



VICTORIA JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

CANDIDATE  
NAME .....

CT GROUP .....

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**CHEMISTRY**

**9729/03**

Paper 3 Free Response

**17 September 2025**

**2 hours**

Additional Materials: Data Booklet

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**READ THESE INSTRUCTIONS FIRST**

Write your name and CT group on this cover page.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer all questions in the spaces provided on the Question Paper.  
If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

**Section A**

Answer **all** questions.

**Section B**

Answer **one** question.

A Data Booklet is provided.

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	
<b>1</b>	<b>/ 20</b>
<b>2</b>	<b>/ 20</b>
<b>3</b>	<b>/ 20</b>
<b>4</b>	<b>/ 20</b>
<b>5</b>	<b>/ 20</b>
<b>Total</b>	<b>/ 80</b>

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This document consists of **23** printed pages and **1** blank page.

## Section A

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

- 1 (a) Potassium is a highly reactive alkali metal that must be stored under oil, while copper is a much less reactive metal that resists corrosion. Table 1.1 shows the melting points of both metals.

Table 1.1

Metal	Melting point / °C
K	63.5
Cu	1085

- (i) Copper does not react with most dilute acids, unlike potassium. With reference to the standard electrode potentials in the *Data Booklet*, explain why this is so. [2]
- (ii) Describe with the aid of a labelled diagram the structure of copper at room temperature. [2]
- (iii) Suggest why the melting point of copper is significantly higher than that of potassium as shown in Table 1.1. [2]
- (iv) Fig. 1.1 shows the first ionisation energies for the elements K to Cu.

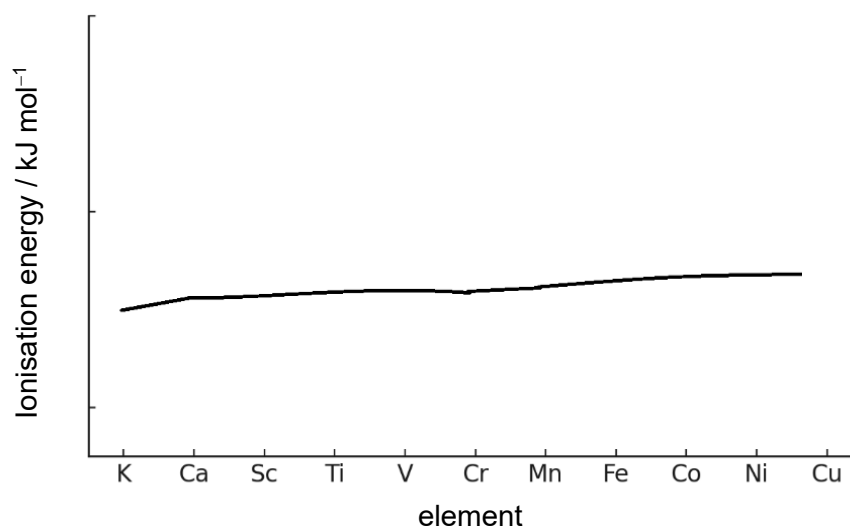


Fig 1.1

Explain why the first ionisation energy remains relatively constant from scandium to copper. [2]

- (v) Using your knowledge in the variation of first ionisation energy of the elements from potassium to copper, sketch the trend of the second ionisation energies on Fig 1.1. [1]

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- (c) Polymerisation is a process where small molecules called monomers are combined to form larger polymer chains. Polymers are large molecules made of many repeat units.


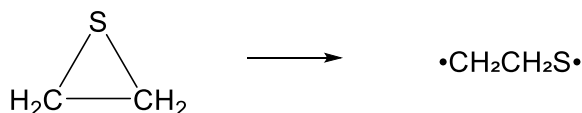
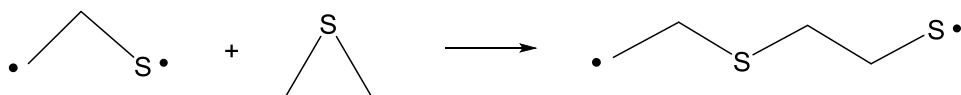
Thiirane, , can undergo free radical ring-opening polymerisation in the presence of a radical initiator, benzoyl peroxide and an excess of dodecanol,  $\text{CH}_3(\text{CH}_2)_{10}\text{CH}_2\text{OH}$ .

Fig. 1.2 shows a proposed mechanism via three reactions.

Reaction 1: Homolytic fission of a C–S bond in thiirane, generating a ‘double-ended’ free radical,  $\bullet\text{CH}_2\text{CH}_2\text{S}\bullet$ , that initiates a chain reaction.



Reaction 2: A chain reaction occurs where the ring opens and units of  $\bullet\text{CH}_2\text{CH}_2\text{S}\bullet$  adds to a growing chain. Repeated steps involve production of other free radicals.



Reaction 3: Termination with dodecanol to form  $\text{CH}_3(\text{CH}_2)_{10}\text{CH}_2\text{O}-(\text{CH}_2\text{CH}_2\text{S})_n\text{H}$ .

Fig 1.2

- (i) Use curly arrows to show the movement of electrons which occur in reactions 1 and reaction 2 on Fig. 1.2. [2]
- (ii) Suggest why thiirane undergoes the reaction more easily as compared to  $(\text{CH}_3)_2\text{S}$ . [1]

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name	formula
MEA	$\text{NH}_2\text{CH}_2\text{CH}_2\text{SH}$
glycine	$\text{NH}_2\text{CH}_2\text{COOH}$
ethanolamine	$\text{NH}_2\text{CH}_2\text{CH}_2\text{OH}$

Arrange the compounds in order of increasing acidity. Explain your answer. [3]

This image shows a full page of a handwriting practice worksheet. It consists of multiple sets of three horizontal dotted lines, providing a guide for letter height and placement. The lines are evenly spaced across the entire page, leaving ample room for writing practice. There is no text or other markings on the page.

[20 marks]



(a) The electrochemical synthesis of ferrate ions usually consists of a sacrificial iron anode and an inert cathode in an electrolytic cell containing a highly concentrated alkaline solution of potassium hydroxide.

- (iii)** Effervescence was observed at the cathode.

**(iv)** Hence construct the equation for the overall reaction for the electrochemical synthesis of ferrate ions. [1]

- (v) In an electrolytic cell above, mass of anode decreased by 0.605 g after 30 minutes.

Assume 100% purity of iron at the anode, determine the current of this cell. [2]

- (vi) Numerous research reported a maximum current efficiency of ferrate ion production in 14 mol dm<sup>-3</sup> KOH solution. When the concentration of KOH approaches its saturated value of around 20 mol dm<sup>-3</sup>, the electrolyte solution will become very viscous, resulting in a lower rate of ferrate ion produced.

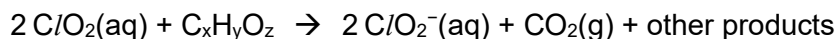
Suggest a reason for the lower rate of production of ferrate ions. [1]

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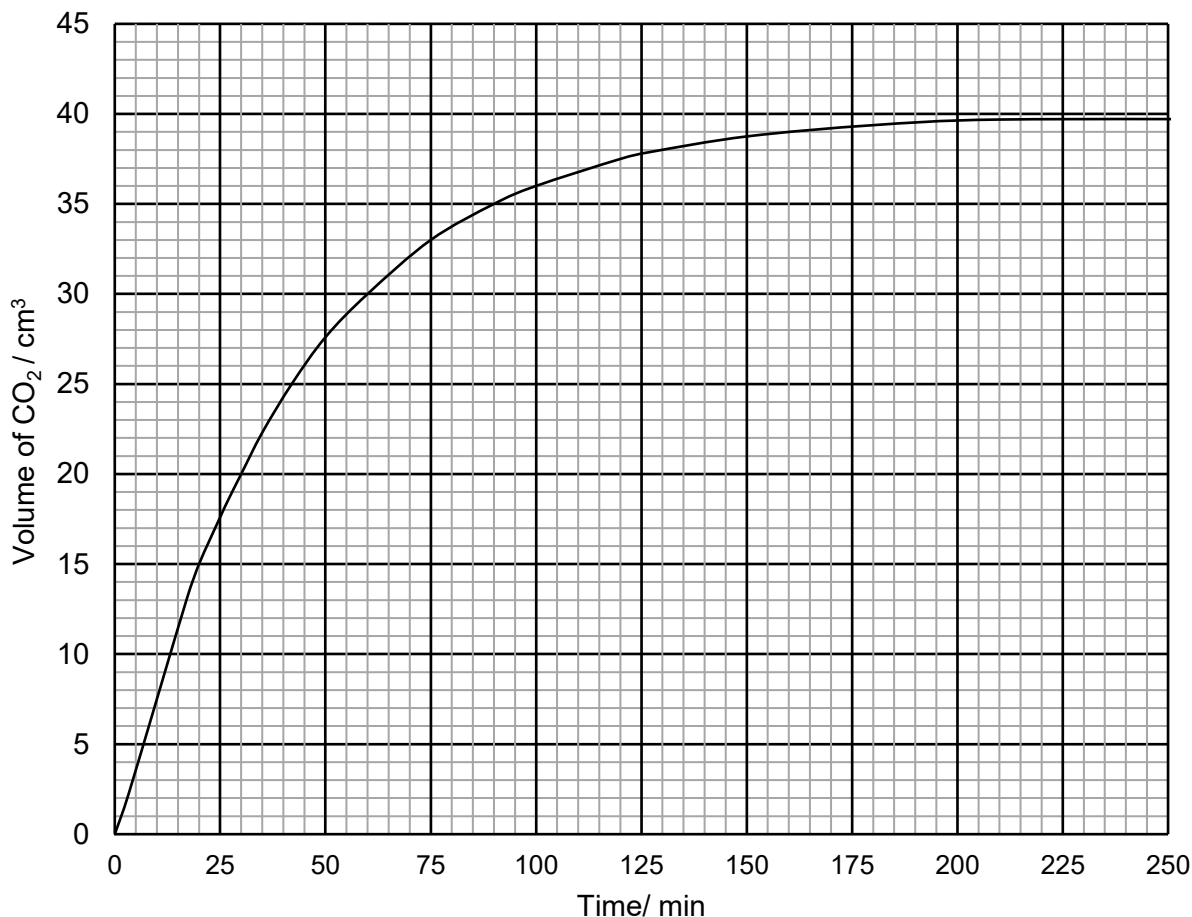




- (b) Chlorine dioxide,  $\text{ClO}_2$ , is also used in the treatment of wastewater to oxidise organic pollutants. A simplified overall reaction is:



To investigate the kinetics of this reaction,  $x$  mol of  $\text{ClO}_2$  was reacted with a large excess of  $\text{C}_x\text{H}_y\text{O}_z$  in  $400 \text{ cm}^3$  of solution. Fig 2.1 shows the volume of  $\text{CO}_2$ , measured at r.t.p., produced over time by this reaction.



**Fig. 2.1**

- (i) The maximum volume of  $\text{CO}_2$  evolved is  $40 \text{ cm}^3$ .  
Use Fig. 2.1 to show that the reaction is overall first order. [1]
- (ii) Calculate the initial rate of  $\text{CO}_2$  formation and hence determine the initial change in concentration of  $\text{ClO}_2$  per min. [3]
- (iii) Assume that the reaction is also first order with respect to  $\text{C}_x\text{H}_y\text{O}_z$ , state and explain the two changes you would expect to observe in the graph in Fig. 2.1, when the above experiment is repeated with twice the concentration of  $\text{C}_x\text{H}_y\text{O}_z$ . [2]



### Table 2.1

THMs	$M_r$	Boiling point / °C	Average concentration / $\times 10^{-6} \text{ g dm}^{-3}$
$\text{CHCl}_3$	119.5	61	54.9
$\text{CHBrCl}_2$	163.9	90	10.7
$\text{CHBr}_2\text{Cl}$	208.3	120	7.7
$\text{CHBr}_3$	252.7	149	3.0

- Using data in Table 2.1, explain your answer with reference to the type and relative strength of intermolecular interactions. [2]

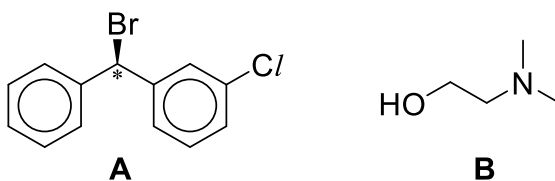
- (iii) Rising global temperatures, a consequence of the enhanced greenhouse effect, directly influence THMs formation.

Describe what is meant by the term *enhanced greenhouse effect*. [1]

[illegible]

[Total:20]

- 3 (a)** Drug **C** can be synthesised by a reaction between **A** and **B** as the first step. The halogenoalkane in **A** undergoes nucleophilic substitution via S<sub>N</sub>2 with the alcohol functional group in **B** to form an ether.



(\*) denotes a chiral centre

- (i) Explain why  $S_N2$  reactions do not occur at the C-Cl bond in **A**. [2]
- (ii) With reference to the structure, suggest why it is more likely for the alcohol rather than the amine functional group in **B** to undergo  $S_N2$  with the halogenoalkane. [2]
- (iii) For drug **C** to be effective, it must be able to bind to the relevant receptors in the body. Using the other enantiomer of **A** as starting reactant would make the drug ineffective.

Consider the nature of the receptors and the S<sub>N</sub>2 mechanism, explain why the drug becomes ineffective. [2]

- (iv) Draw the structural formula of the product from the reaction between **A** and **B**. Show the stereochemistry of the compound in your drawing. [1]

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[3]

[illegible]

- CC(C)C1CCCCC1C

Table 3.1 shows the observations when **F** and **G** are tested under specific conditions.

test	reagents and conditions	<b>F</b> , C <sub>9</sub> H <sub>16</sub> O	<b>G</b> , C <sub>10</sub> H <sub>18</sub> O <sub>4</sub>
1	Na <sub>2</sub> CO <sub>3</sub>	no effervescence	effervescence
2	Warm alkaline iodine(aq)	yellow ppt	yellow ppt

Suggest structures for  $\alpha$ -terpineol, D, E, F and G.

[10]



**4 (a)** Describe the variation in the acid-base behaviour of the Period 3 oxides by reference to the reactions of  $\text{Na}_2\text{O}$ ,  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  separately with phosphoric acid,  $\text{H}_3\text{PO}_4$ , and with sodium hydroxide.

[6]

[illegible]

- equation 4.1       $\text{CH}_3\text{COCH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{C}(\text{OH})_2\text{CH}_3(\text{aq})$

### Table 4.1

Temperature /K	$K_c$
298	1.58
318	1.06

- (i) State Le Chatelier's Principle. [1]
- (ii) Use data in Table 4.1, explain if the formation of gem-diols from propanone is endothermic or exothermic. [2]



- (iii) A sample of 29.5 g of trichloroethanal,  $\text{CCl}_3\text{CHO}$ , is dissolved in  $250\text{ cm}^3$  of water and left to reach equilibrium at 298K similar to the reaction shown in equation 4.1.

At equilibrium, it is found that only 0.01% of  $\text{CCl}_3\text{CHO}$  remains.

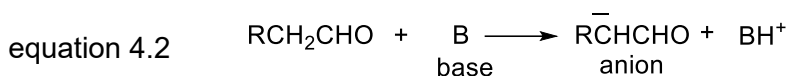
Determine the equilibrium amount of  $\text{CCl}_3\text{CHO}$  and  $\text{CCl}_3\text{C}(\text{OH})_2\text{H}$  and hence calculate the value of  $K_c$  for this hydration. [2]

- (iv) Suggest why  $\text{CCl}_3\text{CHO}$  has a higher  $K_c$  value than that of propanone. [1]

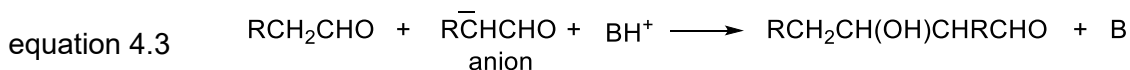
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- (c) Under certain conditions, carbonyl compounds can also react with each other as shown in equations 4.2 and 4.3.

The hydrogen bonded to a carbon that is adjacent to a carbonyl group can be removed by addition of a catalytic quantity of a strong base.



The anion formed then reacts with another molecule of the original carbonyl compound.



- (i) Equation 4.3 shows the overall equation for a two-step mechanism where the first step involves the anion attacking the carbonyl molecule.

Suggest a two-step mechanism. Show all charges, relevant lone pairs and the movement of electron pairs by using curly arrows. [2]

- (ii) Suggest the structure of the final product formed in the reaction of propanone with a strong base. [1]

As shown in Fig. 4.1, carbonyl compound **P** forms **Q** by the same mechanism. **S** can be formed from **Q** via a two-step synthesis.

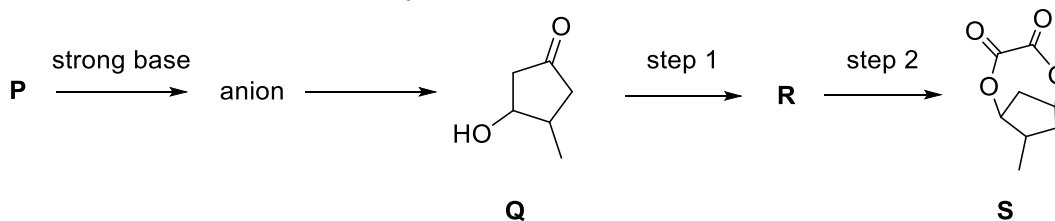


Fig. 4.1

- (iii) State one reagent that can be used to distinguish **Q** from **S**. [1]
- (iv) Suggest the structures of **P** and **R**. [2]
- (v) Suggest reagents and conditions for each of the steps 1 and 2 in Fig. 4.1. [2]

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- 5 (a) Describe and explain the trend in thermal stability of the hydrogen halides  $\text{HCl}$ ,  $\text{HBr}$  and  $\text{HI}$ . Include an equation for the thermal decomposition reaction in your answer. [3]

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- (b) The chlorides sodium and phosphorus behave differently when added to water.

State what you would observe when  $\text{NaCl}$  and  $\text{PCl}_5$  are each added separately to water and suggest the pH of the solution formed in each case. [2]

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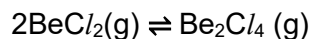
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- (c)** In the gas phase, the chloride of beryllium exists as a mixture of  $\text{BeCl}_2$  and  $\text{Be}_2\text{Cl}_4$  molecules.

equation 5.1



You may assume both  $\text{BeCl}_2$  and  $\text{Be}_2\text{Cl}_4$  behave like ideal gases here.

- (i) State three basic assumptions of the kinetic theory as applied to an ideal gas. [2]
- (ii) Sketch and label a graph showing how the pressure for a given mass of an ideal gas varies with temperature in two different vessels of volumes,  $V_1$  and  $V_2$ , where  $V_1 > V_2$ .

Explain your answer.

- (iii) Draw the structure of  $\text{Be}_2\text{Cl}_4$ . Label the co-ordinate bonds on your structure. [1]
- (iv) A sample of 0.800 mol of  $\text{BeCl}_2$  is allowed to reach equilibrium in a sealed vessel. At equilibrium, it is found that 20% of the original sample of  $\text{BeCl}_2$  has reacted. The total pressure in the vessel is  $1.50 \times 10^4$  Pa.

Determine the equilibrium amount of  $\text{BeCl}_2$  and  $\text{Be}_2\text{Cl}_4$  and hence calculate the value of  $K_p$  for the reaction in equation 5.1. State the units. [3]

[illegible]

- (d) Iodomethane,  $\text{CH}_3\text{I}$ , is used as a reagent in the first step of the Hofmann elimination reaction, which converts amines to alkenes. It reacts with an amine to form a quaternary ammonium salt. Upon heating this salt with moist silver(I) oxide,  $\text{Ag}_2\text{O}$ , an elimination reaction occurs, breaking a  $\text{C} - \text{N}$  bond and producing an alkene.

In Hofmann elimination, the less substituted alkene is typically the major product. This is illustrated as the two-stage process of converting 2-aminobutane to but-1-ene in Fig. 5.1.

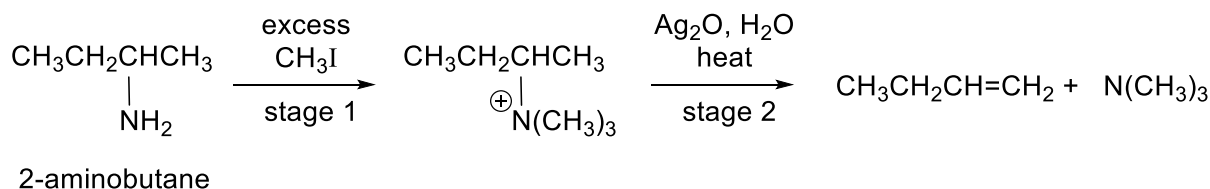
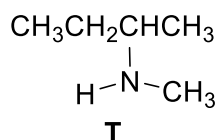


Fig 5.1

- (i) Compound **T** is an intermediate in stage 1 of Fig. 5.1. It is formed via an  $\text{S}_{\text{N}}2$  attack of 2-aminobutane on iodomethane, followed by the removal of a proton on the nitrogen atom by iodide ion.



Suggest the two-step mechanism for the formation of **T**. Show all charges, relevant lone pairs and the movement of electron pairs by using curly arrows.

You may represent 2-aminobutane as  $\text{RNH}_2$ .

[2]

Compound **Z** can be synthesized in 3 steps as shown in Fig. 5.2. Step 2 involves a Hofmann elimination.

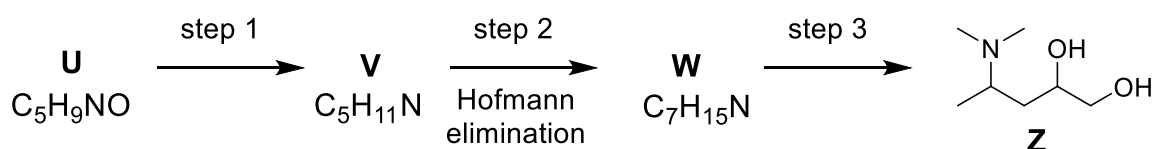


Fig. 5.2

- (ii) Suggest structures of organic compounds **U**, **V** and **W**. [3]
- (iii) Suggest the reagents and conditions required for step 1 and 3. [2]

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