation of the 1st statement.
B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.
C. The 1st statement is false but the 2nd statement is true.
D. Both statements are false.

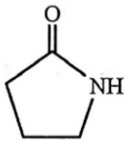
27. The structure of an organic compound is shown below :



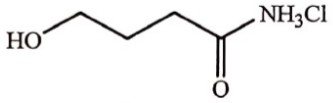
Which of the following combinations concerning whether *cis-trans* isomerism and enantiomerism can occur in the compound is correct ?

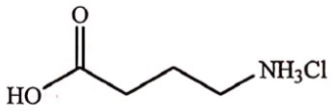
	***cis-trans* isomerism**	**enantiomerism**
A.	No	No
B.	Yes	Yes
C.	Yes	No
D.	No	Yes

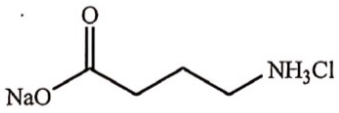
29. The structure of an organic compound is shown below :

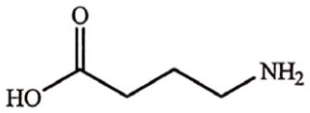


When it is heated with excess NaOH(aq), followed by the addition of excess HCl(aq), a major organic product **Z** is formed. Which of the following is **Z** ?

A. 

B. 

C. 

D. 

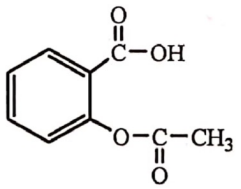
30. When 0.40 mol of $SO_2(g)$ and 0.60 mol of $O_2(g)$ are placed in a 1.0 dm^3 evacuated flask, the following reaction occurs.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

When chemical equilibrium is attained at a certain temperature, the flask is found to contain 0.30 mol of $SO_3(g)$. What is the equilibrium constant K_c for the reaction at this temperature ?

A. 20 mol^{-1} dm^3
B. 6.7 mol^{-1} dm^3
C. 2.0 mol^{-1} dm^3
D. 0.050 mol^{-1} dm^3

33. The structure of aspirin is shown below :



Which of the following statements about aspirin are correct ?

(1) It has an ester group.
(2) It can reduce inflammation.
(3) It has a higher solubility in $Na_2CO_3(aq)$ than in pure water.

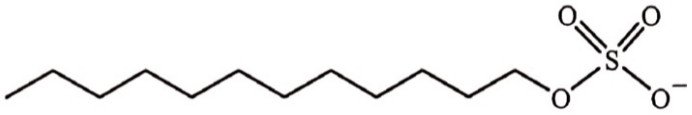
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

34. Which of the following compounds can be used as a monomer for condensation polymerisation ?

(1) $H_2C=CHCH_2CH_2CH=CH_2$
(2) $HOOCCH_2CH_2CH_2CH_2COOH$
(3) $HOCH_2CH_2CH_2CH_2CH_2CH_2OH$

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

35. The structure of a detergent is shown below :



Which of the following statements concerning this detergent are correct ?

(1) It is a soapless detergent.
(2) It can act as an emulsifying agent.
(3) It can increase the surface tension of water.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

9. At a certain temperature, the equilibrium constant K_c for the following reaction is 2.25×10^{-2} mol dm^{-3}.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H > 0$$

In an experiment, 0.84 mol of $PCl_5(g)$, 0.16 mol of $PCl_3(g)$ and 0.16 mol of $Cl_2(g)$ were initially introduced in a closed container of a fixed volume of 4.0 dm^3, and the system was allowed to attain equilibrium at that temperature.

(a) (i) Calculate the reaction quotient Q_c for the system under the initial conditions.

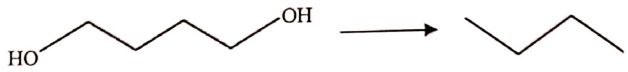
(ii) Explain whether the concentration of $PCl_5(g)$ would increase or decrease just after the reaction started.

(4 marks)

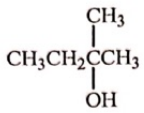
(b) Explain whether K_c would increase, decrease or remain unchanged if the temperature of the equilibrium mixture is increased.

(2 marks)

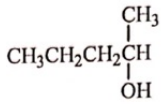
12. Outline a synthetic route, with NO MORE THAN THREE STEPS, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of the organic product.



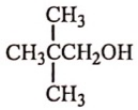
11. Compounds **P**, **Q** and **R** are structural isomers having the molecular formula of $C_5H_{12}O$. Their structures are shown below :



P



Q



R

(a) Give the systematic name of **P**.

(1 mark)

(b) Heating **Q** with acidified $K_2Cr_2O_7(aq)$ under reflux will give an organic product.

(i) Draw a labelled diagram to show the set-up for this reaction.

(ii) State the expected observation for this reaction.

(iii) Write the structural formula of the organic product.

(4 marks)

(c) **W** is an organic compound containing five carbon atoms. Under suitable conditions, **R** can be prepared from the reduction of **W**.

(i) Suggest the structural formula of **W**.

(ii) Suggest a reducing agent required for the reaction.

(2 marks)

(d) Compound **S** is an optically active secondary alcohol. It is also a structural isomer of compounds **P**, **Q** and **R**. Write the structural formula of **S**.

(1 mark)

Marking Scheme

MCQ

Part 1: Organic reaction and Part 2: Plastic

CE90_39	A	CE90_41	A	CE91_30	D	CE91_40	C
CE92_06	B	CE92_20	B	CE92_41	C	CE92_47	B
CE93_30	B	CE93_31	A	CE93_43	D	CE94_19	B
CE94_42	D	CE96_23	A	CE96_24	D	CE96_41	B
CE97_15	C	CE97_20	B	CE98_48	B	CE99_26	B
CE99_27	D	CE00_13	C	CE00_36	A	CE01_21	C
CE01_25	C	CE01_50	C	CE04_17	C (49%)	CE04_27	D (62%)
CE04_33	D (66%)	CE05_24	A (88%)	CE05_49	C (43%)	CE06_43	B (45%)
CE07_16	B (35%)	CE07_23	C (48%)	CE07_42	D (21%)	CE08_47	B (31%)
CE09_12	A (34%)	CE09_24	D	CE09_25	A (82%)	CE09_27	D (47%)
CE10_07	D (83%)	CE10_18	C (63%)	CE10_38	A (54%)	CE11_13	C (73%)
CE11_15	C (53%)	CE11_34	A (69%)	CE11_48	C (46%)	CE11_39	D (62%)
CE11_50	D (56%)						

Part 3: Soaps and Soapless detergents

CE90_37	D	CE90_38	B	CE91_33	B	CE91_49	C
CE92_23	B	CE93_44	B	CE94_24	D	CE94_25	C
CE96_28	A	CE96_29	D	CE97_35	A	CE98_15	D
CE98_41	A	CE99_43	C	CE99_48	C	CE00_18	B
CE00_41	C	CE01_16	C	CE02_21	D	CE03_19	A (67%)
CE03_29	B (53%)	CE03_49	A (45%)	CE04_04	D (46%)	CE04_22	A (59%)
CE04_49	A (58%)	CE05_32	D (72%)	CE05_42	B (79%)	CE06_26	A (63%)
CE06_42	B (54%)	CE07_50	C (63%)	CE08_35	B (67%)	CE09_45	A (45%)
CE09_50	A (82%)	CE10_41	B (64%)	CE11_47	A (57%)		
ASL08(I)_05	A	ASL09(I)_03	C	ASL13(I)_03	D	DSE11SP_26	C
DSE11SP_27	B	DSE11SP_28	C	DSE11SP_30	A	DSE11SP_31	C
DSE11SP_34	D	DSE12PP_27	A	DSE12PP_28	B	DSE12PP_33	D
DSE12PP_34	C	DSE12PP_36	C	DSE12_28	D (47%)	DSE12_29	D (79%)
DSE12_32	A (66%)	DSE12_33	B (65%)	DSE12_34	D (58%)	DSE12_36	C (62%)
DSE13_20	D (58%)	DSE13_29	B (56%)	DSE13_30	D (65%)	DSE13_31	B (70%)
DSE13_32	A (41%)	DSE13_34	C (56%)	DSE13_35	A (31%)	DSE14_27	D (62%)
DSE14_28	A (67%)	DSE14_29	B (55%)	DSE14_32	D (48%)	DSE14_33	D (49%)
DSE14_34	A (63%)	DSE15_26	C (14%)	DSE15_29	C (60%)	DSE15_30	D (85%)
DSE15_32	A (68%)	DSE15_34	C (62%)	DSE16_28	C (58%)	DSE16_29	C (26%)
DSE16_31	A (34%)	DSE16_35	A (64%)	DSE16_32	B (66%)	DSE17_18	B (50%)
DSE17_26	B (60%)	DSE17_29	A (66%)	DSE17_33	C (88%)	DSE17_35	C (43%)
DSE17_36	C (45%)	DSE18_27	A (57%)	DSE18_30	D (83%)	DSE18_31	B (43%)
DSE18_34	C (55%)	DSE18_35	A (59%)	DSE19_23	D	DSE19_29	B
DSE19_31	C	DSE19_32	C	DSE19_36	A		
DSE20_27	D	DSE20_29	C	DSE20_31	D	DSE20_32	A
DSE20_34	A	DSE20_36	A				

Structural Questions

Part 1: Organic reaction

CE90_01a

(i) propanoic acid [1]

$CO_3^{2-} + 2H^+ \longrightarrow CO_2 + H_2O$ [1]

(ii) $CH_3CH_2COOH + CH_3CH_2CH_2OH \rightleftharpoons CH_3CH_2COOCH_2CH_2CH_3 + H_2O$ [1]

OR, $CH_3COOH + CH_3CH_2CH_2OH \rightleftharpoons CH_3COOCH_2CH_2CH_3 + H_2O$

function of concentrated sulphuric acid (conc. H_2SO_4):

1. catalyst
2. speeds up the reaction [1]

CE90_03b

(i) A weak acid is partially (slightly) ionized [1]

to produce hydrogen ions. [1]

OR, $C_nH_{2n+1}COOH \rightleftharpoons C_nH_{2n+1}COO^- + H^+$

(ii) A few drops of phenolphthalein [1]

changes from colourless to pink. [1]

(iii) (1) moles of NaOH used $= 0.18 \times 22.4 \times 10^{-3} = 0.004032$ [1]

(2) $C_nH_{2n+1}COOH + NaOH \longrightarrow C_nH_{2n+1}COONa + H_2O$

moles of $C_nH_{2n+1}COOH$ = mole of NaOH used = 0.004032 [1]

relative molecular mass mass of $C_nH_{2n+1}COOH = \dfrac{0.355}{0.004032} = 88.05$ [2]

(iv) (1) molecular mass $C_nH_{2n+1}COOH = 88.5$

$12n + 2n + 1 + 12 + 16 \times 2 + 1 = 88.5, \quad n = 7$ [1]

So, the molecular formula is C_3H_7COOH [1]

(2) $CH_3CH_2CH_2COOH$ [1]

$CH_3CH(CH_3)COOH$ [1]

CE90_05b

(i) (1) hydrolysis [1]

$CH_3COOCH_2CH_3 + NaOH \longrightarrow CH_3COONa + CH_3CH_2OH$ [1]

OR, $CH_3COOC_2H_5 + OH^- \longrightarrow CH_3COO^- + CH_3CH_2OH$

(2) fruity smell not detected [1]

OR, two layers become one miscible layer

(3) to make soap / soapy detergents [1]

(ii) to condense the reactions / products (or acts as a condenser) [1]

OR, cold finger is to prevent the loss of volatile reagents / products.

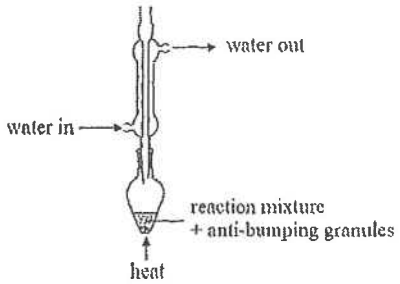
(iii) ethyl ethanoate / ethanol / reactants / products may catch fire from the direct-flame (or inflammable) [1]

OR, spurting out of chemicals during heating

(iv) (1) some reactants (or products) vapourized [1]

OR, the cold finger is an ineffective / poor condenser

(2) [2]



CE92_03a

(i) Rice and yeast solution is put into a conical flask then stoppered it. [1]
Stand it in room condition. [1]
After a few days, ethanol is formed. [1]

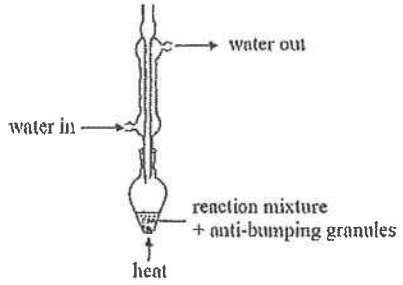
(ii) By distillation or fractional distillation. [1]

(iii) Ethanol is oxidized by air to form ethanoic acid. [1]

(iv) Health hazard: excessive intake of ethanol will damage the liver. [1]
Social problem: cause careless driving [1]

CE94_06b

(i) [3]



deduct mark for no indication of heat / closed system / incorrect labelling the direction of water flow

(ii) (1) Conc. H_2SO_4 is a catalyst. [1]
(2) For heat: to increase the rate of reaction and [1]
For reflux: to reduce the loss of volatile reactants and products. [1]

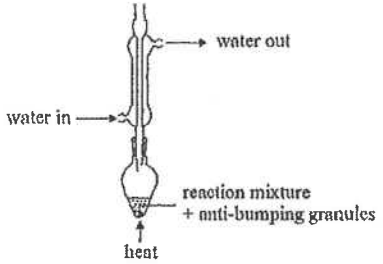
(iii) Two layers of liquid are formed. [1]
OR, pleasant smell is detected.

CE95_07b

(i) ethene / CH_2=CH_2 / C_2H_4 [1]
catalytic hydration [1]

(ii) CH_2=CH_2 + Br_2 ⟶ CH_2BrCH_2Br [1]

(iii) (1) ethanoic acid [1]
(2) [3]



deduct marks for wrong reagents / no indication of heat / closed system / labelling the direction of water flow

(iv) Pass the breath into acidified potassium dichromate (solution). [1]
The colour of the solution will change from orange to green. [1]

CE96_02

(a) moles of C in 1 mole of X = $\frac{60 \times 60\%}{12} = 3$ [1]
The general formula of alkanol is $C_nH_{2n+1}OH$ [1]
Thus, molecular formula of X is C_3H_7OH or C_3H_8O [1]

(b) CH_3–CH_2–CH_2–OH, propan-1-ol [1]

OR, $CH_3-\underset{\underset{OH}{|}}{CH}-CH_3$ propan-2-ol [1]

CE98_09a

(i) condenser [1]

(ii) to prevent bumping (or to ensure uniform heating) [1]

(iii) [1]
$CH_3CH_2CH_2OH \xrightarrow{[O]} CH_3CH_2COOH$

(iv) fractional distillation [1]

(v) The methanol in the reaction mixture is flammable. [1]

(vi) (1) Any TWO of the following: [2]
- effervescence / gas bubbles give out
- two layers of liquids resulted
- pleasant / sweet smell is detected

(2) methyl propanoate [1]

CE99_06b

(i) (1) yeast / enzyme [1]

(2) Fermentation of glucose produces carbon dioxide which reacts with $Ca(OH)_2$ in lime water to give insoluble calcium carbonate. [2]

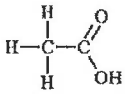
(3) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ [1]

(ii) (1) acidified potassium dichromate solution changes from orange to green. [1]

(2) Oxidation number of Cr in $Cr_2O_7^{2-}$ is +6.

Oxidation number of Cr in Cr^{3+} is +3. [1]

$Cr_2O_7^{2-}$ is reduced because oxidation number of Cr decreases. [1]

(3)  [1]

(iii) (1) drinking a small quantity of wine can reduce the proneness to heart attack. [1]

(2) Excessive drinking can cause brain damage / depression / hepatitis / damage of the liver / stomach ulcer / cancer of mouth, throat and gullet. [1]

CE02_03c

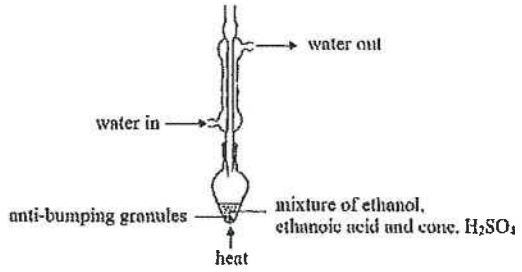
Sodium dichromate [1]

It changes from orange ($Cr_2O_7^{2-}$) to green (Cr^{3+}). [1]

CE02_06c

(i) concentrated sulphuric acid / conc. H_2SO_4 [1]

(ii) [2]



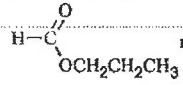
(iii) Iodine has a simple molecular structure. Attraction between I_2 molecules is weak van der Waals' forces. [1]

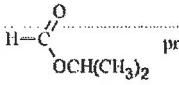
Sodium iodide has an ionic structure. Attraction between Na^+ and I^- ions is strong ionic bond. [1]

Strength of inter-particle attraction in ethyl ethanoate is comparable to that in iodine. [1]

(iv) flammable / C [1]

(v) Any ONE of the following:

 methyl propanoate

 propyl methanoate [2]

CE03_08a

(i) (1) glucose [1]

$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ [1]

(2) yeast. [1]

Yeast provides enzymes for fermentation of glucose. [1]

(ii) Prevent air from entering the jar otherwise ethanol produced will be oxidized. [1]

Prevent building up of pressure in the jar. [1]

(iii) (1) When the concentration of ethanol exceeds 18%, the yeast will not function and fermentation will stop. [1]

(2) distillation [1]

(iv) Ethanol in the wine undergoes oxidation to give ethanoic acid which is sour. [1]

CE04_08c

(i) Ethanol can reduce $Cr_2O_7^{2-}$ (orange) to Cr^{3+} (green). [2]

(1 mark for reduction / oxidation; 1 mark for colour change)

(ii) Conduct the test after the driver has thoroughly rinsed his mouth with water. A positive result probably indicates that the driver has drunk. [1]

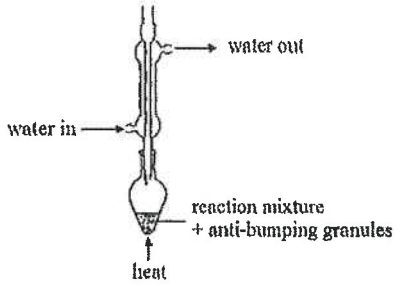
Ethanol is soluble in water. The concentration of ethanol in the breath will drop after the driver has rinsed his mouth. [1]

OR, Conduct the test after a few minutes. A positive result probably indicates that the driver has drunk.

The concentration of ethanol in the air breathed out will drop after a period of time as ethanol is a volatile liquid.

CE04_09b

(i) [2]

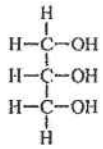


(1 mark for a correct diagram of the set-up; 1 mark for labelling the direction of water flow in the condenser.)

(ii) Heating under reflux can reduce loss of reactants / products by evaporation. [1]

CE05_11

(a) (i)



[1]

(ii) X has a larger molecular size / mass. [1]
Its side-chains can entangle together and relative motion between molecules will be hindered / larger intermolecular force. [1]

(iii) chemical to change the rate of reaction (hydrolysis) but itself remains chemically unchanged after reaction [1]

(iv) use a separating funnel [1]

(b) Any TWO of the following: [2]

- vegetable oils are renewable energy source
- the reserve of petroleum (a source of diesel) is limited
- biodiesel is more biodegradable
- biodiesel does not contain S which causes the formation of acid rain
- the exhaust produced does not contribute much to global warming because the CO_2 in the exhaust is already a part of the natural carbon cycle
- biodiesel burns with a less sooty flame

CE06_02

(a) $CH_3CH_2COOCH_3$ [1]

(b) alkanoic acid / carboxylic acid / fatty acid [1]

(c) propan-1-ol / propanal [1]

(d) The colour of the mixture changes from orange to green. [1]

(e) catalyst [1]

CE07_12

(a)

	C	H	O
Mole	$\frac{0.401}{12}$	$\frac{0.068}{1}$	$\frac{0.531}{16}$
Mole ratio	0.033	0.068	0.033
Simplest mole ratio	1	2	1

Empirical formula of Z: CH_2O [2]

(b) Let the molecular formula of Z be $(CH_2O)_n$.

Formula mass of $Z = \frac{1}{400 \times 10^{-3}} \times 24 = 60$

$(12 + 2 + 16)n = 60, \quad n = 2$

Molecular formula of Z is $C_2H_4O_2$. [2]

(c) (i) $HCOOCH_3$ [1]

Explanations:

from (III): Z is not an acid. [1]

from (IV): No carbon-carbon double bond in Z. [1]

(ii) methyl methanoate [1]

CE11_10b

(i) Anode. It is because the conversion of ethanol to ethanoic acid is an oxidation. [1]

(ii) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$ [1]

(iii) Higher concentration of ethanol produces larger current. [1]

CE11_12

Chemical knowledge [6]

Reaction with oxygen in air

Method:

Burn hexane and hex-1-ene separately on watch glasses.

Observation:

Hexane gives a less sooty flame. / Hex-1-ene gives a more sooty flame.

Explanation:

Carbon percentage by mass of hexane is lower than that of hex-1-ene.

Reaction with bromine

Method:

Add bromine solution to hexane and hex-1-ene separately in test tubes.

Observation:

Bromine solution decolourises in hexane less readily than in hex-1-ene.

Explanation:

Hex-1-ene is unsaturated while hexane is saturated.

OR, Hex-1-ene undergoes addition reaction with bromine while hexane does not undergo addition reaction.

OR, Hexane undergoes substitution reaction with bromine under light.

Effective communication [3]

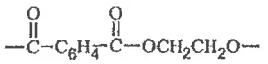
Part 2: Plastic

CE94_03

(b) polyethene / polypropene / polyvinyl chloride / nylon [1]

(d) (i) condensation polymerization [1]

(ii) [1]



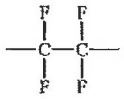
CE07_08

(a) (i)

[1]

OR, $-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-$

(ii) Repeating unit:



[1]

OR, $-CF_2-CF_2-$

Monomer: $CF_2=CF_2$ / tetrafluroethene [1]

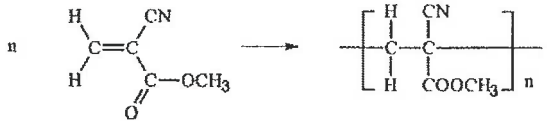
(b) (ii) Carpets may be made of a variety of materials. Separating nylon from carpets may be difficult. [1]

(iii) Poisonous gas / NO_2 / NO / CO / HCN / soot may evolve. [1]

CE08_08

(a) addition polymerization [1]

(b)

 [1]

(c) $CH_2=C(CN)COOH$ [1]

CH_3OH [1]

(d) To keep the superglue in an air-tight container / a dry place. [1]

CE08_09

Chemical knowledge [6]

(a) Add a few drops of concentrated sulphuric acid into the potassium dichromate solution to prepare acidified $K_2Cr_2O_7$ solution. Add excess acidified potassium dichromate solution into ethanol.

(b) Heat the mixture under reflux until no further reaction.

(c) Collect ethanoic acid produced by fractional distillation.

(d) Mix ethanoic acid, ethanol and a few drops of concentrated sulphuric acid.

(e) Heat the mixture under reflux.

(f) Collect ethyl ethanoate by fractional distillation.

Effective communication [3]

CE09_05

(a) cracking [1]

Large molecules break into small molecules. [1]

(b) addition / hydration [1]

(c) fractional distillation [1]

(d) **(i)** Gasohol is less flammable. / More energy can be obtained from gasohol. [1]

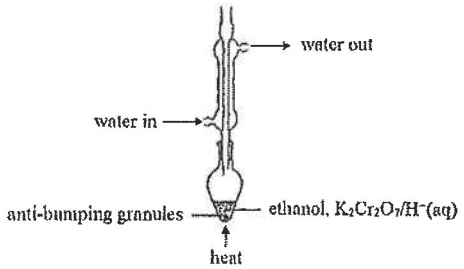
(ii) Gasohol undergoes complete combustion more readily. / Gasohol gives less carbon monoxide / particulates / soot / smoke. [1]

CE09_08

(a) Acidified potassium dichromate / potassium permanganate solution. [1]

(b) Prevent the ethanol from catching fire. / Ethanol is flammable. [1]

(c) (i) [3]

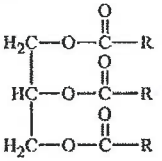


(ii) The new set-up prevents ethanol from escape. / helps the reaction occur for longer time. [1]

<u>Part 3: Soaps and Soapless detergents</u>

CE91_01b

(i)

 [1]

(ii) H_2SO_4 is a catalyst. [1]

(iii) Saponification (making soap) [1]

(iv) $R-COO^-Na^+$ [1]

(vi) • The hydrocarbon tail of Y dissolve in oil. [1]

• And the ionic head of Y dissolve in water. [1]

• After shaking, the oil turns to oil droplets due to the repulsion of the negatively charged ionic heads. [1]

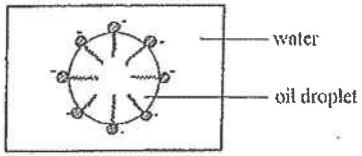
• Oil droplets cannot stick together. [1]

(vii) Emulsification / emulsifying action. [1]

Soap cleaning / detergent cleaning / to remove oil. [1]

CE93_01e

(i) (1)



[2]

(2) The hydrophilic ionic heads of detergent dissolve in water and the hydrophobic hydrocarbon tails dissolve in oil. Water molecules attract the hydrophilic ionic heads and bring the oil into water. [1]

After shaking, the oil becomes oil droplets. Oil droplets so not stick together because of the repulsion between negatively charged oil droplets. [1]

(ii) No, they will stick together and this will weaken or lose their cleaning action. [2]

CE94_05a

(v) Rainbow (conc. H_2SO_4) causes hydrolysis of the fats and greases in drain to form more soluble products (glycerol and carboxylic acid). [2]

CE95_02c

Vinegar [1]

It is acidic / the others are alkaline. [1]

CE95_09a

(i) Step 1: Heat / boil vegetable oil with sodium hydroxide solution. [2]

Step 2: Add concentrated NaCl solution to salt out the soap. [1]

Step 3: Separate (filter) the soap from the solution. [1]

(ii) Formula mass of the soap = $12(n + 1) + (2n + 1) + 2 \times 16 + 23 = 14n + 68$ [1]

$300 < 14n + 68 < 310$

$16.6 < n < 17.3$

$n = 17$ [1]

(iii) (1) petroleum (fraction) [1]

concentrated sulphuric acid [1]

(2) Advantage:

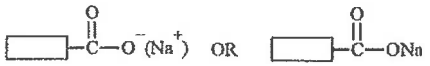
- the soapless detergent can be used in the hard water / acidic solution. [1]

Disadvantage: (any one) [1]

- some soapless detergent is non-biodegradable / may cause water pollution which can kill marine lives.
- may cause skin allergies

CE97_07b(iii)

(1) Compound I [1]

(2)  [1]

(3) The hydrocarbon tail of detergent is hydrophobic and readily soluble in the greasy dirt. [1]

The COO^- (ionic) end is hydrophilic and readily soluble in water. [1]

Water molecules attract the hydrophilic ionic heads and bring the oil into water.

Stirring (shaking) will cause the grease to break down into droplets. [1]

The negative charge on the droplets repels each other and hence oily droplets will become suspended in the aqueous solution and wash away by running water. [1]

CE00_06c

(ii) Detergents have a hydrocarbon tail which is hydrophobic (oil attraction) and an ionic head which is hydrophilic (water attracting), which can make oil into oil droplets for collection. [2]

CE01_06a

(i) Soap react with Ca^{2+} and Mg^{2+} ions in hard water to form scum / precipitate. Thus reduces the effectiveness of soap. [1]

(ii) Soda (sodium carbonate) removes Ca^{2+} and Mg^{2+} by forming insoluble calcium carbonate / magnesium carbonate [1]

$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3$ [1]

OR, $Mg^{2+} + CO_3^{2-} \longrightarrow MgCO_3$

CE02_09a

(i) (1) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ [1]

(2) Oils react with alkalis (undergoes hydrolysis) to give soaps / water soluble substances. [1]

(ii) The glass cleaner should be used in a well-ventilated environment because ammonia has a pungent smell / is toxic. [2]

OR, wear gloves because alkaline solutions can attack skin.

OR, wear safety spectacles because ammonia solutions attacks eyes.

CE04_07b

(i) The structure of the detergent consists of a hydrocarbon tail and an anionic head / the carboxylate ion ($-COO^-$). [1]

When mixed with paraffin oil, the hydrocarbon tail dissolves in the oil / is hydrophobic, while the ionic head dissolves in water / is hydrophobic. [1]

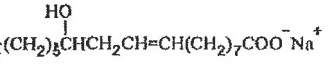
Upon shaking, oil drops, which carry negative charges, are formed. Repulsion of the negatively charged oil drops prevents them from joining together. So, an emulsion is formed. [1]

(ii) Not suitable.
Sea water contains a lot of metal ions, such as Ca^{2+} and Mg^{2+}. [1]
This anionic detergent will react with the metal ions to form scum and hence reduce the effectiveness of the detergent. [1]

CE07_13
Chemical knowledge [6]
- Both soapy and soapless detergents have ionic group / head and long hydrocarbon chain tail.
- Both soapy and soapless detergents have hydrophilic property and hydrophobic property.
- Soapy detergents made from fats / oils, while soapless detergents made from petroleum.
- Soapy detergents have $-COO^-$ group, while soapless detergents have $-SO_3^-$ / $-OSO_3^-$ group.
- Both soapy and soapless detergents act as wetting agents.
- Both soapy and soapless detergents act as emulsifying agents.
- Soapy detergents are usually biodegradable, while soapless detergents usually are not.
- Soapless detergents can be tailor-made, while soapy detergents cannot.

Effective communication [3]

CE09_12
(a) saponification / alkaline hydrolysis [1]
(b) concentrated sodium chloride solution / conc. NaCl(aq) / brine [1]
(c) [1]

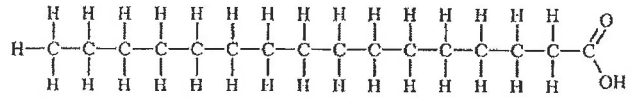


(d) The hydrocarbon tail of white solid is hydrophobic and readily soluble in the greasy dirt. The ionic head of white solid end is hydrophilic and readily soluble in water. [1]
Water molecules attract the hydrophilic ionic heads and bring the oil into water. [1]
Stirring (shaking) will cause the grease to break down into droplets. The negative charge on the droplets repels each other and hence oily droplets will become suspended in the aqueous solution and wash away by running water. [1]
(e) Preparation of soap / detergent *OR* Hyddrolysis of caster oil [1]
AND
Testing the emulsifying property of the product / cleaning action [1]
(f) White precipitate would be observed. [1]

CE11_11
(a) (i) Citrate ions can react with Mg^{2+} or Ca^{2+} ions in hard water to form insoluble substances. [1]
Prevent Mg^{2+} or Ca^{2+} ions from reacting with the soapy detergents to form scum. [1]
(ii) Phosphate ions can cause growth of algae / red tide. [1]

(b) (i) $CH_3(CH_2)_{14}COOH$ [1]

OR,



(ii) Sodium carbonate can reduce the acidity in the acidic environment. [1]
$2H^+ + CO_3^{2-} \longrightarrow CO_2 + H_2O$ [1]

(c) Any 3 points, 1 mark for each point [3]
- This detergent is biodegradable.
- This detergent works well in acidic medium.
- This detergent works well in hard water. / This detergent does not form scum with Mg^{2+} or Ca^{2+} ions in hard water.
- This detergent can save food in the production process.

AL96(II)_07b
(i) $\text{Moles of } (CH_3)_3COH = \frac{25}{74} = 0.338$ [½]

$\text{Moles of HCl} = \frac{36}{36.5} = 0.986$ [½]

$(CH_3)_3COH + HCl \longrightarrow (CH_3)_3CCl + H_2O$

HCl is in excess ∴ $(CH_3)_3COH$ is the limiting reactant. [½]

(ii) $\text{Moles of } (CH_3)_3CCl = \frac{28}{92.5} = 0.303$ [½]

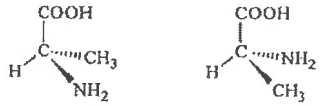
$\%\text{ yield} = \frac{0.303}{0.338} \times 100\% = 89.6\%$ [1]

(iii) Substitution [1]

AL96(II)_07c
(i) Warm the compound with Tollen's reagent / ammoniacal silver(I) oxide / ammoniacal silver nitriate. [1]
Cyclopentanecarbaldehyde gives a silver mirror, while cyclohexanone cannot. [1]
OR, Fehling reagent, only cyclopentanecarbaldehyde gives red precipitate.
OR, $K_2Cr_2O_7/H^+$, only cyclopentanecarbaldehyde changes the color of solution from orange to green.
(ii) Warm the compound with $AgNO_3(aq)$. [1]
$C_6H_5CH_2Cl$ gives a white precipitate, while $C_6H_5CH_2I$ give a yellow precipitate. [1]

AL96(II)_08b
(i) Geometrical isomerism / cis-trans isomerism [1]

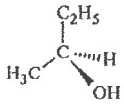
[1]
(ii) Enantiomerism / optical isomerism [1]



[1]

AL98(I)_04

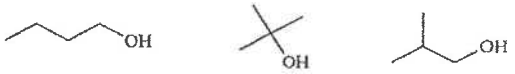
(a) (i)



[1]

(ii) Optical isomerism / enantiomerism [1]

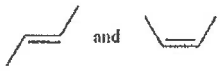
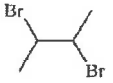
(b) (i)



[½]
[½]
[½]

(ii) Upon reaction with Zn/conc. HCl, **E** gives turbidity slower than $(CH_3)_3COH$, but faster than $CH_3(CH_2)_3OH$ and $(CH_3)_2CHCH_2OH$. [1] [½]

(c) (i)

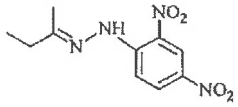
F and **G**  and **H** 

[3]

(ii) Geometrical isomerism / cis-trans isomerism [1]

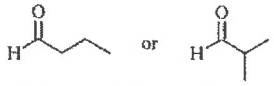
AL98(I)_05

(a)



[1]

(b) (i)



[1]

(ii) Melting point determination: compare the melting point of the red precipitates with those from tables. [1]

AL98(I)_08a

(i) Use a polarimeter: if no rotation then (±); if rotation to the right / there is rotation of plane-polarized light, then (+). [½] [½]

(ii) Add $AgNO_3(aq)$: RCOCl gives white precipitate, AgCl(s); RCOBr gives yellow precipitate, AgBr(s). [½] [½]

ASL99(I)_05

(a) W [1]

Acidified $K_2Cr_2O_7$, heating [1]

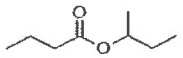
(b) Shake samples with 2,4-dinitrophenylhydrazine solution respectively. [1]

Only Y give a red/orange/yellow precipitate. [1]

OR, Mix samples with Tollen's reagent respectively.

Only Y give a silver mirrow.

(c) Heating reflux, with concentrated H_2SO_4 [1]



[1]

ASL99(II)_11 (modified)

(a) 4-methylpent-2-ene [1]

(b) (i)

[1]

(ii) *Cis-trans* isomerism / geometrical isomerism [1]

(c) (i) Mole ratio of C : H = $\frac{92.3}{12} : \frac{7.7}{1} = 7.69 : 7.7 = 1 : 1$ [1]

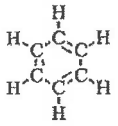
Empirical formula of S is CH

Assume that the molecular formula of S be $(CH)_n$

$(12 + 1)n = 78.1 \rightarrow n = 6$

molecular formula of S is C_6H_6 [1]

(ii)

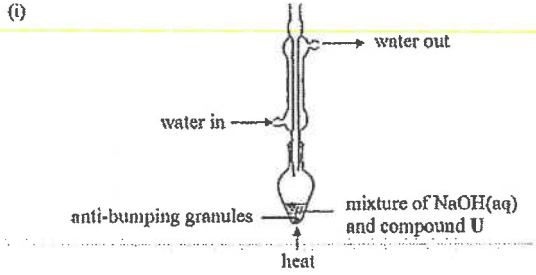


[1]

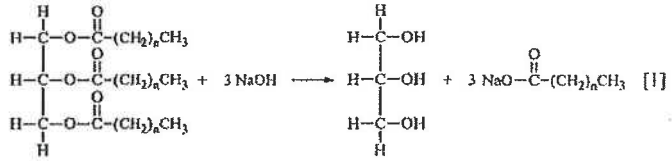
ASL99(II)_13 (modified)

(a) Ester linkage [1]

(b) (i)



[2]

(ii)  [1]

(iii) Mole of NaOH remained after alkaline hydrolysis

$= \frac{100}{10} \times 0.53 \times 27.5 \times 10^{-3} = 0.146$

Mole of NaOH used for alkaline hydrolysis

$= 2 \times 100 \times 10^{-3} - 0.146 = 0.05425$

Mole of compound $\mathbf{U} = \frac{0.05425}{3} = 0.01808$ [1]

Molecular mass of compound $\mathbf{U} = \frac{8.51}{0.01808} = 470.6$ [1]

$12 \times 9 + 16 \times 6 + 1 \times 14 + 3n \times (12 + 1 \times 2) = 470.6$

$n = 6.01$

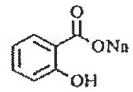
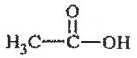
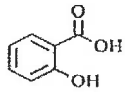
$\therefore$ value of n = 6 [1]

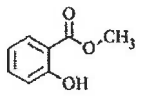
(iv) (I) A white solid float on the top of the saturated sodium chloride solution. [1]

(II) Saturated sodium chloride solution provides a highly polar environment (solvent with high ionic strength) for slightly polar sodium carboxylate to salting out. Nonpolar alkyl group in sodium carboxylate is unlikely miscible in polar solvent. [1]

ASL00(I)_06

(a) Carboxylic acid (carboxyl group), esher, aromatic ring (benzene). [2]

(b) X  Y  Z  [3]

(c)  [1]

AL01(I)_08

(a) Propyl propanoate / $CH_3CH_2CO_2CH_2CH_2CH_3$ [1]

Some propan-1-ol was oxidized to propanoic acid which reacts with excess propan-1-ol to give the ester. [1]

(b) Fractional distillation / chromatography [1]

(c) Any TWO of the following: [2]

- Boiling point determination
- Treat propanal with 2,4-dinitrophenylhydrazine, then determine the m.p. of the crystals formed.
- Compare IR spectrum (finger print region) of the propanal with that of an authentic sample.
- Compare mass spectrum (finger print) of the propanal with that of an authentic sample.

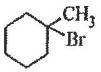
ASL01(II)_10

(a) (i) Reagent: $H_2(g)$, Pt [1]

Condition: high temperature and high pressure [1]

(ii) Shake the samples with acidified potassium permanganate solution respectively. [1]

Only 1-methylcyclohexene can decolorize the purple color of $KMnO_4(aq)$. [1]

(b)  [1]

ASL01(II)_12

(a) The detergent has an ionic head ($SO_3^-Na^+$) and a hydrocarbon tail. [1]

The hydrocarbon tail dissolves in grease droplets / is hydrophobic while the ionic head dissolves in water / is hydrophilic. [1]

The ionic heads of the grease droplets repel from each other and the dirts inside these droplets are then removed. [1]

(b) The detergent with branched hydrocarbon chain is non-biodegradable. [1]

Concentrated suphuric acid and sodium hydroxide solution are used in preparing detergent. [1]

ASL02(I)_03

(a) Mole ratio of C :H :O $= \frac{55.8}{12} : \frac{7.0}{1} : \frac{37.2}{16} = 4.65 : 7 : 2.325 = 2 : 3 : 1$ [1]

Empirial formula of X = C_2H_3O [1]

(b) Let the molecular formula of X be $(C_2H_3O)n$

$82 < (12 \times 2 + 1 \times 3 + 16)n < 90$

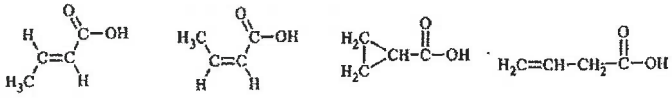
$1.91 < n < 2.09$ [1]

molecular formula of X = C_4H_6O [1]

(c) X reacts with sodium carbonate solution to give carbon dioxide. X possesses COOH.

Double bond equivalence of X is 2,

X possesses C=O and C=C, or X is a cyclic alkanoic acid. [3]



ASL02(II)_11

(a) Heat the samples with acidified $KMnO_4(aq)$ respectively, only $CH_3(CH_2)_3OH$ can decolorize purple $KMnO_4(aq)$. [1]
[1]

OR, Heat the sampes with acidified $K_2Cr_2O_7(aq)$ respectively, only $CH_3(CH_2)_3OH$ can turn orange $K_2Cr_2O_7(aq)$ to green.

(b) Warm the samples with NaOH(aq), followed by acidifying with $HNO_3(aq)$. [1]
Add silver nitrate solution into the resultant mixture. [1]
Chloroalkane will give white precipitate, [1]
while iodoalkane will give yellow precipitate. [1]

ASL03(I)_02

Boiling point increases in the order:
$CH_3(CH_2)_2CH_3 < CH_3(CH_2)_3CH_3 < CH_3(CH_2)_3Cl < CH_3(CH_2)_3OH$ [1]
Both $CH_3(CH_2)_2CH_3$ and $CH_3(CH_2)_3CH_3$ are non-polar. Their intermolecular attraction is weak van der Waals' force. [1]
The strength of van der Waals' forces increases with relative molecular size. [1]
∴ The boiling point of $CH_3(CH_2)_3CH_3$ is higher than the boiling point of $CH_3(CH_2)_2CH_3$.
$CH_3(CH_2)_3Cl$ has a net dipole moment. Its intermolecular attraction is stronger than that in alkanes but weaker than the intermolecular attraction between the alcohol molecules. [1]
Hydrogen bonds exist between the alcohol molecules. ∴ $CH_3(CH_2)_3OH$ has the highest boiling point. [1]

ASL03(II)_09

(a) $CH_3CH_2CH_2Cl \xrightarrow[1]{NaOH(aq),\ \Delta} CH_3CH_2CH_2OH \xrightarrow[3]{K_2Cr_2O_7/H^+(aq)} CH_3CH_2CH_2-C(=O)-OH$ [3]

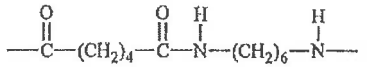
(b) $CH_3CH{=}CH_2 \xrightarrow{HCl(aq)} CH_3-CH(OH)-CH_3 \xrightarrow[1]{K_2Cr_2O_7/H^+(aq)} CH_3-C(=O)-CH_3$ [3]

ASL03(II)_12

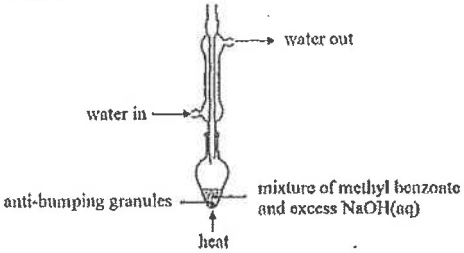
(a)  [1]

(b) Method (I): The waste contains $Cr_2O_7^{2-}$ which is toxic. [1]
Removal of $Cr^{3+}(aq)$ from the product is costly.
Method (II): HNO_3 is a strong acid. Discharge of the waste into waterways leads to environmental pollution. [1]

(c) Excess H_2O_2 in to reaction mixture can easily be removed as it can be decomposed by heating. [1]
Other products of the reactions, namely $H_2O(l)$ and $O_2(g)$, will not cause threat to the environment. [1]

(d)  [1]

ASL04(II)_10

(a) 

[2]

(b) Add $H_2SO_4(aq)$ and filter [1]

(c) Dissolve crude sample in minimum amount of hot water. [½]
Filter mixture while hot. [½]
Allow filtrate to cool and collect crystals by filtration [1]

(d) mole of methyl benzoate $= \frac{3.0}{136.0} = 0.022$ [½]

mole of benzoic acid $= \frac{1.9}{122.0} = 0.0156$ [½]

% yield $= \frac{0.0156}{10.022} \times 100\% = 70.8\%$ [1]

ASL05(I)_03

(a) $CH_3CO_2H + CH_3OH \longrightarrow CH_3CO_2CH_3 + H_2O$ [1]

(b) The reaction of CH_3CO_2H with CH_3OH involves breaking of the O–H in the alcohol and the C–O bond in the acid. [1]
∴ The ^{18}O always resides in the ester, [1]

OR, The mechanism is likely to be:

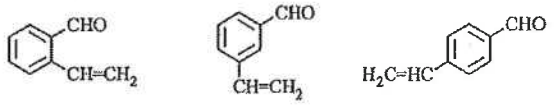
$$CH_3-C(=O)-O-H + H-{}^{18}O-CH_3 \rightleftharpoons CH_3-C(=O)-{}^{18}O-CH_3 + H_2O$$
mass = 76 amu

ASL05(I)_06

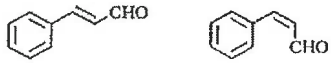
(a) mole ratio of C : H : O $= \frac{81.8}{12} : \frac{6.1}{1} : \frac{12.1}{16} = 6.82 : 6.10 : 0.756 = 9 : 8 : 1$ [1]
Empirical formula is C_9H_8O [1]
Molecular formula is $(C_9H_8O)n$
$130 < n(9 \times 12 + 8 + 16) < 140, \quad n = 1$
Molecular formula is C_9H_8O [1]

(b) A reacts with Tollens' reagent. ∴ A possess an aldehyde functionality / the CHO group. [1]
A is an aromatic compound with molecular formula C_9H_8O. It has a double-bond equivalent (DBE) of 6. [1]
A is likelu to possess a C=C bond or an alicyclic structure. [1]

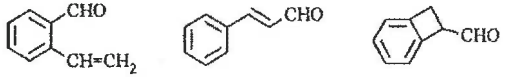
(c) Possible types of isomerism:
Position ismerism: [1]
Structure (Any TWO of the following) [1]



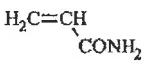
Geometrical isomerism:

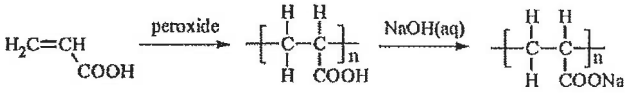


Sructural isomerism



ASL05(I)_07

(a)  [1]

(b)  [2]

(c) (i) Polyacrylamide contains a large number of amide groups ($CONH_2$). These amide groups can form hydrogen bonds with water, [1] [1]
(ii) In sodium polyacrylate, the Na^+ ions have a high affinity for water, and cause the water in the urine to flow towards the diaper. [1]

(d) Any ONE of the following: [1]
- leak-proof tape for undersea cables
- Water absorbent meat packaging
- In gasoline filters for removal of water
- In farming (to retain moisture)

ASL05(II)_09

Boiling point: **B < D < C** [1]
The boiling point of a compound depends on its intermolecular attraction.
The intermolecular attraction of B is van der Waals' force. The attraction force is weakest among the three. [1]
The attraction between molecules of C is hydrogen-bond which is the strongest among the three. ∴ C has the highest boiling point. [1]

ASL05(II)_09

Add water to the liquids. [1]
Both CH_3COCH_3 and $CH_3(CH_2)_4NH_2$ can mix with water in all proportions. [1]
Add a piece of pH paper to the aqueous solutions. [1]
$CH_3(CH_2)_4NH_2$ is alkaline, but CH_3COCH_3 is not. [1]
OR, $CH_3(CH_2)_4NH_2$ has a strong fishly odor while CH_3COCH_3 doe not.

Add Br_2 solution to the two compounds which are not miscible with water. [1]
Only cyclohexene can decolorize Br_2 solution. [1]
OR, Add $AgNO_3(aq)$ to the two compounds which are not miscible with water.
$CH_3CH_2CH_2Br$ gives a pale yellow precipitate slowly.

ASL05(II)_10

(c) When heated under reflux, the CH_3CHO formed will be oxidized by $Cr_2O_7^{2-}/H^+$ to CH_3COOH. [1]
Appropriate method: warm a mixture of excess CH_3CH_2OH and $Cr_2O_7^{2-}/H^+$, and collect the product by simple distillation. [1] [1]

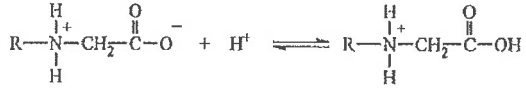
ASL06(I)_01

(a) Structural isomers [1]
(b) Structural isomers [1]
(c) Identical molecule [1]
(d) Identical molecule [1]

ASL06(I)_08 (modified)

(a) $CH_3(CH_2)_4CH_2$– is a non-polar group which can dissolve in dirt; [1]
$-^+NH_2CH_2COO^-$ is a polar group which can dissolve in water. [1]
The Ionic heads of the grease droplets repel from each other and the dirts inside these droplets are then removed. [1]

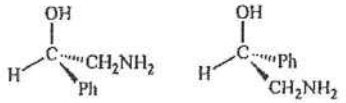
(b) No matter it is used in acidic or alkaline medium, ionic heat still exist to demonstrate cleaning property of a detergent. [1]


[1]


[1]

$R = CH_3(CH_2)_{14}CH_2-$

AL06(II)_05b

(i) (I)  [2]

(II) They rotate the plane of polarization of a beam of plane polarized light to opposite directions. [1]

(ii) The neuroreceptor is likely to be chiral. The reaction between compound B and the neuroreceptor is stereospecific. [1]

(iii) Conduct a chromatographic study. [1]

Compare the R_f value of the suspected stimulant with that of an authentic sample of B. [1]

ASL06(II)_09

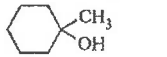
(a) Warm the samples with $K_2Cr_2O_7/H^+(aq)$. [1]

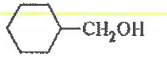
$(CH_3)_3COH$: solution remains orange color

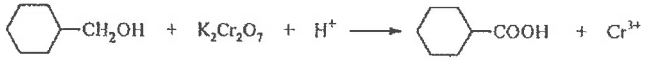
$(CH_3)_2CHCHO$: solution turns from orange ($Cr_2O_7^{2-}$) to green (Cr^{3+}). [1]

$(CH_3)_2CHCHO + K_2Cr_2O_7 + H^+ \longrightarrow (CH_3)_2CHCOOH + Cr^{3+}$ [1]

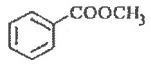
(b) Warm the samples with $K_2Cr_2O_7/H^+(aq)$. [1]

 solution remains orange [½]

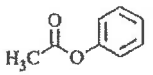
 solution turns from orange to green [½]

 [1]

ASL06(II)_10

(a)  [1]

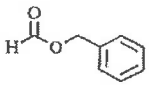
$C_6H_5COOCH_3 + NaOH \longrightarrow C_6H_5COONa + CH_3OH$ [1]

(b)  [1]

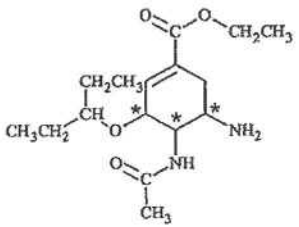
$CH_3COOC_6H_5 + NaOH \longrightarrow CH_3COONa + C_6H_5OH$ [1]

$2CH_3COONa + H_2SO_4 \longrightarrow 2CH_3COOH + Na_2SO_4$ [1]

The smell of vinegar comes from CH_3COOH [1]

(c)  [1]

ASL07(I)_07

(a)  [1]

(b) 4 [1]

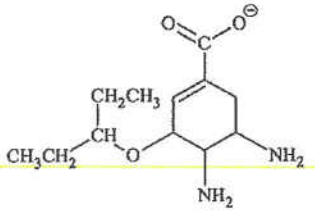
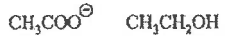
Any TWO of the following [1]

Amide

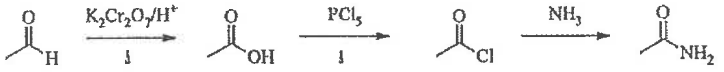
C=C bond

Amine/ NH_2

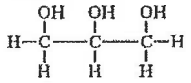
ester

(c)   [2]

ASL07(II)_02

 [2]

ASL08(I)_06

(a)  and $C_{17}H_{35}COONa$ [2]

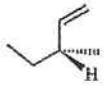
(b)  [1]

ASL08(II)_01

A is an alkaene (it undergoes hydrogenation over Pt.) [½]

Structure of A: Structure of the enantiomers of A:

[½]

   [½] [½]

Hydrogentation of A gives 3-methylpentane which is achiral [1]

B is also an alkene. (It undergoes addition.) [½]

B reacts with Br_2 to give a single compound and with HBr to give a single achiral compound.

Each carbon atom in the double bond of B should have the same substitutents.

G can only be $(CH_3)_2C{=}C(CH_3)_2$ [1]

$(CH_3)_2C{=}C(CH_3)_2 + Br_2 \longrightarrow (CH_3)_2CBrC(CH_3)_2Br$ (single compound) [½]

$(CH_3)_2C{=}C(CH_3)_2 + HBr \longrightarrow (CH_3)_2CHC(CH_3)_2Br$ (single achiral compound) [1]

ASL08(II)_02 (modified)

(a)  [1]

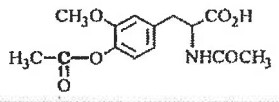
(b) (i) Total no. of mole of products $= \dfrac{(0.2 + 0.167 + 0.117)}{134.5} = 3.60 \times 10^{-3}$ [½]

Moles of 2,4 – dimethylpentane $= \dfrac{0.45}{100} = 4.50 \times 10^{-3}$ [½]

Overall % yield $= \dfrac{3.60 \times 10^{-3}}{4.50 \times 10^{-3}} \times 100\% = 80\%$ [1]

(ii) Mole ratio of 1°, 2° and 3° monochlorinated products formed
= 1.71 : 1 : 1.43 [1]

AL09(II)_05b (modified)

(i) (I)  [1]

(II) Enantiomerism [1]

(III) Both M and N show optical rotation. One of them turns the plane of polarization of a beam of plane polarized light to the left, while the other to the right. [1]

(ii) (I) The double bond is planar. When hydrogenation takes place over Pt, the two H atoms can add to the double bond from either side of the double bond. [1]
There is an equal likelihood of obtaining the enantiomers. [1]
The product is a racemic mixture.

(II) Use an asymmetric catalyst / asymmetric reagent for the hydrogenation. [1]

ASL10(I)_06

(a) Geometrical isomerism / *cis-trans* isomerism [1]

(b) The melting point of a substance depends intermolecular attraction as well as molecular symmetry. [1]
In both dimethyl fumarate and A, the intermolecular attraction is van der Waals' forces and they are of comparable strength.
Dimethyl fumarate, being more symmetrical, can better fit into a solid lattice. ∴ It has a higher melting point. [1]

ASL10(II)_04 (modified)

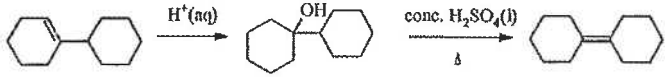
(a) Mole ratio of C : H : O $= \dfrac{62.1}{12} : \dfrac{10.3}{1} : \dfrac{27.6}{16} = 5.18 : 10.3 : 1.73$ [1]
Simlpest ratio of C : H : O =3 : 6 : 1
Empiricial formula of D is C_3H_6O [1]
Let molecular formula of D be $(C_3H_6O)n$
$(12\times3+1\times6+16)n=58$, $n = 1$
Molecular formula of D is C_3H_6O [1]

(b) D does not react with $Cr_2O_7^{2-}/H^+$. It is not aldehyde or alcohol [1]
DBE of D is 1, D possesses C=O or C=C

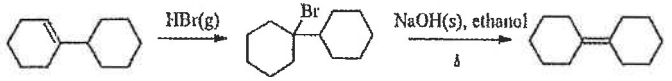
 or  [1]

ASL11(I)_06

(a) 1-cyclohexylcyclohexene [1]

(b)  [2]

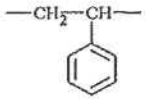
OR



ASL11(II)_07

(a) Br_2; light / UV / peroxide; (excess ethylbenzene) [1]

(b) Elimination / dehydrogenbromination / dehydrogenhalogenation [1]

(c) (i)  [1]

(ii) Peroxide; heat [1]

ASL12(I)_06

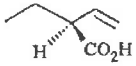
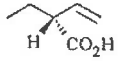
(a) Double bond equivalence of B $= \frac{6 \times 18 + 2 - (6 \times 4 + 10 \times 7 + 2 \times 6)}{2} = 2$

B has two double bonds. [½]

B can undergo catalytic hydrogenation. B contains C=C bond(s). [½]

1 mol of D reacts with excess $NaHCO_3(aq)$ to give 1 mol of $CO_2(g)$. D is a monocarboxylic acid. [1]

Possible structure of B:

 and  [1½]

Possible structure of D:

 [1]

D does not have a chiral centre. It is optically inactive. [½]

ASL12(I)_10

(a) Phenolphthalein / phenol red [1]

(b) No. of moles of excess $OH^-(aq) = 2.50 \times 23.1 \times 10^{-3}$ [½]

No. of moles of NaOH(aq) used $= 3.05 \times 25 \times 10^{-3}$ [½]

No. of moles of $OH^-(aq)$ reacted with aspirin

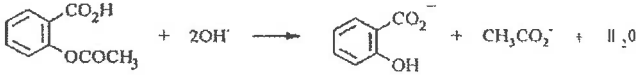
$= 3.05 \times 25 \times 10^{-3} - 2.50 \times 23.1 \times 10^{-3}$

$= 0.0185$ [½]

Mass of aspirin $= 0.0185 \times 180.0 = 3.33$ [½]

% by mass $= \frac{3.33}{2.25} = 148$ [1]

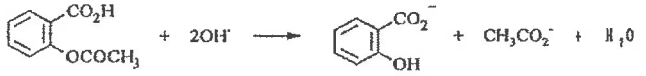
Reason: The ester group in aspirin undergoes alkaline hydrolysis. [½]



The amount of $OH^-(aq)$ consumed is greater than the expected value. [½]

(c) Any ONE of the following: [1]

- Use a smaller amount of aspirin so that a less concentrated NaOH(aq) can be used.
- Heat the reaction mixture to ensure complete hydrolysis of the ester so that the calculation can be based on the reaction:



ASL12(II)_07 (modified)

(a) Peroxide; heat; high pressure [1]

(b) The intermolecular attraction between PE polymers is van der Waals' force (dispersive force). [½]

C–Cl bond is polar. The intermolecular attraction between PVC polymers is predominately dipole-dipole attraction which is a stronger than dispersive force / a stronger van der Waals' force. [1] [½]

(c) (i) Most parts of DEHP (the benzene ring and the aliphatic carbon chain) are hydrophobic. [½]

Emulsifier has a hydrophilic head and a hydrophobic tail. [½]

When DEHP, water and emulsifier are shaken vigorously, the hydrophobic tail of the emulsifier dissolves in DEHP while the hydrophilic head dissolves in water. A cloudy mixture is formed. [½]

The repulsion of the hydrophilic heads prevents the recombination of the droplets and keeps the cloudy mixture stable.

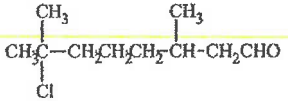
(ii) Chromatography + mass spectrometry [1]

Chromatography + (comparing the R_f value of the peak due to DEHP with that of an authentic sample)

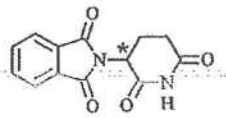
ASL12(II)_08

(a)  [1]

(b) 3,7-dimethyloct-6-enal [1]

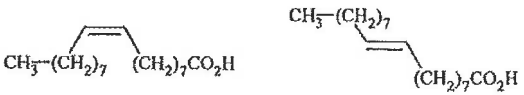
(c)  [1]

ASL13(I)_06 (modified)

(a)  [1]

(b) Receptor molecules in the body are chiral. [½]
The action of chiral drug on receptor molecules is stereo-specific. [1]
The key-and-lock hypothesis applies to the effect of chiral drugs on human bodies.
Mismatching of drug molecules with the targeted receptors may cause undersirable side effect such as requirement of higher dosage ad increasing toxicity. [½]

ASL13(II)_06

(a) 
 [2]

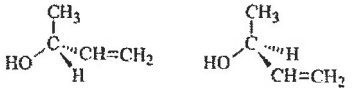
(b) Measure the m.p. of the two compounds. [1]
The trans-isomer has a higher melting point. [1]
OR, Compare the melting points of the compounds with data in chemical literature.
(Accept other appropriate physical methods for differentiating the two compounds.)

ASL13(II)_08

(1) Mole ratio of C : H : O $= \frac{66.7}{12} : \frac{11.1}{1} : \frac{22.2}{16} = 5.56 : 11.1 : 1.39 = 4 : 8 : 1$ [1]
Empirical formula of D = C_4H_8O [1]
∵ the relative molecular mass of D is 72, ∴ molecular formula of D = C_4H_8O [1]
∵ D.B.E. of D is 1, ∴ D possess 1 C=C or 1 C=O bond.

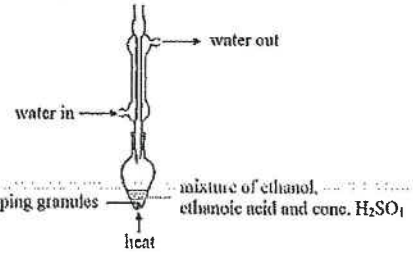
(2) ∵ D exhibits optical isomerism, ∴ D possess a chiral carbon, attached with 4 different groups. [1]

(3) ∵ D can turn acidified $K_2Cr_2O_7$(aq) from orange to green, ∴ D is either a secondary alcohol or an aldehyde. [1]
[1]

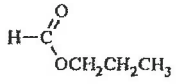
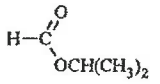
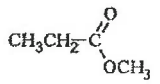
structure of D 

DSE11SP_12

(a) Concentrated sulphuric acid / conc. H_2SO_4 [1]

(b) [2]


(c) Iodine has a simple molecular structure and attraction between I_2 molecules is due to the weak van der Waals' forces. [1]
Sodium iodide has an ionic structure and attraction between Na^+ and I^- ions is due to strong ionic bond. [1]
The strength of inter-particle attraction in ethyl ethanoate is comparable to that in iodine. (Indication of an understanding of the idea of 'like-dissolve-like" in terms of the strength of attraction between particles.) [1]

(d) Any ONE of the following:

propyl methanoate

methylethyl methanoate

methyl propanoate [2]
(1 mark for structure, 1 mark for name.)

DSE11SP_13

(a) For (a) and (b), accept other correct reaction sequences.

$CH_3CH_2CH_2Cl \xrightarrow{a} b \xrightarrow{c} CH_3CH_2CO_2H$

a: NaOH(aq) [3]
b: $CH_3CH_2CH_2OH$
c: $Cr_2O_7^{2-}/H^+$ or MnO_4^-/H^+

(b)
$CH_3CH{=}CH_2 \xrightarrow{d} e \xrightarrow{f} CH_3COCH_3$

d: (1) conc. H_2SO_4; (2) H_2O [3]
e: $CH_3CH(OH)CH_3$
f: $Cr_2O_7^{2-}/H^+$

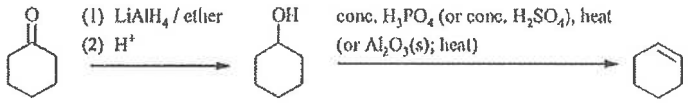
DSE12PP_02

(a) Some components of wine (substances with a pleasant odour) can be oxidized by oxygen in air to give products that have a flat taste. [1]
OR, Ethanol in wine can be oxidized by oxygen in air to give ethanol / ethanoic acid.

(b) (i) The outermost shell of an argon atom is a stable octet structure. ∴ Ar does not readily form bonds with other atoms. [1]
(ii) Ar is denser than air. It displaces air from the bottle, and thus prevents the wine from contact with air. [1]
(iii) He is less dense that air. It will not displace air / it will easily diffuse from the bottle. [1]

(c) The substances with a pleasant odour are volatile organic compounds. Pumping air out from the bottle may also remove these substances. [1]

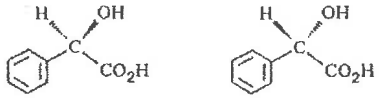
DSE12PP_11



[3]

DSE12PP_12

(a) (i)



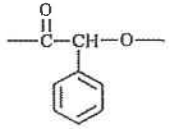
[2]

(ii) They turn the plane of polarization of a beam / plan polarized light in opposite directions. [1]

OR, One of the compounds is laevorotary while the other is dextrorotatory.

OR, Crystals of the two compounds have different appearance.

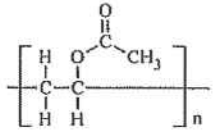
(b) Repeating unit:



[1]

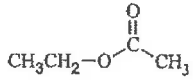
DSE12_02

(b)



[1]

(c) (i)



[1]

(ii) Bromine test – ethenyl ethanoate can decolorize orange / brown / yellow bromine / Br_2 solution immediately while ethyl ethanoate cannot. [1]

(NOT Accept Br).

(Require to mention the reaction of Br_2 with ethenyl ethanoate is much faster than ethyl ethanoate) [1]

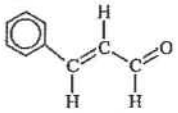
OR

Treating with acidified potassium permanganate solution - ethenyl ethanoate can decolorize purple acidified potassium permanganate solution while ethyl ethanoate cannot.

(Also accept treating with potassium permanganage solution (without acidification) with the correct descriptions of observations – change from purple to brown (ppt)).

DSE12_12

(a)



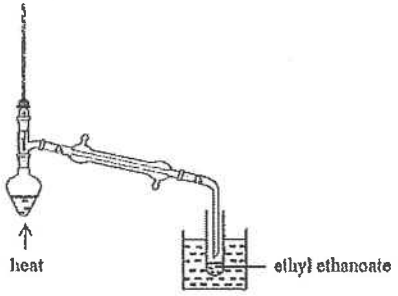
[1]

The bond angles of the alkene should be about 120°. The bonds drawn in 90° are not accepted.

(b) Cinnamaldehyde is a non-polar compound which can dissolve in a relatively non-polar organic solvent like ethyl ethanoate. However, water is a polar solvent. [1]

Both cinnamaldehyde and ethyl ethanoate are relatively non-polar compounds. Their molecules are attracted by weak intermolecular forces / van der Waals' forces.

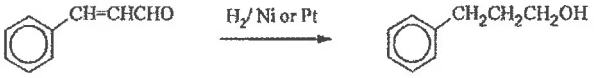
(c)



[2]

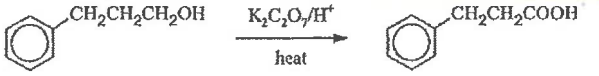
- ✓ 1 mark is given to the drawing of the correct setup
- ✓ No mark will be given to the drawing if:
  - The thermometer or the condenser is missing
  - The setup is a closed system
  - The top of the distillation head is open to air
  - A fractional column is included in the drawing
- ✓ 1 mark is given to the correct labeling and spelling of the distillate (ethyl ethanoate)

(d)



[1]

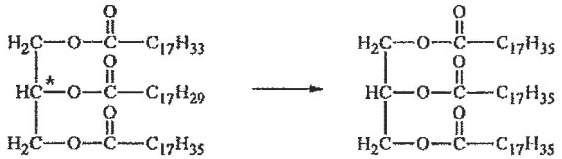
(Accept the aldehyde group (CHO) is NOT reduced by H_2/catalyst to give CH_2OH)



[1]

DSE12_14

(a) (i)



[1]

(ii) Yes. X has one chiral carbon and hence optically active, while Y does not has chiral carbons and hence optically inactive. Thus, there is a change in optical activity for the conversion. [1]

(b) The $C_{17}H_{35}COO^-$ ion has an ionic head (COO^-) and a hydrocarbon tail ($C_{17}H_{35}$). [1]

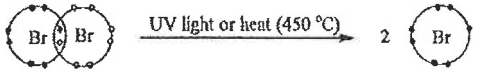
The hydrocarbon tail dissolves in grease droplets / is hydrophobic while the ionic head dissolves in water / is hydrophilic. [1]

The ionic heads of the grease droplets repel from each other and the dirts inside these droplets are then removed. [1]

Effective communication [1]

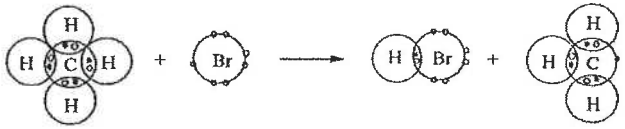
DSE12_15

Chain initiation



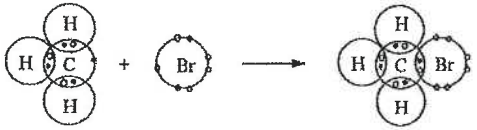
[1]

Chain propagation



[1]

Chain termination



[1]

DSE13_03

(a) Mole ratio of C : H : O $= \frac{2.64}{44} : 2 \times \frac{1.08}{18} : \frac{0.48}{16} = 2 : 4 : 1$ [1]

Empirical formula is C_2H_4O

Molecular formula is $(C_2H_4O)_n$ [1]

$n \times (12 \times 2 + 1 \times 4 + 16 \times 1) = 88.0$

$n = 2$

molecular formula of W is $C_4H_8O_2$ [1]

Alternative method:

No. of C atoms in W $= \frac{2.64}{44} \times \frac{88}{1.32} = 4$ (1)

No. of H atoms in W $= 2 \times \frac{1.08}{18} \times \frac{88}{1.32} = 8$

No. of O atoms in W $= \frac{88 - 12 \times 4 - 8 \times 1}{16} = 2$ (1)

molecular formula of W is $C_4H_8O_2$ (1)

(b)

[2]

Also accept other possible structure, e.g. ester.

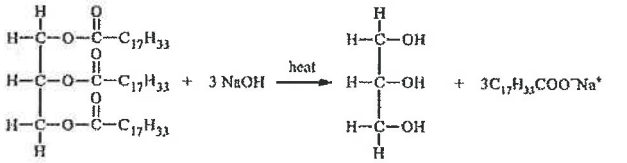
DSE13_04

(a) Ethanedioic acid [1]

DSE13_14

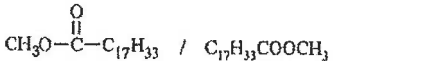
(a) H_2, Ni / Pd / Pt [1]

(b) (i)



[1]

(ii)



[1]

(c) G has a smaller relative molecular mass than F, so G can be vaporized more easily than F. [1]

G burns more completely / more easily than F. [1]

OR, G has a smaller relative molecular mass than F, so G has a lower boiling point than F. ∴ G burns more completely / more easily than F.

OR, G has a smaller relative molecular mass than F, so the molecular size of G is smaller than that of F. The intermolecular attraction / van der Waals' forces between G are weaker than that between F, G can be vaporized more easily than F. ∴ G burns more completely / more easily than F.

DSE13_15

(a) Correct chemical reagent [1]

Correct observations with comparison between the tests on X and Y. [1]

Possible tests and the corresponding observations:

$Cr_2O_7^{2-}/H^+$	Observations: X – no change; Y – from orange to green
MnO_4^-/H^+	Observations: X – no change; Y – from purple to colorless
MnO_4^-/OH^-	Observations: X – no change; Y – formation of brown ppt.
2,4-DNP	Observations: X – formation of orange ppt; Y – no change
CH_3COOH / H^+ / heat	Observations: X – no change; Y – fruity smell substance formed.

2,4-DNP = 2,4-dinitrophenylhydrazine

(b) $LiAlH_4$ / $NaBH_4$ [1]

(c)  and [1]

Geometrical (isomerism) / cis/trans-(isomerism) [1]

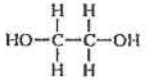
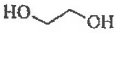
(d) $CH_3\underset{\displaystyle Cl}{\underset{|}{C}}HCH_2CH_2CH_3$ / $CH_3CHClCH_2CH_2CH_3$ [1]

DSE13(II)_02a

(ii) Molecules of cellulose may contain various number of glucose molecules joined together. [1]

OR, Molecules of cellulose is composed of polymer chain of glucose with different length.

DSE14_02

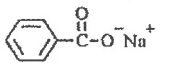
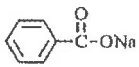
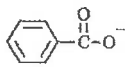
  $HOCH_2CH_2OH$ [1]

It has a smaller molecular size. / It is a small molecule. / It has a short carbon chain. [1]

The hydroxyl groups in it can form hydrogen bonds with water. [1]

DSE14_12

(a) (i) (alkaline) hydrolysis [1]

(ii)  or  or  [1]

(iii) HCl(aq) / H_2SO_4(aq) (accept other reasonable strong acids; not accept H^+) [1]

(iv) X (sodium benzoate) is an ionic compound which has strong(er) interactions with water. [1]

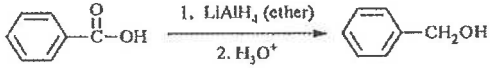
OR, Benzoic acid exists as molecules which has weak(er) intermolecular interactions with water.

OR, X is an ionic compound while benzoic acid exist as molecules.

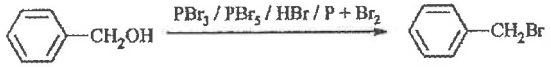
(v) Filter the mixture to obtain the solid benzoic acid. Wash it with deionized water and then dry in oven. [1]

(not accept mixing with drying agents)

(not accept evaporation or crystallization before filtration)

(b) 

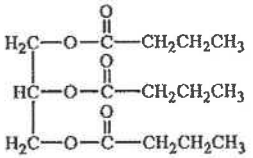
(not accept using $LiAlH_4$ in acidic medium; not accept using $NaBH_4$ and catalytic hydrogenation)



Correct reagent for each step in the conversion. [2]

Intermediate ($C_6H_5CH_2OH$) [1]

DSE14_14

(a) 

Accept represent $-CH_2CH_2CH_3$ as $-C_3H_7$

Accept the answer has 1 to 2 $-CH_2CH_2CH_3$ carbon chains, while the other carbon chains have different chain lengths and structurally correct. [1]

(b) Methylpropanoic acid (2-methylpropanoic acid) [1]

(c) (i)  [1]

(ii) Correct chemical reagent [1]

Correct observations with comparison between the tests on Q and Z [1]

	Q	Z
$Cr_2O_7^{2-}/H^+$	no change	from orange to green
MnO_4^-/H^+	no change	from purple to colorless
MnO_4^-/OH^-	no change	formation of brown ppt.
2,4-DNP	no change	formation of orange ppt.
CH_3CH_2OH/H^+/heat	fruity smell detected	no change
CH_3COOH/H^+/heat	no change	fruity smell detected
CO_3^{2-}	formation of gas (CO_2)	no change
HCO_3^-	formation of gas (CO_2)	no change
Mg / Zn	formation of gas (H_2)	no change

2,4-DNP = 2,4-dinitrophenylhydrazine

(d) (Catalytic) hydrogenation / addition of hydrogen [1]

DSE15_06

(a) Substitution [1]

(b) Light / ultra-violet / UV / heat / radical initiator (e.g. benzoyl peroxide) [1]

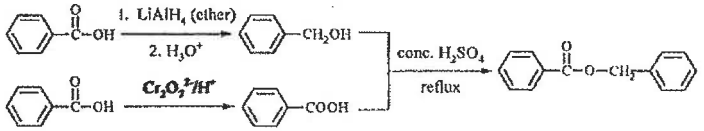
(c) Orange / brown color of bromine fades away [1]
Orange / brown color of bromine changes to colorless (slowly)
(bromine color: NOT accept 'yellow')

(d) Br atom does not have the stable noble gas electronic configuration. [1]
OR Br atom does not have the stable octet electronic configuration.
OR The electronic configuration of Br atom does not fulfill the octet rule.

(e) (i) CH_2Br_2 / $CHBr_3$ / CBr_4 [1]

(ii) Use (large) excess amount of CH_4 [1]
OR, Br_2 is the limiting reactant.

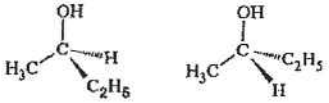
DSE15_12



[3]

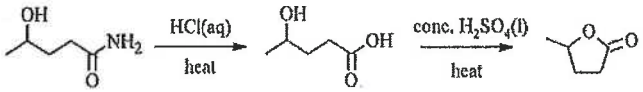
(1 mark for each pair of reactants and product)

DSE15_13



- Suitable diagrams [1]
- Chiral centre / chiral carbon / a carbon atom bonded to four different groups [1]
- Non-superimposable on its mirror image / the two mirror images are two different molecules [1]
- Optically active / can rotate plane-polarized light to different directions [1]
- Effective communication [1]

DSE16_12



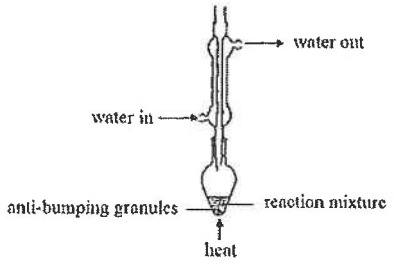
1st step: appropriate reagent and heat [1]

Appropriate intermediate [1]

2nd step: conc. H_2SO_4 and heat [1]

DSE16_13

(a)



[2]

1 mark for correct diagram, 1 mark for correct labels
Not accept "Δ" for 'heat'

(b) $LiAlH_4$ / H_2 (catalyst - Pt) (with appropriate example of catalyst such as Pd, Pt, Ni) [1]
(Not accept $LiAlH_4$ in $H^+(aq)$)

(c) Enantiomers / optical isomers / They are isomers that exhibit enantiomerism. [1]

(d) Optical activity. P and Q rotate plane-polarized light to opposite directions to the same degree / extent. [1]

(e) Correct chemical reagent [1]

Correct observations with comparison between the tests on acetophenone and P [1]

Possible tests and the corresponding observations:

$Cr_2O_7^{2-}/H^+$	acetophenone – no change; P – from orange to green
MnO_4^-/H^+	acetophenone – no change; P – from purple to colorless
MnO_4^-	acetophenone – no change; P – formation of brown ppt.
MnO_4^-/OH^-	acetophenone – no change; P – formation of brown ppt.
2,4-DNP	acetophenone – formation of orange ppt.; P – no change
CH_3COOH / H^+ / heat	acetophenone – no change; P – pleasant odur substance formed.

2,4-DNP = 2,4-dinitrophenylhydrazine

(Accept other chemical tests that can distinguish a ketone from an alkanol, e.g. Na / PCl_5)

DSE17_03

(a) A propene molecule has C=C bond whereas propane molecule has not. [1]
(Not accept: Propene is unsaturated while propane is saturated. / Propene is an alkene while propane is an alkane.)

(b) $HO_2C(CH_2)_4CO_2H$ is a di-functional molecule / has two $-CO_2H$ groups / has two function groups (to react with $-NH_2$ group). [1]
On the other hand, $CH_3(CH_2)_4CO_2H$ is a mono-functional molecule / has only one $-CO_2H$ group / has only one function group (to react with $-NH_2$ group).
Each $HO_2C(CH_2)_4CO_2H$ molecule can react with two $H_2N(CH_2)_6NH_2$ molecules to form a chain, while $CH_3(CH_2)_4CO_2H$ can only react with one $H_2N(CH_2)_6NH_2$ and cannot form a chain.

DSE17_09

FOR Alkanol,

Acidified $K_2Cr_2O_7$(aq) test: only $HOCH_2CH_2CH_2OH$ will produce a orange to green color change. [1]

OR, Acidified / neutral $KMnO_4$(aq) test: only $HOCH_2CH_2CH_2OH$ or $CH_2=CHCO_2H$ will produce a purple to colorless / brown color change.

FOR Alkene,

Br_2(in organic solvent) test: only $CH_2=CHCO_2H$ will produce a brown/orange/yellow to colorless color change. [1]

OR, Br_2(aq) test: only $CH_2=CHCO_2H$ will produce a brown/orange/yellow to colorless color change.

Acidified / neutral $KMnO_4$(aq) test: only $HOCH_2CH_2CH_2OH$ or $CH_2=CHCO_2H$ will produce a purple to colorless / brown color change.

FOR carboxylic acid

Add each liquid into water, [1]

Mg / Zn test: only $CH_3CH_2CO_2H$ or $CH_2=CHCO_2H$ reacts to give a colorless gas (bubbles) / hydrogen gas / H_2(g). [1]

OR, using CO_3^{2-} / HCO_3^-(aq) test: only $CH_3CH_2CO_2H$ or $CH_2=CHCO_2H$ reacts to give a colorless gas (bubbles) / carbon dioxide gas / CO_2(g).

Esterification: with conc. H_2SO_4 and heat / warm, only $CH_3CH_2CO_2H$ or $CH_2=CHCO_2H$ reacts with an alkanol (e.g. ethanol) to give a pleasant smell.

Neutralization: only $CH_3CH_2CO_2H$ or $CH_2=CHCO_2H$ reacts with an alkali (e.g. NaOH(aq)) / a base and water to give out heat.

$CH_3CO_2CH_3$ gives a negative result in the above three chemical tests.

(Do not accept tests like smell, pH/litmus paper, indicator, solubility in water, etc.)

Communication mark [1]

Chemical knowledge = 0 to 2, mark = 0,

Chemical knowledge = 3 to 4, mark = 0 or 1,

Incomplete answer / difficult to understand / no distinguishing intention, mark = 0)

DSE17_12

(a) $CH_3CH_2CH(Br)CH_2CH_3$ / $CH_3CH_2CHBrCH_2CH_3$ [1]

(b) (i) **The OH group in B will change to Br group in C by HBr, and there is no chiral carbon due to no optical activity.** [1]

(Accept: B is an alcohol as B reacts with HBr to have Br group in C.)

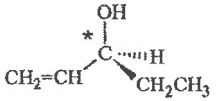
Thus the structure of B is $CH_3CH_2CH(OH)CH_2CH_3$ / $CH_3CH_2CHOHCH_2CH_3$

(ii) Substitution [1]

(c) (i) A has a C=C (or a C=O) double bond as there are 2 hydrogen atoms less in A as compared with B. [1]

A is optically active, so it has a chiral carbon.

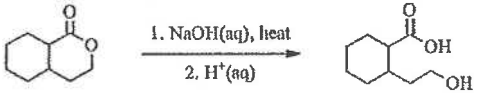
A has the structure



[1]

(ii) H_2 / Pd (heat), or H_2 / Pt (heat), or H_2 / Ni (heat) [1]

DSE17_13



[3]

(intermediate: 1 mark; reagent for each step: 1 mark)

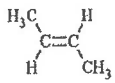
(For 1st step:

1. Reagent accept: OH^-, NaOH or NaOH(aq); Not accept NaOH(s) or solid NaOH.
2. Reagent accept: H^+/ H_2SO_4 / H_2SO_4(aq), or HCl / HCl (aq)
3. For acid hydrolysis / base hydrolysis, "heat" is required.
4. Accept COO^-Na^+ as the intermediate.
5. Not accept O–Na for the intermediate

For 2nd step:

1. Accept COO^-Na^+ as the intermediate for $LiAlH_4$ reduction if the 1st step is alkaline hydrolysis without acidification.
2. Not accept $LiAlH_4$ in acidic medium.
3. Acidification is required after reduction with $LiAlH_4$. $LiAlH_4$ and acidification should be expressed clearly as two steps.

DSE18_04

(b) (i)  [1]

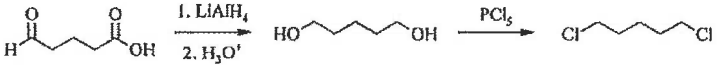
(ii) But-1-ene or methypropene [1]

(c) (i) Pass excess H_2 to ethene in the pressure of Pt / Pd / Ni [1]

OR Catalytic hydrogenation

(ii) Ethene turns Br_2(In CH_3CCl_3) [1]
from brown / orange to colorless, while ethane does not. [1]
(Not accept yellow)
(Accept $KMnO_4/H^+$ - purple to colorless
$KMnO_4$ - purple to brown (precipitate)
$KMnO_4/OH^-$ - purple to brown (precipitate))
(Accept: combustion test; ethene gives more sooty flame, while ethane gives less sooty flame)

DSE18_10



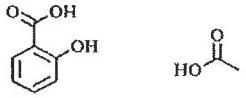
(1) $LiAlH_4$ (2) H_3O^+ [1]
$HOCH_2CH_2CH_2CH_2CH_2OH$ [1]
PCl_3 / PCl_5 / HCl / $SOCl_2$ [1]
(intermediate: 1 mark; reagent for each step: 1 mark)

For 1st step
1. Not accept $LiAlH_4$ in acidic / aqueous medium. Not accept $NaBH_4$ for reducing –COOH
2. Acidification is required after reducing with $LiAlH_4$. $LiAlH_4$ and acidification should be expressed clearly as two steps.
3. Accept "dry ether" is omitted in the $LiAlH_4$ step.

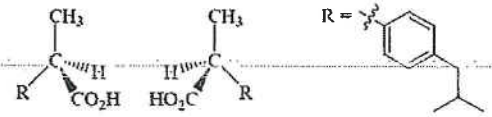
DSE18_12

(a) Reduce fever / inflammation / risk of heart attack / Rheumatoid arthritis [1]
(Not accept hypertension)

(b) –COOH group of aspirin reacts with hydrogencarbonate ions in water. [1]
to give a soluble sodium salt / soluble ions / soluble $–COO^-$. [1]
(Not accept soluble substance / soluble compound)

(c) (i)  [2]

(ii) Hydrolysis of ester in acidic medium is a reversible reaction [1]
And if the reaction mixture is heated under reflux for a long time, it attains equilibrium position and reactants and products co-exist in the system.

(d)  [2]

Note:
1 mark for the correct spatial arrangements of the chiral centers of the two enantiomers.
1 mark for the correct structures of the four substituents connected to the chiral center.

DSE19_03a

(i) bromine (in organic solvent) [1]
(Not accept aqueous bromine solution)

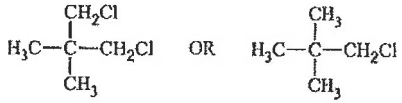
(ii) $CH_3–CH=CH–CH_3 + Br_2 \longrightarrow CH_3–(CHBr)_2–CH_3$ [1]
But-2-ene / an alkene reacts with Br_2, and Br_2 is decolourised / all Br_2 is consumed [1]
/ a colourless product is formed.

DSE19_05

(a) chlorine / Cl_2 [1]
(Not accept Cl_2(aq))

(b) Light / hυ / ultra-violet / UV / radical initiator [1]

(c) Substitution (reaction) [1]

(d) (i)  [1]

1,3-dichloro-2,2-dimethylpropane or 1,1-dichloro-2,2-dimethylpropane
OR 1,3-dichlorodimethylpropane or 1,1-dichlorodimethylpropane
(The structure and the systematic name must be matched.)

(ii) The structure other to the answer in (i) [1]

(iii) Structural isomer / position isomer [1]

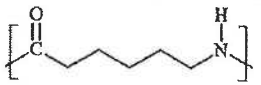
DSE19_13

(a) (i) ethanal / acetaldehyde / CH_3CHO [1]

(ii) Because ethanal has a low boiling point / is volatile, so was easily distilled off [1]
/ vaporised out and cannot be further oxidised to give ethanoic acid.

(b) (i) † Ethanamide [1]

(ii) Method 1: 1. PCl_3 2. NH_3 [1]
(Correct sequence in Method 1 is required)
OR Method 2 : NH_3 with heating (Ignore the states of the reagents used)

(c) (i)  [1]
(Accept answer without the square bracket; Not accept answer with "n" next to the square bracket.)

(ii) As there is no losing of small molecules during the polymerization, it can be regarded no condensation is involved.
OR Accept "No H_2O/HCl is formed."
NOT accept no other product / no side product

DSE19_15

Any FOUR of the following FIVE items (1 mark for each) : [4]

- **It reduces the water surface tension so that water can spread and wet the surfaces. / It is a wetting agent so water can spread and wet the surfaces.**
- **The hydrocarbon tails of the detergent particles dissolve in the oil (hydrophobic),**
- **while the ionic heads of detergent particles dissolves in water (hydrophilic).**
- **Water molecules attract the hydrophilic ionic heads and bring the oil into water.**
- **By stirring, the oil breaks up into tiny droplets and these droplets cannot come together again due to the repulsion between ionic heads/negative charges.**

Communication mark [1]

Chemical knowledge = 0 to 3, communication mark = 0

Chemical knowledge = 4 to 5, communication mark = 0 or 1)

Incomplete answer or difficult to understand, communication mark = 0)

Notes:

- Candidates may answer this question by using sketches with clear and easily understand annotations.
- For item 2 and 3, also accept:
  - The detergent particles has an ionic head and a hydrocarbon tail. (1 mark)
  - The tail dissolves in grease droplets / is hydrophobic, while the head dissolves in water / is hydrophilic. (1 mark)

DSE20_05

5. (a) Carboxyl (group) / $-CO_2H$ (group) / $-COOH$ (group) / $-CO_2H$ / $-COOH$ / CO_2H / $COOH$ 1
(Not accept: acid / alkanoic acid / organic acid / $COOH^-$ / CHO_2 / $HO_2CCH_2CH_2CO_2H$ / carboxylic acid group)

(b) (i) $HO_2CCH_2CH_2CO_2H$ / $HOOCCH_2CH_2COOH$ / $(CH_2COOH)_2$ 1
(Not accept: $HOOCC_2H_4COOH$)
$HO_2CCH(CH_3)CO_2H$ / $HOOCCH(CH_3)COOH$ 1
$HO_2CCH_2COOCH_3$ / $HO_2CCOOCH_2CH_3$ (1)

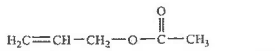
(ii) • The enthalpy change when solutions of an acid and an alkali / a base react together / neutralise under standard conditions to produce 1 mole of water. 1
(Accept: 25°C (298K) and one atmospheric pressure (760 mmHg, 103 kPa)
• As indicated in the equation, the reaction produces 2 moles of water, hence y / 2 represents the standard enthalpy change of neutralisation. 1
(Accept: No unit)

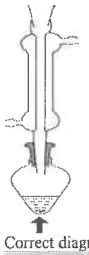
(iii) • Less negative than -57.3 kJ mol^{-1} 1
• **W** is a weak acid when compared with HCl(aq), energy / heat energy / heat is needed to ionise the hydrogen in the carboxyl / $-CO_2H$ group. 1
/ **W** is a weak(er) acid, energy / heat energy / heat is needed to ionise the hydrogen in the carboxyl / $-CO_2H$ group.
(Accept: absorb energy to break the O–H bond in carboxyl group.)
(Not accept: dissociate)

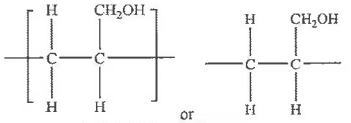
DSE20_10

10. (a) (i) $H_2C{=}CH{-}CH_2{-}Cl + NaOH \rightarrow H_2C{=}CH{-}CH_2{-}OH + NaCl$ / $H_2C{=}CH{-}CH_2{-}Cl + OH^- \rightarrow H_2C{=}CH{-}CH_2{-}OH + Cl^-$ 1
(State symbols not required) (Ignore incorrect state symbols)

(ii) † substitution (reaction) 1

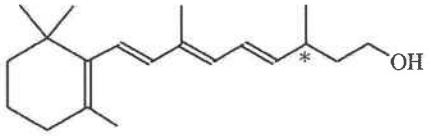
(b) (i)  1
(Accept $H_2C{=}CHCH_2OOCCH_3$ / $H_2C{=}CHCH_2OCOCH_3$ / $CH_2{=}CHCH_2OOCCH_3$)

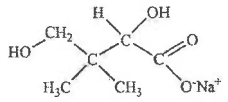
(ii)  2
Correct diagram (1 mark);
(The diagram should show the flask and the condenser are two pieces of glassware.)
(Not accept closed system apparatus. E.g. condenser fitted with a stopper)
Correct labels for water in, water out and heat (1 mark)
(Not accept labelling heat with a triangle or an arrow only)

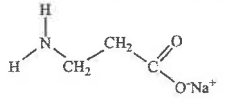
(c)  1
(Accept condensed representation)

DSE20_11

11. (a) **Z** 1

(b)  1

(c) **U** : $HOCH_2C(CH_3)_2CH(OH)CO_2^-Na^+$ / $HOCH_2C(CH_3)_2CH(OH)CO_2Na$ 1


V : $H_2NCH_2CH_2CO_2^-Na^+$ / $H_2NCH_2CH_2CO_2Na$ 1


(d) (i) $Na_2CO_3(aq)$ 1

(ii) • Colourless gas evolves when $Na_2CO_3(aq)$ is put into **X**, but not **W**, **Y** nor **Z**. 1
• Only **X** has a carboxyl group but **W**, **Y** and **Z** have not. 1
(Accept **X** has COOH group / **X** is an acid / **X** is acidic)

SECTION 12 Patterns in the Chemical World

Multiple-Choice Questions

CE08_22

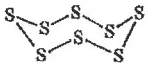
Comparing the elements in the second period of the Periodic Table, from lithium to fluorine which of the following statements is/are correct?

(1) They show a gradual change from having metallic property to having non-metallic property.
(2) They show a gradual increase in the number of electron shells in their atoms.
(3) They show a gradual decrease in melting point.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

CE10_31

The structure of a sulphur molecule in sulphur powder is shown below:



Which of the following statements is correct?
(Relative atomic mass: S = 32.1)

A. The relative molecular mass of sulphur is 32.1.
B. The oxidation number of sulphur in the molecule is 0.
C. The attraction between sulphur molecules is covalent bond.
D. Double bonds are present between adjacent atoms in sulphur molecules.

DSE12PP_30

In which of the following reactions, is/are the transition metal species NOT acting as a catalyst?

(1) action of acidified MnO_4^-(aq) on SO_3^{2-}(aq) at room temperature
(2) action of Ni(s) on a mixture of $H_2C{=}CH_2$(g) and H_2(g) at high temperature
(3) action of Pt(s) on a mixture of CO(g) and O_2(g) at high temperature

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE12PP_35

1st statement	2nd statement
The melting point of the non-metals in Period 3 of the Periodic Table decreases from sulphur to argon.	The relative atomic mass increases from sulphur to argon in Period 3 of the Periodic Table.

DSE12_31

Which of the following oxides would form an acidic solution when added to water?

A. Carbon dioxide
B. Silicon dioxide
C. Aluminium oxide
D. Lithium oxide

DSE13_26

Which off the following is NOT a characteristic property of transition metals?

A. They form colored compounds.
B. They exhibit variable oxidation numbers in their compounds.
C. They react with dilute hydrochloric acid to give hydrogen gas.
D. They exhibit catalytic property in elemental sate or as compounds.

DSE13_36

1st statement	2nd statement
Both aluminum oxide and magnesium oxide exhibit similar acid-base properties.	Both aluminum oxide and magnesium oxide are ionic oxides.

DSE14_36

1st statement	2nd statement
Aluminium oxide is soluble in water.	Aluminium oxide is an amphoteric oxide.

DSE15_25

Which of the following statements concerning the Periodic Table is correct?

A. The melting point of the Group I elements increases down the group.
B. The boiling point of the Group VII elements increases down the group.
C. The elements are arranged in the order of increasing relative atomic mass.
D. The electrical conductivity of the third period elements increases from left to right.

DSE15_35

1st statement	2nd statement
The melting point of silicon is higher than that of aluminium.	The number of electrons in a silicon atom is greater than that in an aluminium atom.

DSE16_30

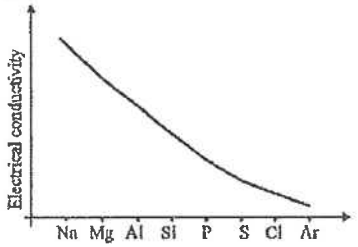
Which of the following trends involving Na, Mg and Al is INCORRECT?

A. Melting point of metal: Al > Mg > Na
B. Electronegativity of metal: Al > Mg > Na
C. Metal reactivity with water: Na > Mg > Al
D. Base strength of metal oxide: Al_2O_3 > MgO > Na_2O

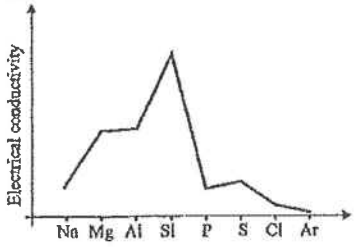
DSE14_30

Which of the following graphs (not drawn to scale) correctly shows the variation in electrical conductivity of the elements in the third period of the Periodic Table at room temperature?

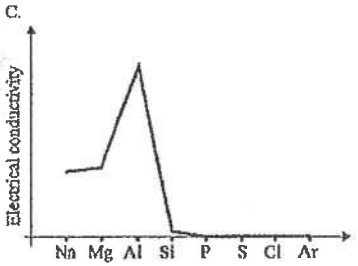
A.



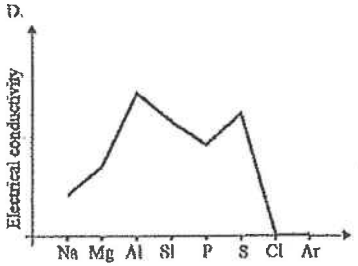
B.



C.



D.



DSE16_36

1st statement	2nd statement
$P_4O_{10}(s)$ can react with NaOH(aq).	$P_4O_{10}(s)$ is an acidic oxide.

DSE17_22

Which of the following statements concerning burning coal under room conditions are correct?

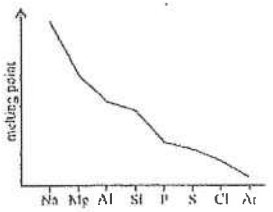
(1) Burning coal forms both acidic and non-acidic substances.
(2) Burning coal forms both gaseous and non-gaseous substances.
(3) Burning coal forms both poisonous and non-poisonous substances.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

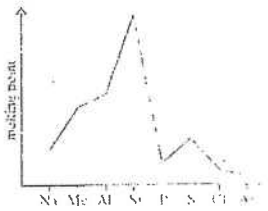
DSE17_25

Which of the following graphs (not drawn to scale) shows the variation in melting points of the elements in the third period of the Periodic Table?

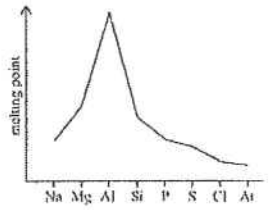
A.



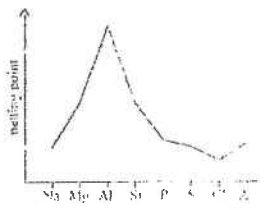
B.



C.



D.



DSE17_30

Which of the following statements concerning silicon dioxide solid is correct?

A. There are single covalent bonds between silicon atoms and oxygen atoms.
B. It is insoluble in sodium hydroxide solution.
C. It has a simple molecular structure.
D. It conducts electricity at room temperature.

DSE18_28

Which of the following statements is correct?

A. The boiling point of argon is lower than that of neon.
B. The boiling point of nitrogen is lower than that of oxygen.
C. The melting point of silicon is lower than that of sodium.
D. The melting point of aluminium is lower than that of magnesium.

DSE18_32

Which of the following processes can illustrate the characteristics of transition metals?

(1) Mixing $AgNO_3(aq)$ and $NaCl(aq)$
(2) Mixing $FeSO_4(aq)$ and $Br_2(aq)$
(3) Mixing $CuSO_4(s)$ and $H_2O(l)$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE19_33

Which of the following does NOT exhibit a characteristic of iron as a transition metal ?

A. Iron corrodes readily.
B. Iron can be used as a catalyst.
C. Iron can form two chlorides.
D. Iron(II) sulphate solution is green.

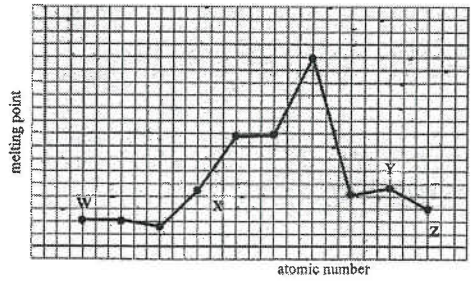
DSE20_28

28. Which of the following statements concerning the oxides of elements in the third period of the Periodic Table is correct ?

A. $SiO_2(s)$ dissolves in water to form a neutral solution.
B. $P_4O_{10}(s)$ dissolves in water to form an acidic solution.
C. $Al_2O_3(s)$ dissolves in water to form an alkaline solution.
D. $Cl_2O(g)$ dissolves in water to form $Cl_2(aq)$ and $O_2(g)$ only.

DSE20_30

30. The sketch below shows the melting points of ten consecutive elements in the second and third periods of the Periodic Table, arranged in the order of increasing atomic numbers. Sodium is one of these ten elements. Which of W, X, Y or Z may represent sodium ?



A. W
B. X
C. Y
D. Z

DSE21_28

28. Which of the following statements correctly describes the property of an amphoteric oxide ?

A. It can react as an acid or as a base.
B. It can react with water to form an acid and an alkali.
C. It can be simultaneously oxidised and reduced in a reaction.
D. It can react with water to form an oxidising agent and a reducing agent.

DSE21_33

33. Which of the following statements concerning the elements in the third period of the Periodic Table going from Na to Cl is / are correct ?

(1) The bond type of the elements changes from metallic bonding to covalent bonding.
(2) The oxide of the elements changes from acidic to basic.
(3) The electrical conductivity of the elements keeps decreasing.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

Structural Questions

AL96 (I)_04a

BaO is a basic oxide, while CO_2 is an acidic oxide.

(i) State all observations when dilute HCl(aq) is added to BaO(s).

(1.5 marks)

(ii) State all observations when CO_2 is bubbled, until in excess, into the following solutions.

(1) dilute HCl(aq)
(2) $Ca(OH)_2(aq)$

(2.5 marks)

AL96 (II)_06c (modified) [Similar to DSE14_11]

State THREE characteristic properties of transition elements, apart from complex ion formation. In each case, illustrate your answer with an example involving copper or vanadium.

(3 marks)

AL98 (I)_03b

Sketch the trends for the properties mentioned in (i) and (ii) below, and account for the trend in each case.

(i) Melting point of the alkali metals, Li, Na and K

(2 marks)

(ii) Boiling point of the Period 3 elements, Na, Mg and Al

(2 marks)

AL99 (I)_03 [Similar to DSE17_14]

When $KMnO_4(aq)$ is added dropwise to acidified $Na_2C_2O_4(aq)$, decolorization is slow at the beginning and then becomes faster.

(a) Write the balanced equation for the reaction involved.

(1 mark)

(b) Explain why the rate of decolorization increases.

(2 marks)

AL99 (I)_03

Describe how to detect the presence of water of crystallization in an inorganic salt.

(1 mark)

AL02 (I)_03

Account for the following observation:

When hydrated copper(II) hydroxide solid is shaken with deionized water, the liquid portion off the mixture is very pale blue. On the addition of an aqueous solution of ammonium chloride, the liquid portion shows no significant change in color. However, if instead, aqueous ammonia is added, an intense blue color is observed.

(3 marks)

AL02(I)_03

CO_2 and SiO_2 are oxides of Group IV elements. Account for the fact that CO_2 is a gas while SiO_2 is a high melting solid under room temperature and atmospheric pressure.

(2 marks)

ASL02(I)_04

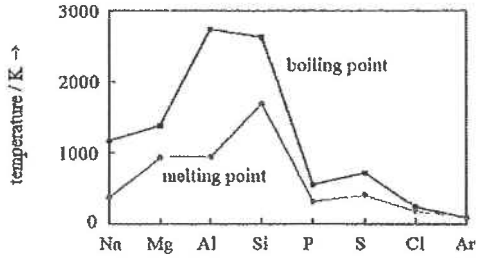
Sketch the variations of their boiling points and account for the variations.

Na, Mg and Al

(3 marks)

AL02(II)_02 [Similar to DSE19_14]

The graph below shows the variations of melting points and boiling points of the Period 3 elements.



Explain why

(a) silicon, a metalloid, has a very high melting point;

(2 marks)

(b) the boiling points of the metals are in the order:
Al > Mg > Na

(3 marks)

(c) there is generally a larger difference between the melting point and the boiling point for metals than for non-metals;

(2 marks)

(d) the melting point of sulphur is the highest among the non-metals.

(2 marks)

AL05(I)_01 [Similar to DSE16_14]

(a) Sketch the variation in electrical conductivity of the Period 3 elements from sodium to argon at room temperature and atmospheric pressure.

(2 marks)

(b) Explain the variation in (a).

(3 marks)

AL05(II)_04

Aluminium hydroxide is an active ingredient of antacid. Two paths for the production of aluminium hydroxide using Al(s), H_2SO_4(aq) and NaOH(aq) as reactants are outlined below:

Paths I: $Al(s) \longrightarrow Al_2(SO_4)_3(aq) \longrightarrow Al(OH)_3(s)$

Paths II: $Al(s) \longrightarrow Na[Al(OH)_4](aq) \longrightarrow Al(OH)_3(s)$

(a) Use chemical equations to describe the reactions in Path I and in Path II.

(4 marks)

(b) Work out the number of moles of H_2SO_4 and NaOH required for producing 2 mol of $Al(OH)_3$ via Path I and via Path II.

(1 mark)

(c) Suggest, with explanation, whether Path I or Path II is recommended for the production of aluminium hydroxide.

(2 marks)

AL05(II)_01

Each of six reagent bottles labeled **A**, **B**, **C**, **D**, **E** and **F** contained one of the following solutions:

$AgNO_3$(aq), $BaCl_2$(aq), H_2SO_4(aq), NH_3(aq), NaOH(aq) and $Na_2S_2O_3$(aq)

In an attempt to identify the contents of the bottles, a series of tests were conducted by mixing two of the solutions. The table below lists the observations in these tests.

Solutions being mixed	Observations
A and **C**	A brown precipitate is formed
A and E	A white precipitate is formed
A and F	A brown precipitate is initially formed, and the precipitate dissolves when F is in excess.
B and **C**	Only heat is liberated
B and **D**	A pale yellow precipitate is formed slowly
B and E	A white precipitate is formed

Identify, with explanation, the contents of the six reagent bottles based on the above information.

(6 marks)

AL06(I)_03 (modified)

The table below **lists the melting** points of three oxides of the Period 3 elements:

Oxide	Na_2O	Al_2O_3	SO_2
Melting point /°C	920	2040	−75

Account for the large difference in the melting points of the three oxides.

(3 marks)

AL06(I)_03

Write chemical equations for the following reactions:

(a) The reaction of S(s) with concentrated HNO_3 to give SO_4^{2-}(aq) and NO_2(g).

(1 mark)

(b) The reaction of Mn^{2+}(aq) with O_2(g) under alkaline conditions to give $Mn(OH)_3$(s).

(1 mark)

(c) The disproportionation of MnO_4^{2-}(aq) in water to give MnO_4^-(aq) and MnO_2(s).

(1 mark)

ASL06(II)_11 [Similar to DSE13_13]

The symbols p, q, r, s, t, u, v and w represent eight consecutive elements in the second and third periods of the Periodic Table The table below lists their boiling points:

Element	p	q	r	s	t	u	v	w
Boiling point / K	4203	5103	77	90	85	27	1163	1383

(a) Deduce from the above information which elements q and r represent respectively.

(4 marks)

(b) Explain why the boiling point of t is higher than that of u.

(2 marks)

(c) Explain why the boiling point of v is lower than that of w.

(2 marks)

AL07(I)_03

A mixture of Fe^{3+}(aq) and Cu^{2+}(aq) is separated by paper chromatography using a mixture of propanone and 6 M HCl(aq) as the mobile phase. Suggest how you would identify chemically the Fe^{3+}(aq) and Cu^{2+}(aq) on the chromatographic paper.

(3 marks)

ASL07(II)_02 [Similar to DSE15_10]

Account for the difference in hydrolytic behavior of the following oxides of the Period 3 elements:

Na_2O, SiO_2 and SO_2

(3 marks)

ASL07(II)_03

Aluminium is commonly extracted from bauxite, which contains mainly hydrated alumninium oxide with compounds of iron and silicon as impurities. The extraction consists of two stages: (1) removal of impurities from bauxite to give aluminium oxide, and (2) electrolysis of molten aluminium oxide.

(a) In Stage (1), bauxite is treated firstly with sodium hydroxide solution and subsequently with carbon dioxide to convert it to aluminium hydroxide. The aluminium hydroxide is then strongly heated to give aluminium oxide.

Outline the chemistry involved in obtaining aluminium oxide in Stage (1) and write chemical equations for the reactions involving the aluminium-containing species.

(5 marks)

(b) In Stage (2), an electrolytic bath consisting of a molten mixture of aluminium oxide and cryolite, Na_3AlF_6, is used.
Suggest why cryolite is used in the electrolysis.

(2 marks)

(c) Knowing that aluminium is highly abundant in the earth's crust, a student remarked, "Recycling of used aluminium objects is economically unsound."
Do you agree with the student? Explain.

(1 mark)

AL08(II)_02

The following four substances all exist in the form of white powder:

Baking soda ($NaHCO_3$), cornstarch, finely ground sugar, and plaster of Paris ($CaSO_4 \cdot \frac{1}{2}H_2O$)
Suggest how you would do experiments at home to distinguish the four substances from one another. (You are *not* allowed to taste the substances.)

(4 marks)

ASL09(I)_09 [Similar to DSE16_14, DSE19_14]

Write an essay to discuss the variation in physical properties of elements in period 3 of the Periodic Table.

(6 marks)

AL10 (I)_03 [Similar to DSE12PP_13]

State the expected observation in each of the following experiments, and account for the observation with the aid of chemical equation(s).

Adding NH_3(aq) dropwise to $CuSO_4$(aq) until in excess.

(3 marks)

ASL10 (II)_05 [Similar to DSE18_14]

Account for the following:

(a) The boiling point of neon is lower than that of argon.

(2 marks)

(b) $Al_2O_3(s)$ is soluble in both aqueous acids and aqueous alkalis.

(2 marks)

ASL11(I)_04

Although both K and Br are Period 4 elements, KOH and HOBr exhibit different acid-base behavior.

(2 marks)

AL11(I)_07

For each of the following pairs of species, suggest a chemical test to distinguish between them and write the chemical equation(s) of the reaction(s) involved.

(a) $Ba^{2+}(aq)$ and $Pb^{2+}(aq)$

(2 marks)

(b) $Cl^-(aq)$ and $Br^-(aq)$

(2 marks)

AL11 (II)_06

State the expected observation(s) in each of the following experiment, and write the chemical equation(s) of the reaction(s) involved.

$NaOH(aq)$ is added dropwise to $Al(NO_3)_2(aq)$ until in excess.

(3 marks)

AL12(I)_01 [Similar to DSE15_10, DSE17_14]

Apart from complex formation, state TWO properties of iron that characterize it as a transition metal.

(2 marks)

ASL12(I)_11 [Similar to DSE16_14]

Write an essay on the classification of elements according to bonding and structure, and comment on the electrical conductivity property of each class.

(10 marks)

ASL12(II)_05 [Similar to DSE19_14]

Sketch the variation of the melting point of the following elements: Na, Mg, Si, S and Cl. Account for the variation.

(5 marks)

ASL13(II)_02 [Similar to DSE12PP_09, DSE18_14]

For the following oxides, comment on their behavior with water. Explain your answer.

$Na_2O(s)$ $Al_2O_3(s)$ $SiO_2(s)$ and $P_4O_{10}(s)$

(4 marks)

AL13(II)_02

Suggest why transition metal compounds are usually colored.

(2 marks)

DSE11SP_14

Compare the acid base properties of sodium oxide (Na_2O) and sulphur dioxide (SO_2) with reference to how they interact with water molecules.

(4 marks)

DSE12PP_09 [Similar to ASL13(II)_02]

(a) Using the following notations to complete the table below so as to provide information about the structure and acid-base property of the oxides of Period 3 elements.

IC: ionic crystal CN: covalent network SM: simple molecular structure
AC: acidic BA: basic AM: amphoteric

	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
Structure					
Acid-base property					

(2 marks)

(b) By considering the trend of acid-base property and that of bonding of these oxides, state the relationship between the two trends.

(1 mark)

(c) Outline chemical tests to show how these oxides can be classified into acidic, basic and amphoteric.

(4 marks + 1 mark)

DSE12PP_13 [Similar to AL10(I)_03]

In an experiment, excess aqueous ammonia is added to an aqueous solution of copper(II) sulphate. The following equilibrium is established and the resulting solution is deep blue in color.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$$

(c) When $H_2SO_4(aq)$ is added slowly to the equilibrium mixture until in excess, a blue precipitate is formed and the precipitate subsequently dissolves in the excess acid forming a blue solution. Account for these observations with the help of relevant chemical equation(s).

(5 marks)

DSE12_16

Consider the following oxides:

Na_2O MgO Al_2O_3 SiO_2 P_4O_{10} SO_2 Cl_2O

(a) Which of the oxides listed above can conduct electricity in molten state?

(1 mark)

(b) Explain why SiO_2 has the highest melting point among the covalent oxides listed above.

(2 marks)

(c) Write a chemical equations for the reaction between $Al_2O_3(s)$ and NaOH(aq).

(1 mark)

DSE13_13 [Similar to ASL06(II)_11]

Lithium, beryllium, carbon (graphite) and nitrogen are elements of the second period of the Periodic Table. Arrange them in increasing order of melting point, and explain the order in terms of structure and bonding.

(4 marks + 1 mark)

DSE14_11 [Similar to AL09(II)06c]

Vanadium is a transition metal, its chemical symbol is V. The formulae and the colors of three aqueous vanadium-containing ions are shown below:

Formula	$VO^{2+}(aq)$	$V^{3+}(aq)$	$V^{2+}(aq)$
Color	Blue	Green	violet

(a) Based on the given information, suggest TWO properties of vanadium to characterize it as a transition metal.

(1 mark)

DSE15_10 [Similar to ASL07(II)_02, AL12(I)_01]

(a) For each of the oxides below, draw its electron diagram (showing electrons in the outermost shells only), and stat its behavior in water.

(i) Na_2O

(2 marks)

(ii) Cl_2O

(2 marks)

(b) Using iron as an example, illustrate TWO characteristics of transition metals.

(2 marks)

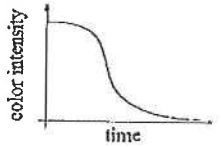
DSE16_14 [Similar to AL05(I)_01, ASL09(I)_09, ASL12(I)_11]

Arrange sodium, aluminium, silicon and sulphur in decreasing order of electrical conductivity at room conditions, and explain your answer in terms of bonding and structure.

(4 marks + 1 mark)

DSE17_14 [Similar to AL99(I)_03, AL12(I)_01]

At 60°C, $MnO_4^-(aq)$ reacts with $C_2O_4^{2-}(aq)$ in an acidic medium to give $Mn^{2+}(aq)$. $CO_2(g)$ and $H_2O(l)$. The graph below shows the variation of the color intensity of the reaction mixture with time.



Based on the information above, write the chemical equation for the reaction and illustrate THREE characteristics of transition metals exhibited by manganese.

(5 marks + 1 mark)

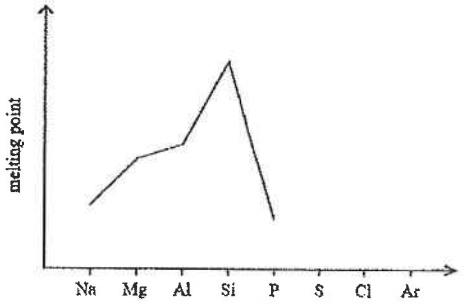
DSE18_14 [Similar to ASL10 (II)_05, ASL13(II)_02]

Using Na_2O, Al_2O_3 and SO_2 as examples, illustrate the acid-base behavior of the oxides of the third period elements with the aid of relevant reactions.

(5 marks + 1 mark)

DSE19_14 [Similar to AL02(II)_02, ASL09(I)_09, ASL12(II)_05]

The following graph shows an incomplete sketch of the variation in melting points of the elements in the third period of the Periodic Table.



(a) Complete the sketch on the graph above.

(1 mark)

(b) Explain why the melting point of Mg is higher than that of Na.

(1 mark)

(c) Explain why the melting point of Si is higher than that of P.

(2 marks)

DSE20_12

12. An experiment was performed to study the following reaction :

$KO_2CCH(OH)CH(OH)CO_2Na(aq) + 3H_2O_2(aq) \rightarrow HCO_2K(aq) + HCO_2Na(aq) + 2CO_2(g) + 4H_2O(l)$
(colourless)

When 10 cm^3 of 0.25 M $KO_2CCH(OH)CH(OH)CO_2Na(aq)$ and 3 cm^3 of 6% $H_2O_2(aq)$ were mixed at 60°C, it was found that only a few gas bubbles evolved. Then a small amount of pink $CoCl_2(aq)$ solution was added to the mixture. Gas bubbles formed vigorously and the mixture turned to green due to the formation of a cobalt(III) compound. When no more gas evolved, the green mixture turned back to pink.

There is a view saying that cobalt illustrates THREE characteristics of transition metals according to the observation of this experiment. Suggest reasons to support this view.

DSE21_12

12. (a) Silicon dioxide is an acidic oxide. However, the pH of a mixture of silicon dioxide and distilled water is 7.

(i) Suggest why silicon dioxide is classified as an acidic oxide.

(ii) Explain why the pH of the mixture is 7.

(b) Phosphorus(V) oxide is an acidic oxide. With the aid of a chemical equation, explain why the pH of a mixture of phosphorus(V) oxide and distilled water is smaller than 7.

(c) Refer to the following reaction :

$Cu_2O(s) + H_2SO_4(aq) \rightarrow Cu(s) + CuSO_4(aq) + H_2O(l)$

State how this reaction can demonstrate that copper exhibits TWO characteristics of transition metals.

2022

*13. Describe the acid-base properties of the products formed (if any) when the following oxides are added to water separately. Chemical equations are NOT required.

Na_2O MgO Al_2O_3 Cl_2O

(5 marks)

3. (c) The major ingredient in a certain brand of iron supplement tablets is $FeSO_4$. Several pieces of these iron supplement tablets were dissolved in deionised water to obtain an aqueous solution **S**. The concentration of $Fe^{2+}(aq)$ ions in solution **S** was determined by using the following two methods :

(i) **Method (I) : using volumetric analysis**

The chemical equation for the reaction involved in the titration is as follows :

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

25.00 cm^3 of solution **S** was acidified and then titrated with 0.0041 M $KMnO_4(aq)$. The mean volume of the $KMnO_4(aq)$ required to reach the end point was 32.35 cm^3.

(1) The colour of the reaction mixture changed from pale yellow to pale pink at the end point of the titration. Explain the colour change.

(2) Calculate the concentration of $Fe^{2+}(aq)$ ions in solution **S**.

(4 marks)

Marking Scheme

MCQ

CE08_22	A (33%)	CE10_31	A (60%)	DSE12PP_30	A	DSE12PP_35	B
DSE12_31	A (81%)	DSE13_26	C (72%)	DSE13_36	C (62%)	DSE14_36	C (66%)
DSE15_25	B (49%)	DSE15_35	B (69%)	DSE16_30	D (68%)	DSE14_30	C (77%)
DSE16_36	A (65%)	DSE17_22	D (50%)	DSE17_25	B (75%)	DSE17_30	A (37%)
DSE18_28	B (69%)	DSE18_32	D (45%)	DSE19_33	A		
DSE20_28	B	DSE20_30	B				

Structural Questions

AL96 (I)_04a

(i) **BaO dissolves forming colorless solution.** [1]
Heat evolves [½]

(ii) (1) No change / solution remains colorless. [1]
(2) White precipitate / solution turns milky. [½]
Precipitate redissolves / solution turns clear again. [1]

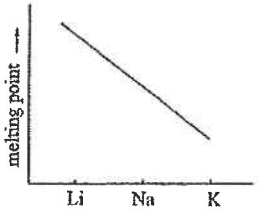
AL96 (II)_06c (modified)

Any THREE of the following: [3]

- Exhibition of **variable oxidation states**, e.g. Cu^+ & Cu^{2+} / V^{2+}, V^{3+}, VO^{2+}, VO_2^+
- Formation of **colored compounds**, e.g. $Cu^{2+}(aq)$ is blue, $VO_2^+(aq)$ is yellow
- Exhibition of **catalytic properties**, e.g. V_2O_5 in contact process, CuO in syngas formation.
- Exhibition of **paramagnetic properties**, e.g. Cu^{2+} / V^{2+} are paramagnetic

AL98 (I)_03b

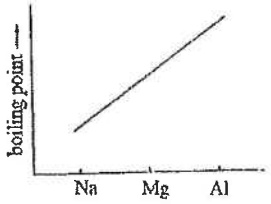
(i)



[1]

Atomic size: Li < Na < K [½]
∴ Attraction of nucleus on the delocalized electron / strength of metallic bond decreases in the order: Li > Na > K, hence m.p. decreases. [½]

(ii)



[1]

The atomic radius decreases and the no. of electron involved in metallic bond increases in the order: Na, Mg, Al [½]
∴ Attraction of nucleus on the delocalized electron in the same order. [½]

AL99 (I)_03

(a) $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ [1]

(b) **Mn^{2+} acts as a catalyst for the reaction** [1]
At the beginning, when $[Mn^{2+}]$ is low, rate of reaction is slow [½]
When $[Mn^{2+}]$ builds up gradually, the reaction occurs much faster [½]

AL99 (I)_03

Heat the sample [½]
Water vapor will turn anhydrous $CoCl_2$ from blue to pink / anhydrous $CuSO_4$ from white to blue. [½]
(0 mark if heating is not mentioned.)

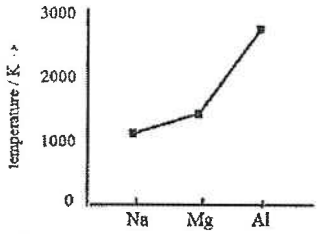
AL02 (I)_03

Hydrated $Cu(OH)_2$ has a very low solubility in water / concentration of $Cu^{2+}(aq)$ in the liquid portion is very low. ∴ It has a very pale blue color. [1]
The extent of hydrolysis of $NH_4^+(aq)$ is very small. $[NH_3(aq)]$ in $NH_4Cl(aq)$ is very low. Thus, the concentration of $[Cu(NH_3)_4]^{2+}(aq)$ is low.
$NH_3(aq)$ reacts with $Cu(OH)_2(s)$ to give a complex ion $[Cu(NH_3)_4]^{2+}(aq)$ which has a deep blue color. [1]
$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ [1]

AL02(I)_03

CO_2 exists as simple molecules and the intermolecular attraction is van der Waals' forces. [1]
SiO_2 has a giant covalent network structure.
Attraction between CO_2 molecules is weak, but attraction between Si and O atoms in $SiO_2(s)$ is strong. [1]

ASL02(I)_04



Strength of metallic bond increases with number of electrons taking part in metallic bond per atom and decreases with increasing in size of atom. [1] [1]
For Na, Mg and Al,
No of valence electron : Al > Mg > Na [½]
Size of atom: Al < Mg < Na [½]
Hence, boiling point increases in the order Al > Mg > Na

AL02(II)_02

(a) Silicon has a giant covalent network structure. [1]
Melting of Si involves breaking down of the network structure, a large number of covalent bonds. Hence, a large amount of energy is required. [1]

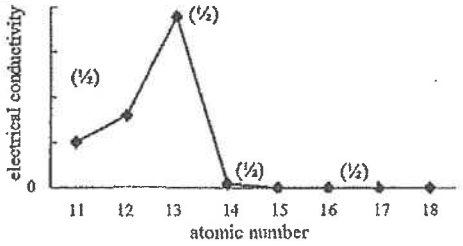
(b) Strength of metallic bond increases with number of electrons taking part in metallic bond per atom and decreases with increasing in size of atom. [1]
For Na, Mg and Al,
No of valence electron : Al > Mg > Na [½]
Size of atom: Al < Mg < Na [½]
Hence, boiling point increases in the order Al > Mg > Na

(c) For metals, metallic bonding persists in the liquid state and this strong bonding has to be overcome during vaporization. [1]
Non-metals (P, S, Cl, Ar) exis as simple molecules. The molecules are held by week van der Waals' forces. Only a small amount of energy is needed for the elements in liquid state to undergo vaporization. [1]

(d) Sulphur exists as S_8, phosphorus as P_4, chlorine as Cl_2 and argon as Ar. [1]
Strength of van der Waals' forces depends on the number of electrons per molecules / relative molecular mass / polarizability of molecules. [1]
S_8 has the larger molecular size. Hence, melting point of sulphur is the highest.

AL05(I)_01

(a) [2]



(b) Explanation:
Na, Mg and Al are good electrical conductors.
For Na, Mg and Al, the number of valence electrons available for delocalization increases with atomic number. ∴ electrical conductivity increases. [1]
Si is a semi-conductor. [1]
P, S, Cl and Ar exist in simple molecular structures. They do not possess delocalized electrons for electrical conductivity and are insulators. [1]

AL05(II)_04

(a) Paths I: $2Al(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2(g)$ [1]
$Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ [1]
Path II: $2Al(s) + 2OH^-(aq) + 6H_2O(l) \longrightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$ [1]
$Al(OH)_4^-(aq) + H^+(aq) \longrightarrow Al(OH)_3(s) + H_2O(l)$ [1]

(b) Path I: Production of 2 mol of $Al(OH)_3$ requires 3 mol of H_2SO_4 and 6 mol of NaOH [½]
Path II: Production of 2 mol of $Al(OH)_3$ requires 1 mol of H_2SO_4 and 2 mol of NaOH [½]

(c) Path II is better because less reactants are used [1]
and less heat is produced. [1]

AL05(II)_01

The six solutions are:

A: $AgNO_3(aq)$ B: $H_2SO_4(aq)$ C: $NaOH(aq)$
D: $Na_2S_2O_3(aq)$ E: $BaCl_2(aq)$ F: $NH_3(aq)$

A is $AgNO_3(aq)$ [1]
C is $NaOH(aq)$ while F is $NH_3(aq)$ [1]
C and F are alkalis because $AgNO_3(aq)$ reacts with alkalis to give brown $Ag_2O(s)$ [1]
$2Ag^+(aq) + 2OH^-(aq) \longrightarrow Ag_2O(s) + H_2O(l)$
$Ag_2O(s)$ reacts with excess $NH_3(aq)$ to give $[Ag(NH_3)_2]^+(aq)$
$Ag_2O(s) + H_2O(l) + 4NH_3(aq) \longrightarrow 2[Ag(NH_3)_2]^+(aq) + 2OH^-(aq)$
B is $H_2SO_4(aq)$ as it undergoes neutralization with C. (heat is evolved)
E is $BaCl_2(aq)$ as it reacts with $SO_4^{2-}(aq)$ ions (in B) to give a white precipitate. [1]
$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$
E also reacts with $AgNO_3(aq)$ to give a white precipitate AgCl(s) [1]
D is $Na_2S_2O_3(aq)$ because it reacts with acid (B) to give a pale yellow precipitate. [1]
$S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow S(s) + SO_2(g) + H_2O(l)$

AL06(I)_03 (modified)

$Na_2O(s)$ and $Al_2O_3(s)$ are ionic compounds. $SO_2(g)$ is a covalent compound and it exists as simple molecules. [1]
The attraction between SO_2 molecules is weak van der Waals' forces. ∴ $SO_2(g)$ has a very low melting point. [1]
The charge : radius ratio of Al^{3+} is greater than that of Na^+. $Al_2O_3(s)$ has a stronger ionic bond than that in $Na_2O(s)$. ∴ m.p. of $Al_2O_3(s)$ > m.p. of $Na_2O(s)$ [1]

AL06(I)_03

(a) $S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2H_2O(l) + 6NO_2(g)$ [1]
(b) $4Mn^{2+}(aq) + O_2(g) + 8OH^-(aq) + 2H_2O(l) \longrightarrow 4Mn(OH)_3(s)$ [1]
(c) $3MnO_4^{2-}(aq) + 2H_2O(l) \longrightarrow 2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq)$ [1]

ASL06(II)_11

(a) q has the highest b.p. and [1]
a sudden drop in b.p. occurs from q to r. [1]
q: carbon r: nitrogen [1]

(b) Both t and u have simple molecular structure.
t has more electrosn while u has less electrons. [1]

OR t exists in diatomic molecules while u in monoatomic molecules

t has stronger van der Waals' forces than that in u. [1]

(c) Both v and w have metallic bonds.

Number of electrons participated in metallic bond formation in v is less than that in w, [1]

Cationic size of v is larger than that of w, [1]

So metallic bond of v is weaker. [1]

AL07(I)_03

Place the chromatographic paper in an atmosphere of ammonia. [1]

$Fe^{3+}(aq)$ reacts with $OH^-(aq)$ to give brown $Fe(OH)_3(s)$. [1]

$Cu^{2+}(aq)$ reacts with $NH_3(aq)$ to give deep blue complex $[Cu(NH_3)_4]^{2+}(aq)$. [1]

ASL07(II)_02

Na_2O is an ionic oxide. O^{2-} reacts with H_2O to give an alkaline solution. [1]

$O^{2-} + H_2O \longrightarrow 2OH^-$

SiO_2 has a giant covalent network structure. It has no reaction with water. [1]

In SO_2, S carries a partial positive charge and it is susceptible to (nucleophilitic) attack by H_2O. An acid solution is formed. [1]

$H_2O + SO_2 \longrightarrow H_2SO_3$

ASL07(II)_03

(a) Aluminium oxide is amphoteric. It reacts with NaOH(aq) to give $Al(OH)_4^-(aq)$.

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$ [1]

Compound of silicon will also react to give soluble silicates. [1]

Oxides of iron are not amphoteric. They can be removed by filtration. [1]

CO_2 is weakly acidic. Addition of CO_2 can convert $Al(OH)_4^-(aq)$ to $Al_2O_3(s)$ while the silicates remain unreacted.

$[Al(OH)_4]^-(aq) + H^+(aq) \longrightarrow Al(OH)_3(s) + H_2O(l)$ [1]

The $Al(OH)_3(s)$ is removed by filtration and then heated to obtain $Al_2O_3(s)$.

$2Al(OH)_3(s) \longrightarrow Al_2O_3(s) + 3H_2O(g)$ [1]

(b) $Al_2O_3(s)$ has a very high melting point. [1]

Additional of cryolite can lower the temperature of the electrolytic bath. [1]

(c) No.

Open-end question. Possible answers: [1]

The extraction of Al from its ore involves electrolysis and a huge amount of energy is required.

Aluminium objects do not contain much impurities. Cost of removal of impurities is low.

AL08(II)_02

(This question has many possible answers. Marker should exercise their judgment when awarding marks. The principle for awarding marks is 1 point for giving a correct test for each of the compounds.)

For example,

Add water. Only baking soda and sugar are water soluble. [1]

To the water-soluble substance, add vinegar. Only baking soda give effervescence. [1]

Plaster of Paris gives a lot heat when added to water. [1]

For the water-insoluble substances, add tincture of iodine. Only starch will give a purple color. [1]

ASL09(I)_09

Boiling point: increases from Na to Si and then decreases to Ar. [2]

For Na, Mg and Al, the interatomic attraction is metallic bond. Its strength increases with the number of valence electrons. ∴ b.p. Na < Mg < Al

Si has a giant covalent network structure. It has the highest boiling point.

For the simple molecules, the intermolecular attraction is van der Waals' forces. The strength of which depend on relative molecular mass. Phosphorus exists as P_4, sulphur as S_8, chlorine as Cl_2 and argon as Ar. ∴ b.p. Ar < Cl_2 < P_4 < S_8

Melting point: increases from Na to Si then decreases to Ar. [2]

Melting point depends on both the strength of interatomic / intermolecular forces and degree of compactness of particles in solid state.

For Na, Mg and Al, the interatomic attraction is metallic bond. Its strength increases with the number of valence electrons. ∴ b.p. Na < Mg < Al

Si has a giant covalent network structure. It has the highest boiling point.

For the simple molecules, the intermolecular attraction is van der Waals' forces. The strength of which depend on relative molecular mass. Phosphorus exists as P_4, sulphur as S_8, chlorine as Cl_2 and argon as Ar. ∴ m.p. Ar < Cl_2 < P_4 < S_8

Electronegativity: increases from Na to Cl [2]

As the atomic decreases across the period, the effective nuclear charge experienced by the outermost electrons increases. Hence, electronegativity increases across the period.

AL10 (I)_03

A pale blue precipitate is formed. The precipitate dissolves in excess $NH_3(aq)$ to give a deep blue solution. [1]

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ [1]

$Cu(OH)_2(s) + 4NH_3(l) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ [½] [½]

ASL10 (II)_05

(a) Both neon and argon exist as monoatomic molecules. Their intermolecular attraction is van der Waals' forces. [1]

Ar has a greater number of electrons per molecule / has greater relative molecular (atomic) size / has greater polarizability. ∴ Ar has a higher boiling point. [1]

(b) $Al_2O_3(s)$ is amphoteric. [1]

$Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O(l)$ [½]

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$ [½]

ASL11(I)_04

K is highly electropositive while O is electronegative. In KOH, K exists as K^+ ions and O as OH^- ions. [½]

KOH is basic because it ionizes in water to give $K^+(aq)$ and $OH^-(aq)$ ions. [½]

HOBr is acidic because it ionizes in water to give $H^+(aq)$ and $OBr^-(aq)$ ions. [½]

$HOBr(aq) \rightleftharpoons H^+(aq) + OBr^-(aq)$

Br is an electronegative element. Ionization of HOBr is in water gives $H^+(aq)$ and $OBr^-(aq)$ instead of $OH^-(aq)$ and $Br^+(aq)$ as the latter system is highly unstable. / $OBr^-(aq)$ is stabilized by electronegative Br. [½]

AL11(I)_07

(a) Add HCl(aq) / KCl(aq). Only $Pb^{2+}(aq)$ gives a white precipitate. [1]

$Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$ [1]

OR, Add NaOH(aq). Only $Pb^{2+}(aq)$ gives a white precipitate which is soluble in excess alkali).

$Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$

$Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$

OR, Add KI(aq). Only $Pb^{2+}(aq)$ gives a yellow precipitate.

$Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$

(b) Add acidified $AgNO_3(aq)$. $Cl^-(aq)$ gives a white precipitate, while $Br^-(aq)$ gives a pale yellow precipitate. [1]

$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ [1]

OR, Add $Cl_2(aq)$. Only $Br^-(aq)$ gives a brown solution.

$Cl_2(aq) + 2Br^-(aq) \longrightarrow Br_2(aq) + 2Cl^-(aq)$

OR, Treat solution wit acidified $KMnO_4(aq)$. $Cl^-(aq)$ causes decolorization slowly; $Br^-(aq)$ gives an orange solution.

$10X^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \longrightarrow 5X_2(g/l) + 2Mn^{2+}(aq) + 8H_2O(l)$

AL11 (II)_06

White precipitate is formed and the precipitate dissolves in excess alkali to give a colorless solution. [1]

$Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ [1]

$Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH)_4]^-(aq)$ [1]

ASL12(I)_01

Any TWO of the following: [2]

- Fe compound are colored, e.g. $Fe^{3+}(aq)$ is yellow.
- Iron / Fe compounds can have catalytic properties.
- e.g. Fe in the Haber process / $Fe^{2+}(aq)$ catalyze the reaction of $I^-(aq)$ with $S_2O_8^{2-}(aq)$.
- Iron can exhibit variable oxidation states, e.g. Fe^{2+} and Fe^{3+}
- Many Fe compounds are paramagnetic, e.g. Fe^{3+}.
- Many Fe compounds are non-stiochiometric, eg. FeS.

ASL12(I)_11

Chemical Knowledge (10 marks)

Chemical knowledge (including bonding, structure and electrical conducting property of solids) covers four areas A, B, C and D.

Solid substance can be classified into four types, namely metals, molecular solids, giant covalent network solids and ionic solids.

A. Metal (and alloys) e,g. Na, Fe [3]

- Bonding between atoms is metallic bond which is non-directional.
  Metallic bond is electrostatic attraction between metallic cations and delocalized electrons.
- Metals are good electrical conductor as the delocalized electrons can move in the direction of the applied voltage.

B. Molecular solid [5]

Simple molecular, e.g. P_4, S_8, glucose, etc.

- Within a molecule, atoms are attracted by covalent bond / sharing of electrons.
  Attraction between molecules is mainly van der Waals' forces, sometimes hydrogen-bond or even ionic bond.
- Most simple molecular solids are insulators as molecules are electrically neutral.

Macromolecular, e.g. polymeric materials, proteins, carbohydrates

- Bonding between atoms in molecule is predominately covalent bond.
  Attraction between molecules is commonly van der Waals' forces, e.g. polyethene
- Most polymeric materials are insulator, e.g. polyethene

C. Covalent network solid, e.g. Si, C, SiO_2 [3]

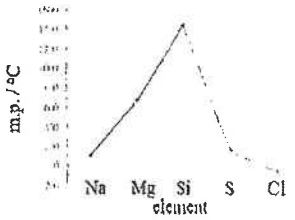
- Bonding between atoms is covalent bond in covalent network structure (diamond / graphite / silicon)
- Electrical conducting property:
  Insulators (e.g. diamond / silica) + explanation (bonding electrons are localized)
  Conductors (e.g. graphite / carbon nanotubes)
  Semi-conductors (e.g. Si). The electrical conductivity of semi-conductors increases with temperature and is affected by the addition of doping agent (e.g. In an Sb)

D. Ionic solid, e.g. NaCl, MgO [3]

- Bonding between cations and anions is ionic bond / transfer of electrons from an electropositive atom to an electronegative atom.

- Structure: giant ionic lattice, e.g. NaCl structure, CsCl structure
- With cations and anions occupying fixed positions in the lattice, ionic solids cannot conduct electricity.

ASL12(II)_05



[2]

Both Cl & S exist as simple molecules. Their intermolecular attraction is van der Waals' forces. [½]

They have low melting point. [½]

Both Na & Mg have metallic structure. Their interparticle attraction is metallic bond.

Si has a covalent network structure. The atoms are held by covalent bond. It has the higher melting point among the five elements.

Chlorine exists as Cl_2 molecules and sulphur as S_8. [1]

The strength of van der Waals' force increases with the number of electrons in the molecule. ∴ m.p. of S > m.p. of Cl

Metallic bond strength is affected by (1) no. of valence electrons per atom participating in metallic bonding; (2) atomic radius; (3) degree of compactness. [1]

As compared with Na, (1) Mg has greater number of valence electrons, (2) Mg atoms has a smaller size, and (3) Mg atoms are more closely packed in solid state. ∴ m.p. of Mg > m.p. of Na.

(For metallic bond strength, accept any ONE of the correct explanations.)

ASL13(II)_02

Behavior with water: [2]

- $Na_2O(s)$ dissolves in water to give an alkaline solution.
- $Al_2O_3(s)$ and $SiO_2(s)$ are insoluble.
- $P_4O_{10}(s)$ dissolves in water to give an acidic solution.

Explanation: [2]

Across period 3, the structure of the oxides changes from ionic crystals to covalent network and then to simple molecules.

- $Na_2O(s)$ is an ionic oxide. The O^{2-} ions react with water to give $OH^-(aq)$ ions.
- $Al_2O_3(s)$ is an ionic solid with a very strong ionic bond. The interactions between ions and water are much weaker than the ionic bond in Al_2O_3. It is insoluble in water.
- $SiO_2(s)$ has a giant covalent network structure. Its atoms are bounded by strong covalent bonds. It is insoluble in water.
- $P_4O_{10}(s)$ hydrolyzes in / reacts with water to give an acidic solution.

AL13(II)_02

Transition metal ions usually have unoccupied 3rd (or 4th) electron shell. [1]

Transition of electrons in these electron shell involves absorption of electromagnetic radiation in the visible light region. [1]

Thus transition metal compounds are usually colored.

DSE11SP_14

Sodium oxide dissolves in water to give an alkaline solution ($NaOH(aq)$). [1]

$Na_2O(s) + H_2O(l) \longrightarrow 2Na^+(aq) + 2OH^-(aq)$ [1]

Sulphur dioxide dissolves in water to give an acidic solution ($H_2SO_3(aq)$). [1]

$SO_2(aq) + H_2O(l) \rightleftharpoons SO_3^{2-}(aq) + 2H^+(aq)$ [1]

DSE12PP_09

(a) [2]

	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
Structure	IC	IC	CN	SM	SM
Acid-base property	BA	AM	AC	AC	AC

(b) Ionic oxides are basic, while covalent oxides are acidic. [1]

(c) (In this question, award 1 mark for the reagents used in each of tests for acidic, basic and ampoteric oxides, and 1 mark for a correct observation. One possible method is shown below.)

Add each oxide to HCl(aq) and measure the pH of the mixture. Only MgO(s) and [1]
$Al_2O_3(s)$ react with HCl(aq) and the pH increases. These two oxides demonstrate [1]
basic properties.

Add each oxide to NaOH(aq) and measure the pH of the mixture. Only $Al_2O_3(s)$, [1]
$SiO_2(s)$, $P_4O_{10}(s)$ and $SO_2(g)$ react with NaOH(aq) ($SiO_2(s)$ reacts with hot conc. NaOH(aq), and the pH decreases. These oxides demonstrate acidic properties.

$Al_2O_3(s)$ reacts both cases. It is amphoteric. [1]

Effective communications (Award 1 mark if candidates can express their ideas clearly.) [1]

DSE12PP_13

(c) $H_2SO_4(aq)$ reacts with the $NH_3(aq)$ present:

$H^+(aq) + NH_3(aq) \longrightarrow NH_4^+(aq)$ [1]

OR, $H_2SO_4(aq) + 2NH_3(aq) \longrightarrow (NH_4)_2SO_4(aq)$

Removal of $NH_3(aq)$ causes the position of the following equilibrium to shift to the left. [1]

$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$

$NH_3(aq)$ is a weak base:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ [1]

When $[Cu^{2+}(aq)]$ builds up it will react with the $OH^-(aq)$ ions to give the blue precipitate.

$Cu^{2+}(aq) + OH^-(aq) \longrightarrow Cu(OH)_2(s)$ [1]

When excess $H_2SO_4(aq)$ is added, it will react with the $Cu(OH)_2(s)$ formed to give a blue solution.

$Cu(OH)_2(s) + 2H^+ \longrightarrow Cu^{2+}(aq) + 2H_2O(l)$ [1]

(3 marks for chemical equations; 1 mark for explanation of the shift in equilibrium position; 1 mark for the formation of blue precipitate.)

DSE12_16

(a) Na_2O, MgO, Al_2O_3 [1]

(b) SiO_2 **has a giant covalent structure**, and the Si and O atoms are linked by **strong covalent bonds.** (Not accept strong covalent structure / giant covalent bonds) [1]

Other covalent oxides are discrete molecules attracted by weak van der Waals' forces / weak intermolecular forces / weak dipolar interactions. (NOT accept VDW forces) [1]

(c) $Al_2O_3 + 2OH^- + 3H_2O \longrightarrow 2\,Al(OH)_4^-$ [1]

OR $Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2NaAl(OH)_4$

DSE13_13

Nitrogen < lithium < beryllium < carbon (graphite) [1]

N_2 **has the lowest melting point as it has a simple molecular structure, weak van der Waals' forces / intermolecular forces** need to be overcome. [1]

Both Li and Be have metallic structure, metallic bond in Li is weaker than that in Be. ∴ Li < Be in melting points. [1]

C has the highest melting point as it has a **giant covalent structure**, large amount of energy is needed to **break strong covalent bonds between atoms** in melting. [1]

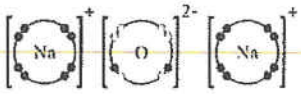
Effective communication [1]

DSE14_11

(a) Vanadium exhibits **variable oxidation numbers** and its ions in aqueous solution **carry colors.** [1]

DSE15_10

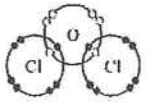
(a) (i)



[1]

It gives an alkaline / a base solution / NaOH / sodium hydroxide [1]

(ii)



[1]

It gives an acidic solution / HOCl / hypochlorous acid [1]

(b) Any TWO of the following (answers should have examples) [2]

- Fe can have variable oxidation numbers – +2, +3, Fe^{2+}, Fe^{3+}
- Fe can acts as a catalyst – e.g. Fe in Haber Process
- Fe forms colored compounds – $Fe^{2+}(aq)$ is green, $Fe^{3+}(aq)$ is yellow
- Fe can form complexes – e.g. the Fe complex in rust indictor, $K_3[Fe(CN)_6]$
- Fe has magnetic properties – e.g. iron metal can be attracted by magnets.

DSE16_14

Electrical conductivity: aluminium > sodium > silicon = sulphur (or: silicon > sulphur) [1]

Any 3 of the following items, each 1 mark [3]

- **Both aluminium and sodium have giant metallic structures with delocalized / mobile electrons so that electrical conductivity of them is high / their electrical conductivity is higher than that of silicon and sulphur.**
- **The number of delocalized / mobile electrons of aluminium is more than that of sodium so that electrical conductivity of aluminium is higher than that of sodium.**
- **Silicon has giant covalent structure and its electrons are not mobile and cannot conduct electricity / its electrical conductivity is lower than that of aluminium and sodium.**

  OR, **Silicon has giant covalent structure and its electrons are not mobile. But silicon is a semi-metal and can conduct electricity in some conditions.**
- **Suphur has simple molecular structure and its electrons are not mobile and cannot conduct electricity / its electrical conductivity is lower than that of aluminium and sodium.** [1]
- Effective communication

DSE17_14

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(aq) + 8H_2O(l)$ [1]

Manganese exhibits **variable oxidation numbers.** The oxidation number of manganese changes from +7 in MnO_4^- to +2 in Mn^{2+} in the reaction. [1]

Manganese forms colored ions in aqueous solution. **$MnO_4^-(aq)$ ions exhibit purple / $Mn^{2+}(aq)$ ions exhibit pale pink.** [1]

From the graph, it shows that the reaction rate increases when Mn^{2+} ions form / when the reaction proceeds. [1]

Manganese has catalytic properties. **Mn^{2+} ions act as a catalyst for the reaction.** [1]

Communication mark [1]

Chemical knowledge = 0 to 2, mark = 0,
Chemical knowledge = 3 to 4, mark = 0 or 1,
Incomplete answer / difficult to understand, mark = 0)

DSE18_14

$Na_2O(s)$ dissolves in water to give **NaOH(aq)** [1]

$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$

OR $Na_2O(s)$ reacts with HCl(aq) to give NaCl(aq) and H_2O

$Na_2O(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O$

$Al_2O_3(s)$ reacts with HCl(aq) to give $AlCl_3(aq)$ and H_2O [1]

$Al_2O_3(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s)$ reacts with NaOH(aq) to give $NaAl(OH)_4(aq)$ and H_2O [1]

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \longrightarrow 2NaAl(OH)_4(aq)$

$SO_2(g)$ dissolves in water to give $H_2SO_3(aq)$. [1]

$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$

OR $SO_2(g)$ reacts with NaOH(aq) to give $Na_2SO_3(aq)$ and $H_2O(l)$

$SO_2(g) + 2NaOH(aq) \longrightarrow Na_2SO_3(aq) + H_2O(l)$

Able to mention Na_2O is a basic (alkaline) oxide, Al_2O_3 is an amphoteric oxide, and SO_2 is an acidic oxide. [1]

Communication mark [1]

Chemical knowledge = 0 to 3, communication mark = 0

Chemical knowledge = 4 to 5, communication mark = 0 or 1)

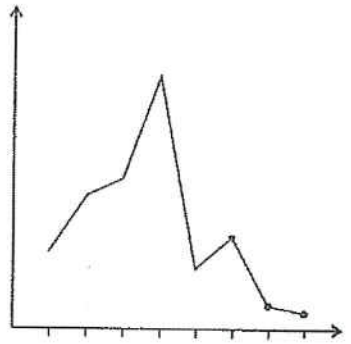
Incomplete answer or difficult to understand, communication mark = 0)

Notes:

- If the candidate gives the answer in the form of a chemical equation, it is not necessary to have the chemical equation correctly balanced.
- **The answer should state the reagents and products correctly (including the water formed in the neutralization reaction).**
- **If the candidate gives the answer in the form of a correct ionic equation, or state the reagents and the products in correct ionic forms, the answer is considered to have correct chemical concept, but failed to state the reagents and products completely. (Maximum) Deduct 1 mark for the whole question. Example: If the candidate only stated 4 correct ionic equations, but in each of the entries the reagents and the products were not stated explicitly, maximum 3 marks will be awarded for the chemical knowledge.**
- The following answers are considered to have the products stated correctly.

DSE19_14

(a) [1]



1: The m.p. of S must not be higher than that of Mg;

2: The m.p. of Cl and Ar must not be higher than that of P;

3: The m.p. of Ar must be lower than that of Cl

(b) **The metallic bond in Mg is stronger than that in Na as Mg has more delocalised electrons / more outermost shell electrons than Na.** [1]

OR **The metallic bond in Mg is stronger than that in Na as Mg has two outermost shell delocalised electrons while Na only has one**

(c) Melting of Si needs high energy to break the strong covalent bonds between Si atoms in the giant covalent structure. [1]

Melting of P only needs smaller energy to break the weak intermolecular forces. / P has a simple molecular structure, there are weak van der Waals' forces between molecules. [1]

OR Si has a giant covalent structure while P has a simple molecular structure. [1]

High energy is needed to break the strong covalent bonds between Si atoms, while smaller energy is needed to break the weak van der Waals' forces between phosphorus molecules. [1]

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12. • Cobalt/Co^{2+} acts as a catalyst as the rate of formation of gas bubbles (CO_2) increases / rate of reaction increases when Co^{2+} ions are added, 1
- and the pink Co^{2+} ions regenerate / remain (chemically) unchanged / do not consume at the end of reaction. 1
- Coloured ion / formation of coloured compound: $Co^{2+}(aq)$ is pink / the cobalt(III) compound formed is green. 1
- Variable oxidation states: cobalt has cobalt(II) and cobalt(III) compounds / can exist as Co^{2+} and Co^{3+}. 1

(The answers have to be illustrated with the experimental observations provided in the question.)