VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY 8873/02

Paper 2 Structured Questions **12 September 2024**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Name and CT group in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
Section A	1	/ 16
	2	/ 25
	3	/ 19
Section B	4 / 5	/ 20
Total		/ 80

This document consists of **23** printed pages.

Section A

Answer **all** questions in this section in the spaces provided.

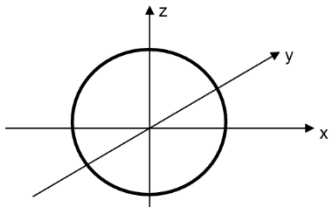
1 (a) (i) Write down the electronic configurations of the following species.

- Na : **$1s^2 2s^2 2p^6 3s^1$**
- Al^{2+} : **$1s^2 2s^2 2p^6 3s^1$**

[1]

(ii) The electronic configuration of copper atom is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$.

Sketch the shape of the filled orbital of copper atom with the highest energy on the axes in Fig. 1.1 and label the orbital.

- 

4s

Fig. 1.1

[1]

(iii) Write a balanced equation for the third ionisation energy of aluminium.

- **$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$**

[1]

(iv) Explain why the third ionisation energy of aluminium is greater than the first ionisation energy of sodium.

- **Al^{2+} has a greater nuclear charge than Na as it has more protons.**
  The shielding effect is the same for both Al^{2+} and Na as both have the same electronic configuration (OR number of electrons).
- **Hence, Al^{2+} has a greater effective nuclear charge leading to a greater third ionisation energy than the first ionisation energy of sodium.**

[2]

(b) Period 3 elements and their compounds show trends in their physical and chemical properties.

(i) Sketch a graph to show the melting points of the first five elements in Period 3 on Fig. 1.2.

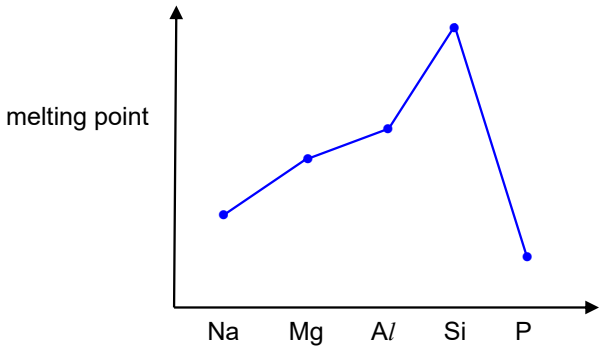


Fig. 1.2

1m: Na, Mg and Al (increasing trend),
1m: Si (highest) and P (lowest)

[2]

(ii) Explain the variation in melting point of the first five Period 3 elements in terms of their structure and bonding.

- **Na, Mg and Al have giant metallic structure. Melting point increases from Na to Al due to increasing strength of metallic bonds caused by increasing delocalised electrons. More energy is needed to break the stronger metallic bonds.**
- **Si has a giant molecular structure. It has the highest melting point because a large amount of energy is needed to break the strong covalent bonds between the silicon atoms.**
- **P_4 has a simple molecular structure. It has a low melting point because a small amount of energy is needed to overcome the weak instantaneous dipole-induced dipole interactions between the molecules.**

Accept intermolecular forces of attractions instead of id-id.

[3]

(iii) An excess of cold water is added to the oxide of sodium and the chloride of silicon separately.

Describe the reactions of these compounds with water. Write relevant equation for any reaction that occurs and suggest the pH of the mixture produced in each case.

- **Na_2O dissolves in water to form sodium and oxide ions. The oxide ions react with water to form a strongly alkaline solution of pH 13** (accept pH 12–14). **Heat is released as the reaction is exothermic.**
- **$Na_2O + H_2O \rightarrow 2NaOH$**
- **$SiCl_4$ reacts violently with water with heat released. Being covalent, it undergoes complete hydrolysis to give a strongly acidic solution of pH 2** (accept pH 1–3)
- **$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$**

[4]

(c) Tennessine, Ts, is an unstable man-made element. It is found below astatine, At, in Group 17. The chemical properties of Ts and its compounds can be predicted.

Suggest an equation for the reaction of NaTs and Br_2, assuming Ts follows the same trends as the other elements in Group 17. Explain your answer.

- **$2NaTs + Br_2 \rightarrow 2NaBr + Ts_2$**
- **Br_2 is a stronger oxidising agent than Ts_2. Down the group, the oxidising strength of the halogen decreases as it is harder to gain electrons due to the weakening of electrostatic forces of attraction between the nucleus and incoming electrons.**

[2]

[Total: 16]

2 (a) The reaction of ammonia with oxygen to form nitrogen monoxide, NO, is an important industrial process to manufacture nitric acid.

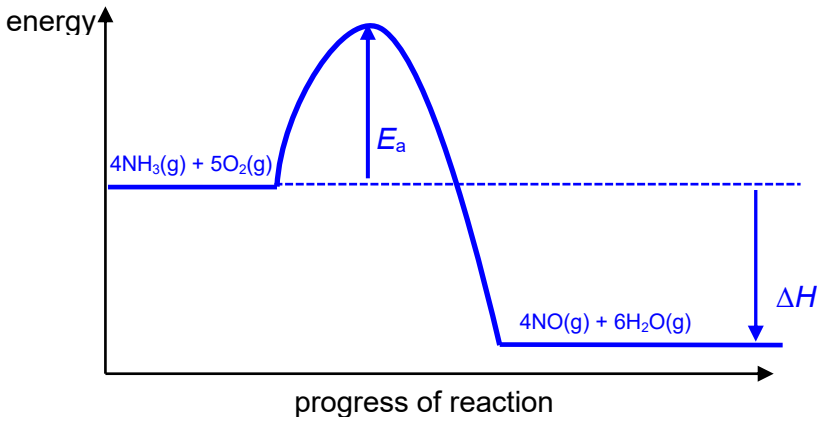
The equation for this reaction is shown in **equilibrium 2.1**.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta H = -905 \text{ kJ mol}^{-1} \quad \textbf{equilibrium 2.1}$$

(i) The forward reaction in **equilibrium 2.1** converts NH_3 into NO.

Draw the energy profile for this reaction in the diagram below.

Label the following parts in your diagram.
- reactants
- products
- activation energy, E_a
- enthalpy change, ΔH



- correct shape of graph + showing energy level of reactants higher than products + label + reactants and products
- correct labels: (1) activation energy, (2) enthalpy change with correct direction of arrows

[2]

(ii) Write an expression for the equilibrium constant, K_c in **equilibrium 2.1**.

- $K_c = \frac{[H_2O]^6[NO]^4}{[NH_3]^4[O_2]^5}$

[1]

(iii) Deduce the units of K_c in **equilibrium 2.1**.

- **mol dm^{-3}**

[1]

(iv) The reaction in **equilibrium 2.1** is carried out in a laboratory.

34.0 g of ammonia and 32.0 g of oxygen was allowed to react in a reaction chamber with a volume of 50 cm^3. At equilibrium, it was found that 20% of ammonia has reacted.

Calculate a value for the equilibrium constant, K_c.

	$4NH_3$ +	$5O_2$ ⇌	$4NO$ +	$6H_2O$
initial amount	$\frac{34}{14.0+3\times1.0} = 2.00$	$\frac{32}{16.0\times2} = 1.00$	0	0
change	$-(\frac{20}{100}\times2.0) = -0.400$	$-(\frac{5}{4}\times0.400) = -0.500$	+ 0.400	$+(\frac{6}{4}\times0.400) = 0.600$
equilibrium amount	1.60	0.500	0.400	0.600
equilibrium concentration	$\frac{1.60}{50/1000} = 32.0$	$\frac{0.500}{50/1000} = 10.0$	$\frac{0.400}{50/1000} = 8.00$	$\frac{0.60}{50/1000} = 12.0$

$K_c = \frac{(12.0)^6(8.00)^4}{(32.0)^4(10.0)^5} = 0.11664 = 0.117$ mol dm^{-3}

Correct concentrations for both reactants and products at equilibrium
Correct value for K_c (no need to mark unit again.)

[2]

(v) Explain how a low temperature and a low pressure would lead to a high yield of nitrogen monoxide in **equilibrium 2.1**.

- **At low temperature, according to Le Chatelier's principle (LCP), the position of equilibrium 2.1 will shift to the right to favour the exothermic reaction which will release heat to counteract the heat loss, resulting in more NO formed.**
- **At low pressure, according to LCP, the position of equilibrium 2.1 will shift to the right to favour the reaction which will produce more gaseous molecules to counteract the reduction in pressure of the system, resulting in more NO formed.**

[2]

(vi) In industry, **equilibrium 2.1** is carried out at a high temperature of 900°C.

Suggest why the industry employs this temperature for **equilibrium 2.1** instead of the conditions in **(a)(v)**.

- **At low temperature, the rate of reaction for equilibrium 2.1 is slow and hence, a high temperature at 900°C will ensure that the rate of production of NO is reasonably high.**

[1]

(vii) Suggest which gas, oxygen or nitrogen monoxide, requires a higher pressure to be liquefied at the same temperature. Explain your answer in terms of intermolecular forces of attractions.

- **O_2 requires a higher pressure than NO as it is a non-polar molecule with weaker instantaneous dipole–induced dipole interactions.**
- **NO is a polar molecule with stronger permanent dipole–permanent dipole interactions between molecules.**

[2]

(b) The nitrogen monoxide, NO, formed in **equilibrium 2.1** is a pollutant gas. This gas is also present in the exhaust of vehicles, together with nitrogen dioxide, NO_2.

In the internal combustion engines of vehicles, the temperature is high enough for nitrogen gas, N_2, to react with oxygen gas, O_2 to form NO and NO_2 as shown below.

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H = +180 \text{ kJ mol}^{-1}$$

$$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$$

The formation of nitrogen monoxide from nitrogen and oxygen is endothermic.

(i) Explain the meaning of *endothermic* reaction in terms of breaking and forming of chemical bonds.

- **In endothermic reaction, the energy required to break the bonds in the reactants is more than the energy released from bonds formed in the products.**

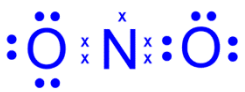
[1]

(ii) It was found that the product mixture contains more nitrogen monoxide than nitrogen dioxide. Suggest a reason why the product mixture contains a greater amount of nitrogen monoxide than nitrogen dioxide.

- **There Is insufficient oxygen gas (or air) in the car engine for complete combustion of N_2 to form NO_2.**

[1]

(c) **(i)** Draw a dot-and-cross diagram for a molecule of NO_2.

- 

[1]

(ii) State the shape and suggest a value for the O–N–O bond angle in a molecule of NO_2.

- **shape: bent**
- **bond angle: 150°** Accept a range from 120° to 180°

[2]

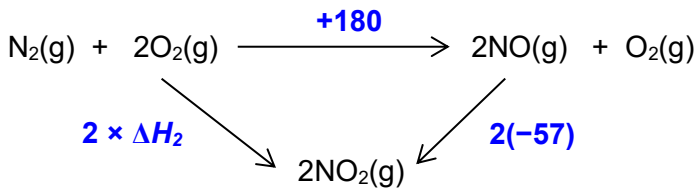
(iii) Write an equation to represent the enthalpy change of formation of NO_2.

- **$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$**

[1]

(iv) Using the information given in **(b)**, ΔH_1 and the energy cycle below, calculate the enthalpy change of formation of $NO_2(g)$, ΔH_2.

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g) \qquad \Delta H_1 = -57.0 \text{ kJ mol}^{-1}$$



- **$2\Delta H_2 = 180 - 2(57.0)$**
- **$\Delta H_2 = \frac{1}{2}(66) = +33.0 \text{ kJ mol}^{-1}$**

1 mark for correct application of Hess's law
1 mark for correct substitution of the energy changes and calculation.

[2]

(d) Nitrogen exhibits a range of oxidation numbers in its compounds.

Table 2.1 shows the oxidation number of nitrogen in different species.

Table 2.1

species	oxidation number of nitrogen
NO_3^-	+5
NO_2	+4
NO	+2
N_2O	+1
N_2	0
NH_2OH	–1
NH_4^+	–3

Nitric acid, HNO_3, can be reduced to different nitrogen-containing products, depending on the choice of reducing agent.

For example, copper metal can reduce HNO_3 to NO_2, but aluminium metal reduces HNO_3 to NH_4^+.

(i) Write a balanced equation for the reaction between aluminium and nitric acid to form Al^{3+} and NH_4^+.

- **$3NO_3^- + 30H^+ + 8Al \rightarrow 3NH_4^+ + 9H_2O + 8Al^{3+}$**

[1]

(ii) With reference to the change in oxidation numbers of nitrogen when nitric acid reacts with Cu metal and when nitric acid reacts with Al metal, deduce which metal is a weaker reducing agent. Explain your answer.

- **Copper can reduce N from +5 in HNO_3 to +4 in NO_2. Aluminium can reduce nitrogen from +5 in HNO_3 to –3 in NH_4^+.**
  (Accept when using copper as oxidation number of N dropped by 1 which is lower as compared when Al is used where oxidation number of N dropped by 8)

- **Copper is a weaker reducing agent as it decreases the oxidation number of N to a smaller extent.**

[2]

(e) $Fe^{3+}(aq)$ is an oxidising agent. It can be reduced to Fe^{2+} in a redox reaction as shown below.

$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$$

Fe^{3+} can oxidise NH_2OH to form one of the nitrogen-containing products listed in Table 2.1.

In an experiment, 25.0 cm^3 of 0.100 mol dm^{-3} NH_2OH required 21.70 cm^3 of 0.230 mol dm^{-3} of $Fe^{3+}(aq)$ for complete reaction.

(i) Calculate the number of moles of Fe^{3+} that reacts with one mole of NH_2OH. Hence, determine the number of moles of electrons lost by one mole of NH_2OH in the reaction.

Amount of NH_2OH used = $0.100 \times \frac{25.0}{1000}$ = 0.00250 mol

Amount of Fe^{3+} used = $0.230 \times \frac{25.0}{1000}$ = 0.00499 mol

- **Amount of Fe^{3+} that reacts with one mole of NH_2OH**

  = $\frac{0.00499}{0.00250}$ = 1.996 = 2 mol

  2 mol of Fe^{3+} gained 2 mol of electrons.

- **Hence, one mole of NH_2OH lost 2 mol of electrons.**

correct amount of NH_2OH and Fe^{3+}
correct number of moles of electrons to 1 mol of NH_2OH

[2]

(ii) With reference to **Table 2.1**, identify the nitrogen-containing product formed in the reaction.

- **N_2O**

[1]

[Total: 25]

3 (a) Hydrogen peroxide is a chemical used for bleaching processes in pulp, paper and textile industries.

At room temperature, hydrogen peroxide decomposes to form water and oxygen gas as shown below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The rate of decomposition of hydrogen peroxide can be followed by measuring the volume of oxygen collected at regular time intervals. It is found that the decomposition has a constant half-life of 0.55 min.

(i) Define the term *half-life*.

- **Half-life is the time taken for the concentration of a reactant to fall to half its initial value.**

[1]

(ii) Complete Fig. 3.1 to show how the rate constant, *k*, varies with the concentration of H_2O_2, at constant temperature.

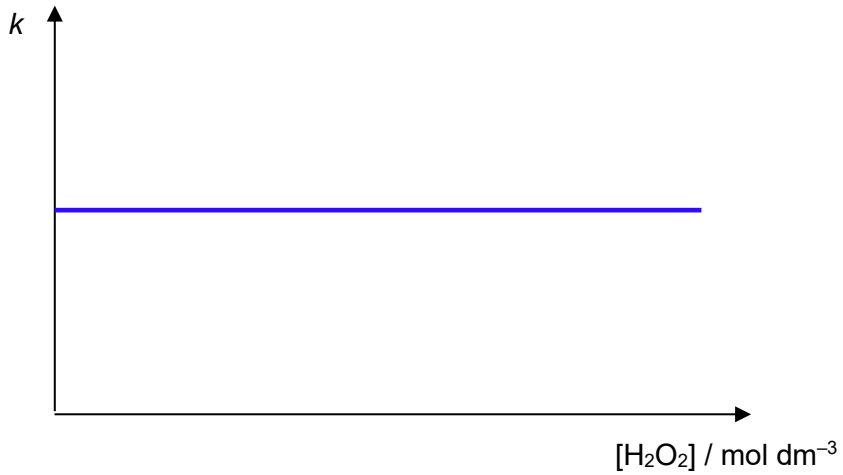


Fig. 3.1

[1]

(iii) State what happens to the rate of the decomposition when the concentration of hydrogen peroxide is increased.

Explain your answer in terms of the collision theory.

- **When concentration increases, the number of hydrogen peroxide molecules in a given volume increases resulting in more collisions per unit time.**
- **Frequency of effective collisions between hydrogen peroxide molecules increases resulting in a higher rate of decomposition.**

[2]

(b) Oxygen produced from the decomposition of hydrogen peroxide can also be used as the propellant in rockets.

The decomposition of hydrogen peroxide can be catalysed by manganese(IV) oxide nanoparticles.

(i) Define the term *nanoparticles*.

- **Substances with all dimensions ranging from 1 nm to 100 nm.**

[1]

(ii) Explain why manganese(IV) oxide in the form of nanoparticles is a more effective catalyst than it is in the bulk form.

- **Nanoparticles have high surface area to volume ratio.**
- **Hence more hydrogen peroxide molecules can be adsorbed onto the surface of the catalyst for reaction to occur.**

[2]

(iii) As the use of nanoparticles becomes increasingly popular, it is observed that the amount of nanoparticles in river water has also increased.

Explain why the presence of nanoparticles in river water may increase the chances of organ dysfunction in fishes.

- **Manganese(IV) oxide nanoparticles are small enough to enter the bodies of fishes and get into the blood stream, thus damaging their organs.**

[1]

(iv) State what is meant by the term *heterogenous* when it is applied to manganese (IV) oxide catalyst in this reaction.

- **Heterogeneous means that the physical states of manganese (IV) oxide catalyst and hydrogen peroxide are different.**

[1]

(v) Outline, in three stages, the mode of action when manganese(IV) oxide catalyses the decomposition of hydrogen peroxide.

- **Adsorption: During adsorption, the covalent bonds within the hydrogen peroxide molecules are weakened and this reduces the activation energy of the reaction. This also increases the surface concentration of hydrogen peroxide.**
- **Reaction: The adjacent hydrogen peroxide molecules react to form products. This reaction has lower activation energy (E_a) than the uncatalysed reaction.**
- **Desorption: The oxygen and water molecules break free from the catalyst surface and the clean surface of the catalyst is regenerated.**

[3]

(c) The relative atomic mass of an element depends on the percentage abundance of each isotope present.

A sample of oxygen contains three isotopes as shown in Table 3.1.

Table 3.1

isotope	relative isotopic mass	percentage abundance / %
^{16}O	15.9949	99.757

^{17}O	16.9991	0.038
^{18}O	17.9992	0.205

Calculate the relative atomic mass of oxygen in this sample, giving your answer to **two** decimal places.

$$A_r = \frac{95.757 \times 15.9949 + 16.9991 \times 0.038 + 17.9992 \times 0.205}{100}$$
$$= 15.9982$$
$$= 16.00$$

1 mark for correct substitution of relative isotopic mass + relative abundance
1 mark for correct value and correct approximation to two decimal places.

[2]

(d) Peracetic acid, CH_3CO_3H is prepared from the reaction of ethanoic acid and hydrogen peroxide. Peracetic acid is a colourless liquid with a pungent odour. It is used as a fungicide in food processing.

Peracetic acid is classified as a weak Brønsted-Lowry acid by chemist.

(i) Define, with the aid of an equation, the term *weak Brønsted-Lowry acid* with reference to peracetic acid.

- **$CH_3CO_3H \rightleftharpoons CH_3CO_3^- + H^+$**
- **Paracetic acid is a proton donor which dissociates partially.**

[2]

(ii) Both ethanoic acid, CH_3CO_2H, and peracetic acid are organic acids.

The K_a value for ethanoic acid is 1.8×10^{-5}.

The K_a value of peracetic acid is 6.3×10^{-9}.

Solutions of equal concentration of the two acids $CH_3CO_2H(aq)$ and $CH_3CO_3H(aq)$ are prepared separately.

Suggest how the pH values of these two solutions differ. Explain your answers in terms of the K_a values and the equilibrium positions in each solution.

- **Ethanoic acid has a higher K_a value than paracetic acid so the equilibrium position for the dissociation of the acid is more on the right.**
- **This results in a higher concentration of H^+ in the solution, leading to a lower pH.**

[2]

(iii) A buffer is prepared by mixing an equal amount of peracetic acid and its sodium salt.

Write an equation to show how this buffer mixture resists pH change when a small amount of sodium hydroxide is added to it.

- **$CH_3CO_3H + NaOH \rightarrow CH_3CO_3^-Na^+ + H_2O$**

  No equilibrium arrow allowed.

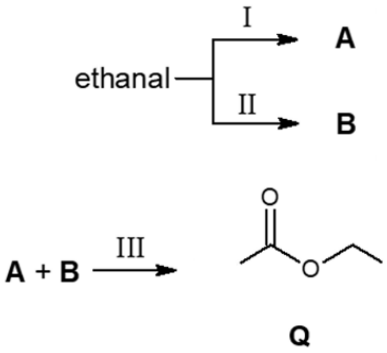
[1]

[Total: 19]

Section B

Answer **one** question from this section in the spaces provided.

4 **(a)** Ethanal can be used to synthesise compound **Q** via the following reaction scheme.



B turns damp blue litmus paper red but **A** does not.

(i) Name the functional group present in compound **Q**.

- **ester**

[1]

(ii) State the systematic name of compound **Q**.

- **ethyl ethanoate**

[1]

(iii) State the reagents and conditions required for steps I, II and III.

Give the structures of **A** and **B**.

- Step I **$NaBH_4$ (in methanol) or $LiAlH_4$ in dry ether or H_2 gas with Pt or Pd catalyst or Ni catalyst with heat**
- Step II **$KMnO_4(aq)$ or $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat**
- Step III **concentrated H_2SO_4 catalyst, heat**

1 mark for 1 step

- **A is CH_3CH_2OH**
- **B is CH_3CO_2H**

1 mark each

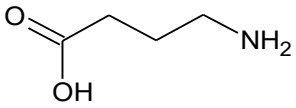
[5]

(iv) Write a balanced equation for the acid hydrolysis of compound **Q**.

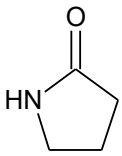
- **$CH_3CO_2CH_2CH_3 + H_2O \rightarrow CH_3CO_2H + CH_3CH_2OH$**

[1]

(b) 4-aminobutanoic acid is a useful compound that can be used to make plastic **R**. It can also be used to synthesise pyrrolidione.



4-aminobutanoic acid



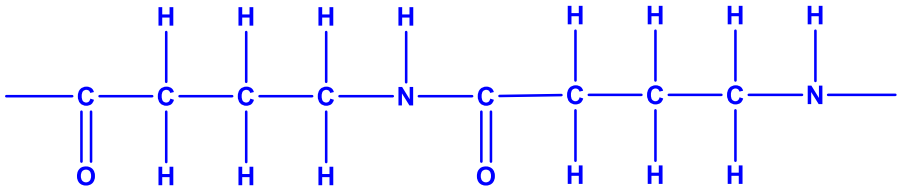
pyrrolidione

(i) State the type of polymerisation reaction to form plastic **R**.

- **Condensation polymerisation**

[1]

(ii) Draw a displayed formula of two repeat units of the polymer **R**.

- 

[1]

(iii) Name the intermolecular forces of attractions that could exist between polymer chains of **R**.

- **Hydrogen bonds and induced dipole–instantaneous dipole interactions /permanent dipole−permanent dipole interactions**

[1]

(iv) Explain why plastic **R** can be regarded as a thermoplastic and can be easily recycled.

- **There are only weak intermolecular forces of attractions between the polymer chains that can be easily overcome on heating causing the plastic to melt. There are also no cross-links between the polymeric chains.**
- **Plastic R is a thermoplastic as it will soften (melt) when heated and harden again on cooling making recycling easy.**

[2]

(c) A student used the apparatus shown in Fig. 4.1 to find the enthalpy change of combustion of ethanol, ΔH_c (ethanol).

$$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H_c \text{ (ethanol)}$$

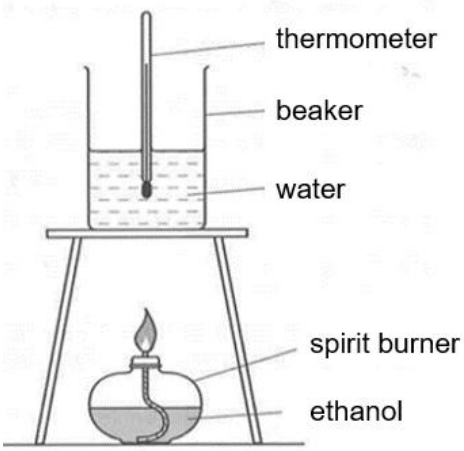


Fig. 4.1

The measurements recorded by the student are shown in Table 4.1.

Table 4.1

volume of water / cm^3	100
initial mass of spirit burner and ethanol / g	65.5
final mass of spirit burner and ethanol / g	64.8
initial temperature of water / °C	30.0
highest temperature of water / °C	78.5

The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

(i) Define the term *standard enthalpy change of combustion*.

- **The heat (or energy) evolved when 1 mole of a substance is completely burnt in excess oxygen at 298 K and 1 bar.**

[1]

(ii) Calculate the enthalpy change of combustion of ethanol in kJ mol^{-1}, using the data from Table 4.1.

- **Q = (100)(4.18)(78.5 – 30.0) = 20273 J**
  $n_{ethanol}$ = (65.5 – 64.8) ÷ 46.0 = 0.01522 mol
- **ΔH_c = −20273 ÷ 0.01522 = −1332000 J mol^{-1} = −1322 kJ mol^{-1}**

1 mark for correct calculation of Q
1 mark for correct determination of ΔH with correct unit and sf. (ecf)

[2]

(iii) The accepted value for the enthalpy change of combustion of ethanol is –1366 kJ mol^{-1}. Give a reason why your answer in **(b)(ii)** is different from this value.

- **Some heat is lost to the surroundings.**
- **The combustion of ethanol may not be complete leading to less heat produced.**

[1]

(iv) Use the bond energies in the Data Booklet, calculate the enthalpy change of combustion of ethanol, ΔH_c (ethanol).

- **Heat absorbed to break bonds**
  =5BE(C–H) + BE(C–C) + BE (C–O) + BE(O–H) + 3BE(O=O)
  =5 × 410 + 350 + 360 + 460 + 3 × 496 = 4708 kJ mol^{-1}

  Heat evolved from bonds formed
  =4BE(C=O) + 6BE(O–H)
  =4 × 805 + 6 × 460 = 5980 kJ mol^{-1}

- **ΔH_c (ethanol) = 4708 – 5980 = –1272 kJ mol^{-1}**

[2]

(v) Explain why the value calculated using bond energies is different from the accepted value for ΔH_c (ethanol) of –1366 kJ mol^{-1}.

- **The bond energies given in the *Data Booklet* are the average bond energies of that particular covalent bond in different types of molecules, and may not apply to the specific molecules in this reaction.**

[1]

[Total: 20]

5 Fig. 5.1 shows the synthesis of compound **X** which can exist as *cis-trans* isomers.

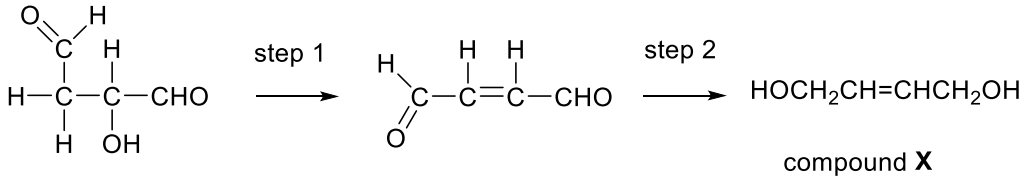


Fig. 5.1

(a) **(i)** Name the functional groups present in compound **X**.

- **primary alcohol and alkene**

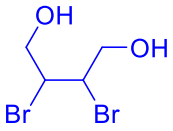
- [1]

(ii) State the reagents and conditions required for steps 1 and 2.

- Step 1 **Heat with excess concentrated H_2SO_4 or heat with Al_2O_3**
- Step 2 **$NaBH_4$ (in methanol) or $LiAlH_4$ in dry ether (ignore heat; not H_2)**

[2]

(iii) Draw the skeletal formula of product formed when compound **X** is treated with bromine in tetrachloromethane.

- 

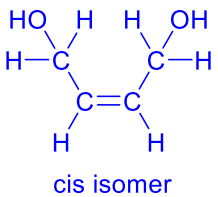
[1]

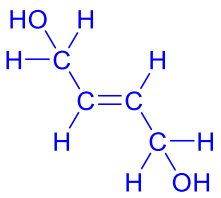
(iv) Explain why **X** can show *cis-trans* isomerism.

- **There is restricted rotation of the π bond in the double bond between the carbon atoms and there are two different groups bonded to each carbon atom of the C=C bond.**

[1]

(v) Draw and identify the *cis* and *trans* isomers of **X**.


cis isomer

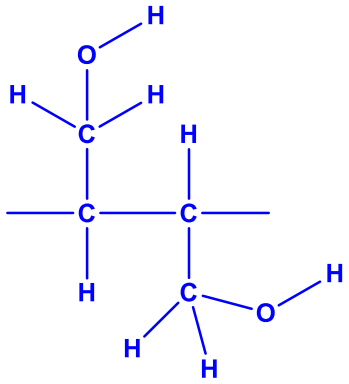

trans isomer

- **Two structures**
- **Labelling of cis and trans isomers.**

[2]

(b) **(i)** Compound **X** can be used to make polymer **Y**.

Draw the displayed formula of one repeat unit of the polymer **Y**.



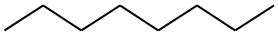
[1]

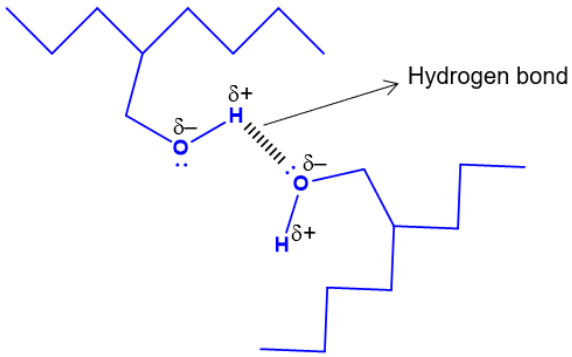
(ii) Explain why polymer **Y** is considered an addition polymer.

- **Polymer Y is an addition polymer as it is formed by addition of monomers to form a polymer with no loss of atoms from the monomers.**

[1]

(iii) Draw a labelled diagram showing the strongest forces of attractions (include the name) between two polymer chains of **Y**.

You can use  as a simplified representation of the polymer chain.



1 mark for identifying relevant atoms used to form hydrogen bond
1 mark for labelled diagram with lone pair and dipoles

[2]

(iv) Laundry beads are packaged in water-soluble films that dissolve during washing, releasing the detergent.

Suggest with explanation whether Polymer **Y** would be a suitable material for making these water-soluble packaging films.

- **Polymer Y is a suitable material because it contains –OH groups that can form hydrogen bonds with water molecules, thus it can dissolve in water.**

[1]

(c) The reduction of copper(II) ions, Cu^{2+} by iodide ions is represented by the equation below.

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

To investigate how the rate of reaction depends on the concentration of the two reactants, two experiments were carried out. In each experiment, the concentration of one reactant was in large excess to keep it almost constant, whilst the concentration of the other reactant was measured over time. Data from the experiments are shown in Table 5.1.

Table 5.1

	experiment 1	experiment 2
time / s	$[Cu^{2+}]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}
0	1.000	1.000
20	0.850	0.640
40	0.700	0.410
60	0.550	0.250
80	0.400	0.165
100	0.250	0.100
120	0.100	0.060

(i) Fig. 5.2 shows the graphical results for experiment 1.

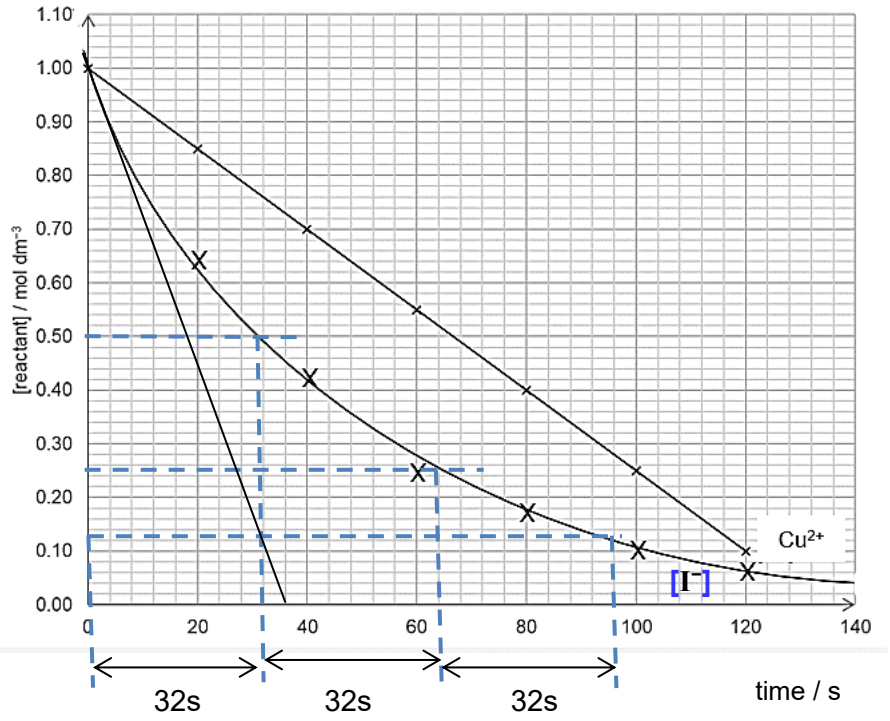


Fig. 5.2

Use the graph to determine the order of reaction with respect to Cu^{2+}.

Justify your answer.

- **The graph of $[Cu^{2+}]$ against time is a straight line (or with a constant gradient). This means the rate of reaction remains constant when $[Cu^{2+}]$ is changing.**
- **Thus, the order of reaction with respect to $[Cu^{2+}]$ is zero.**

[2]

(ii) Plot the graph of experiment 2, using the same axes in Fig. 5.2.

[1]

(iii) Use your graph in Fig 5.2 to determine the order of reaction with respect to iodide ions. Justify your answer.

- **The graph of $[I^-]$ against time has a constant half-life of 32 s.**
- **Thus, the order of reaction with respect to I^- ions is 1.**

1 mark for showing construction lines on graph for at least 2 half-lives

[2]

(iv) Use your answers from **(c)(i)** and **(c)(iii)** to write the rate equation for the reaction.

- **Rate = $k[I^-]$**

[1]

(v) Use your graph in Fig 5.2 to determine the initial rate of reaction for experiment 2.

Hence, use the initial rate you have calculated to determine the rate constant of the reaction and include its units.

- **Initial rate = gradient of tangent at t = 0**
  = 1 ÷ 36
  = 0.02778 mol dm^{-3} s^{-1}

- **k = initial rate ÷ $[I^-]$**
  = 0.02778 ÷ 1
  = 0.0278 s^{-1}

[2]
[Total: 20]

Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

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