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 and **1** blank page.

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 ……

Al^{2+} ……... [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.

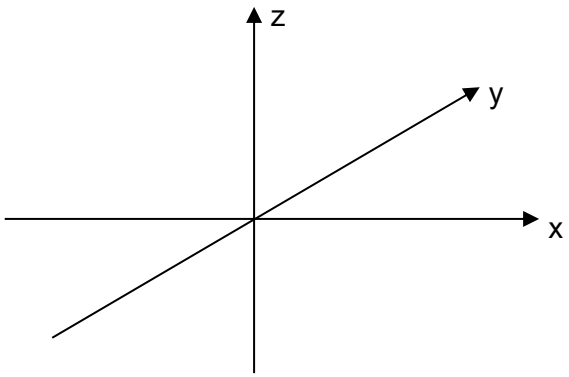

Fig. 1.1

[1]

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

……..... [1]

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

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……..… [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.

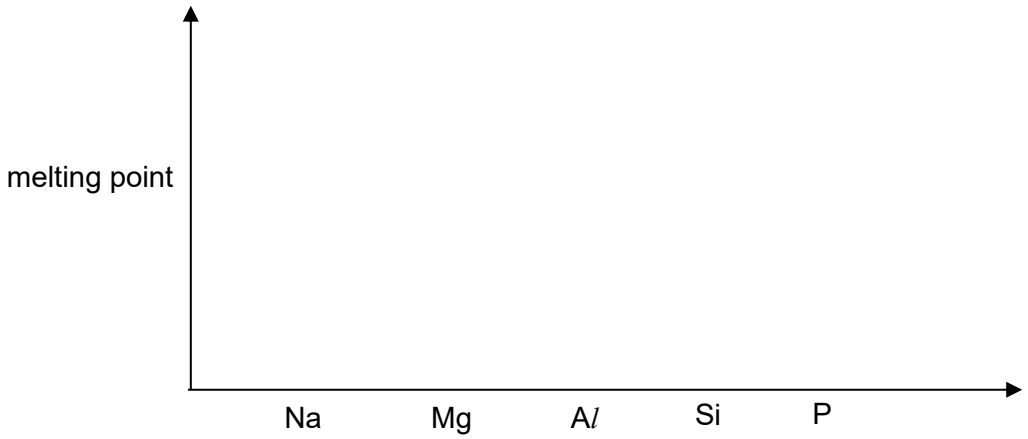

Fig. 1.2

[2]

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

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…….. [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.

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…… [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.

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…… [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.

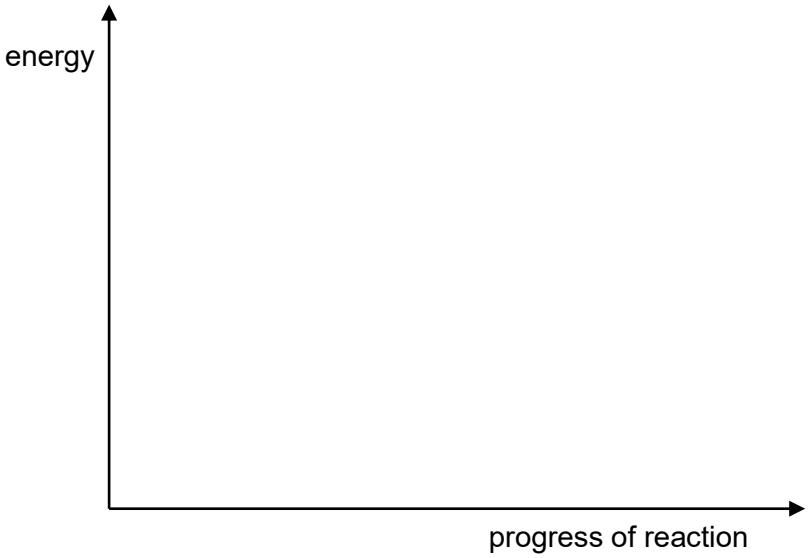
The equation for this reaction is shown in **equilibrium 2.1**.

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



[2]

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

…….. [1]

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

……... [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 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.

[2]

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

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…… [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)**.

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…… [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 attraction.

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…… [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.

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…… [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.

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…… [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.

……...

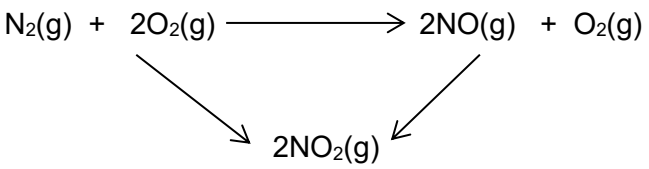
……. [2]

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

…..……..…... [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.

$$NO(g) + ½O_2(g) \rightarrow NO_2(g) \quad \Delta H_1 = -57.0 \text{ kJ mol}^{-1}$$



[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^+.

……..…… [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.

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……..……..…… [2]

(e) $Fe^{3+}(aq)$ is an oxidising agent. It can be reduced to Fe^{2+} 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.

[2]

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

……..... [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*.

……

…… [1]

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

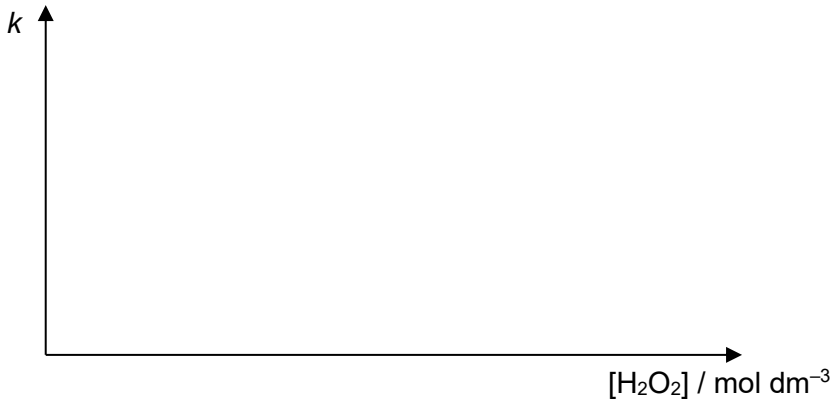

Fig. 3.1

[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 collision theory.

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…… [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*.

……

…… [1]

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

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…… [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.

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…… [1]

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

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…… [1]

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

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…… [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.

[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.

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…….…..... [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 answer in terms of the K_a values and the equilibrium positions in each solution.

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……..... [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.

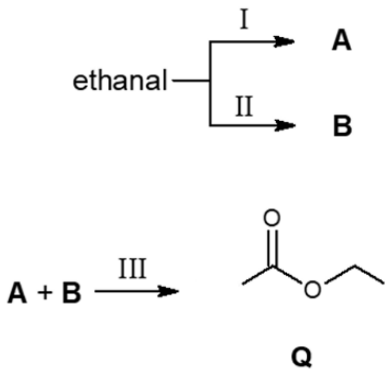
……..... [1]

[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**.

…….. [1]

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

…….. [1]

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

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

Step I ……..……..…….

Step II ..……..

Step III …..…….…….

A	**B**

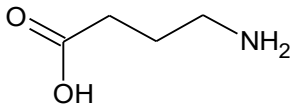
[5]

(iv) Compound **Q** can be hydrolysed to form an alcohol and a carboxylic acid.

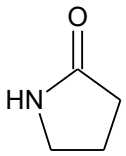
Write a balanced equation for the acid hydrolysis of compound **Q**.

…….…….. [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**.

…….. [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**.

…….[1]

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

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…….. [2]

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

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

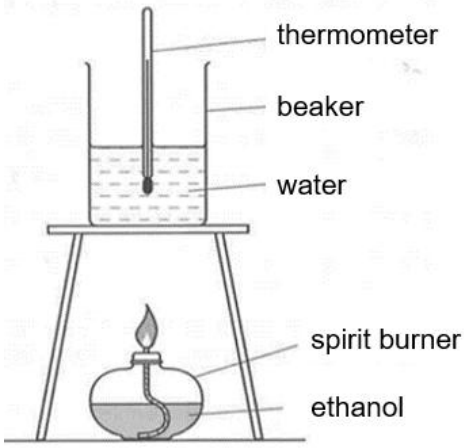

Fig. 4.1

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*.

……

…….. [1]

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

[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.

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…… [1]

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

[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}.

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…… [1]

[Total: 20]

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

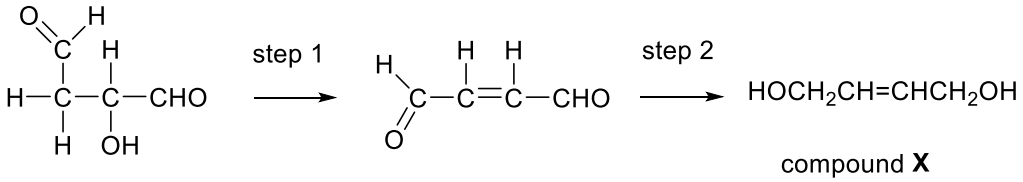

Fig. 5.1

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

……... [1]

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

step 1 ……...

step 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.

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……

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…….. [1]

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

[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.

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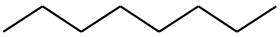
…….. [1]

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

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

[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.

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…… [1]

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(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

Fig. 5.2 shows the graphical results for experiment 1.

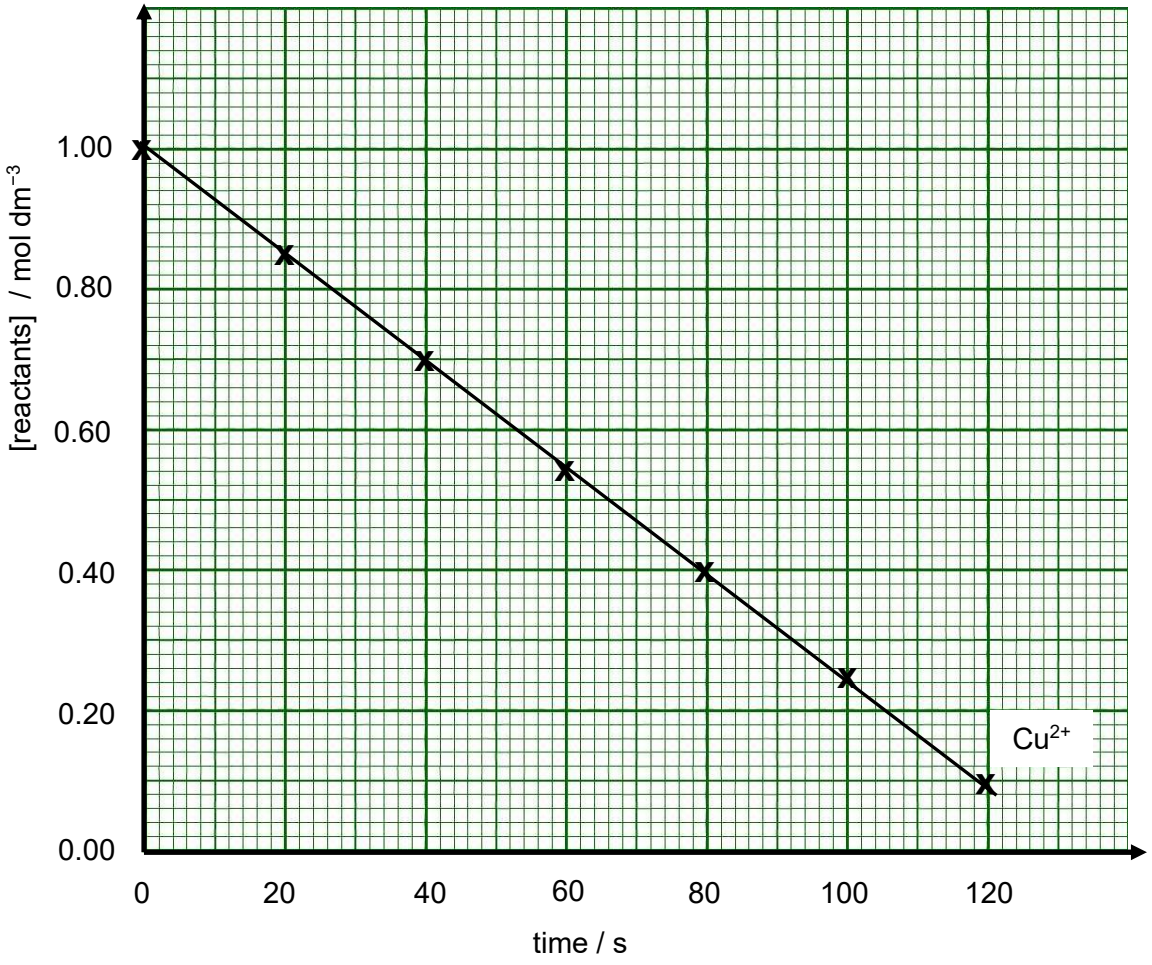

Fig. 5.2

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

Justify your answer.

……

……

…… [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.

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…… [2]

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

…… [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.

[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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