Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS/A LEVEL

S25-2410U20-1

2410U20-1

TUESDAY, 20 MAY 2025 – MORNING

CHEMISTRY – AS unit 2
Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 6.**	**10**	
Section B	**7.**	**10**	
	8.	**17**	
	9.	**18**	
	10.	**11**	
	11.	**14**	
	Total	**80**	

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ADDITIONAL MATERIALS

- A calculator, pencil and ruler
- **Data Booklet** supplied by WJEC

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.
Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

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

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q11**(b).

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SECTION A

Answer **all** questions.

1. Draw the **skeletal** formula of pentane-2,4-diol. [1]

2. Give the **name** of the straight chain alkane that has the same molecular formula as 2,2,4-trimethylpentane. [1]

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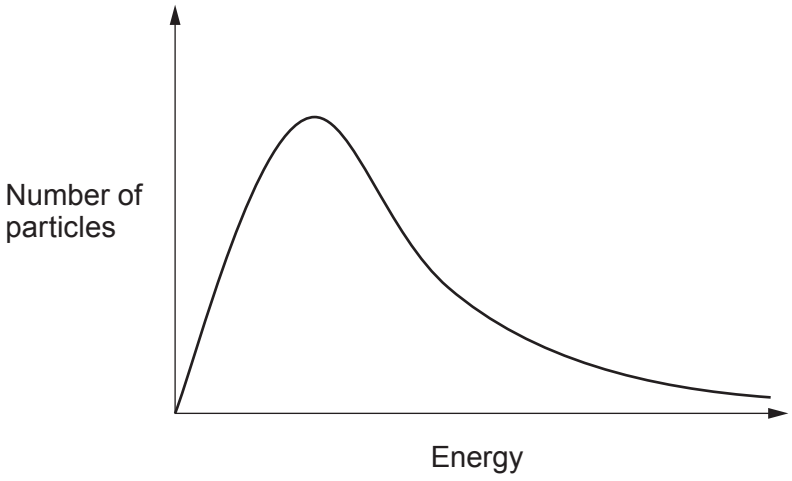
3. (a) The diagram below shows the Boltzmann energy distribution curve for a reaction at 298 K.



On the diagram, draw the curve for the same reaction at 288 K. [1]

(b) State how a catalyst increases the rate of a reaction. [1]

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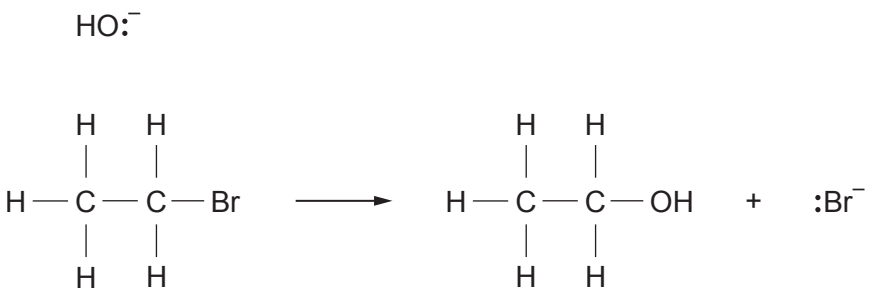
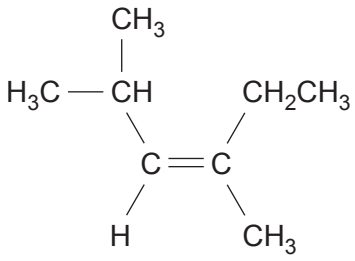
4. Complete the diagram below to show the mechanism for the nucleophilic substitution of bromoethane to form ethanol. You should include any relevant dipoles in the reactants. [2]



5. Name the compound shown by the structure drawn below. [2]



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6. Use the information in the following equations.

$$V + W \longrightarrow X + Y \qquad \Delta H^{\theta} = -275\,kJ\,mol^{-1}$$

$$X + Y \longrightarrow Z \qquad \Delta H^{\theta} = 160\,kJ\,mol^{-1}$$

Give ΔH^{θ} for the reactions shown below.

(a) $X + Y \longrightarrow V + W$ [1]

ΔH^{θ} = ... kJ mol^{-1}

(b) $V + W \longrightarrow Z$ [1]

ΔH^{θ} = ... kJ mol^{-1}

10

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SECTION B

Answer **all** questions.

7. A reaction used to produce chloromethane is initiated by shining ultraviolet light into a mixture of methane gas and chlorine gas.

(a) (i) Name the mechanism for this reaction. [1]

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(ii) Give the reaction mechanism for the production of chloromethane from methane and chlorine. Show the initiation and propagation stages. [3]

Initiation

Propagation

(b) (i) Explain why the mixture produced in this reaction could contain ethane. [1]

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(ii) Explain why the mixture produced in this reaction could contain dichloromethane. [2]

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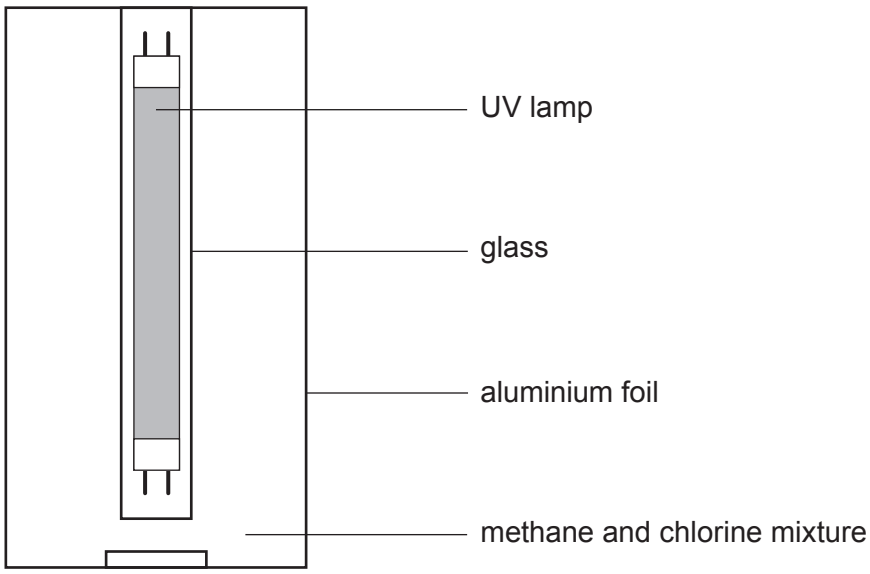
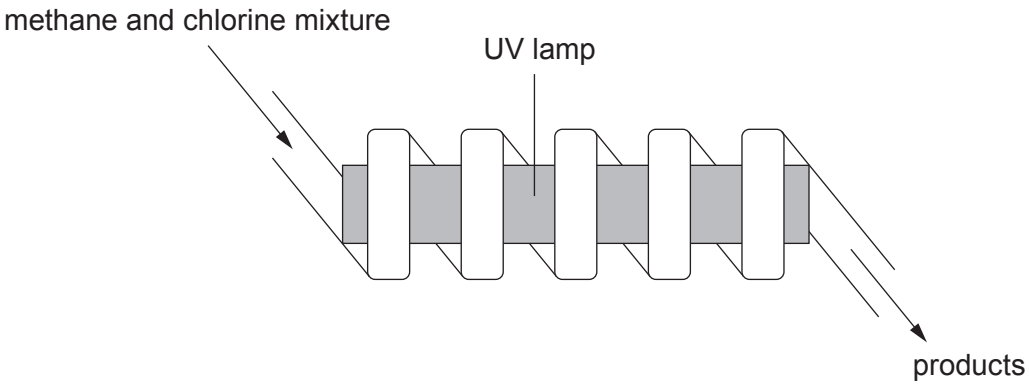
(c) The original reaction to produce chloromethane was carried out in an aluminium-lined container. The gas mixture was exposed to ultraviolet light for a prolonged period of time. This method produced large quantities of side-products.



A possible improvement to this method, designed to minimise the formation of side-products, involves passing the mixture of methane and chlorine through a narrow transparent tube wrapped around an ultraviolet light source.



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(i) Suggest why this improvement could lead to fewer side-products in the mixture. [1]

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(ii) This method was tested using different flow rates of the methane and chlorine mixture to find the best yield of chloromethane. The composition of the product mixture was found and recorded below.

Flow rate / $cm^3 s^{-1}$	Percentage of product mixture				
	CH_4	Cl_2	CH_3Cl	CH_2Cl_2	C_2H_6
1	2	1	12	48	37
2	6	3	43	28	20
3	10	5	72	8	5
4	34	17	42	5	2
5	58	29	10	2	1

Use this data to determine the optimum flow rate for the production of chloromethane.

Explain the results recorded at this flow rate. [2]

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Turn over.

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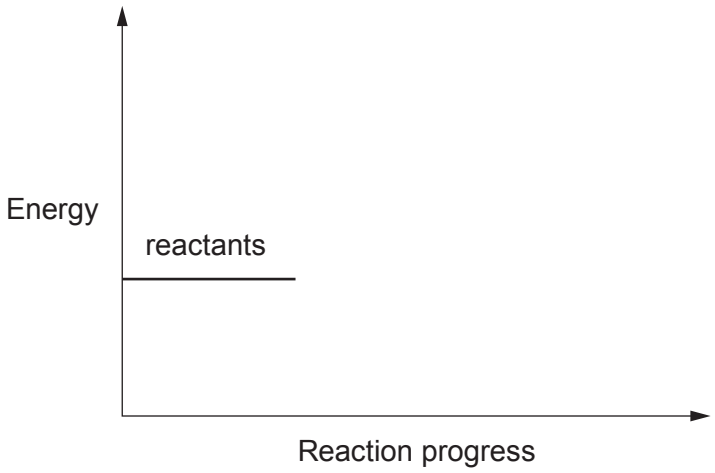
8. The reaction between hydrated barium hydroxide and ammonium chloride is a rare example of an endothermic solid-state reaction.

(a) Complete the reaction profile below to show the enthalpy change involved in an endothermic reaction. Label the enthalpy change clearly on the diagram. [1]



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(b) The enthalpy change for this reaction can be calculated using standard enthalpy changes of formation.

(i) Give the meaning of the term standard enthalpy change of formation. [2]

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(ii) The standard enthalpy changes of formation, $\Delta_f H^\theta$, of the substances involved in this reaction are given below.

Substance	$\Delta_f H^\theta$ / kJ mol^{-1}
H_2O	–286
NH_3	–45.9
$BaCl_2.2H_2O$	–1460
$Ba(OH)_2.8H_2O$	–3350
NH_4Cl	–314

Using a Hess cycle or otherwise, calculate the standard enthalpy change for this reaction. [3]

$$Ba(OH)_2.8H_2O + 2NH_4Cl \longrightarrow BaCl_2.2H_2O + 8H_2O + 2NH_3$$

Enthalpy change = ... kJ mol^{-1}

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(c) (i) A student performed an experiment to determine the enthalpy change for this reaction.

He weighed 31.5 g of hydrated barium hydroxide into a glass beaker and recorded its temperature. He started his stopwatch and recorded the temperature again after 30 seconds.

After 1 minute, he added excess ammonium chloride and thoroughly mixed the solids using a stirring rod. He then measured the temperature every 30 seconds for a further 4 minutes.

His results are shown below.

Time / s	Temperature / °C
0	21
30	21
60	—
90	17
120	5
150	–8
180	–20
210	–19
240	–18
270	–17
300	–16

Plot the results on the grid opposite. Calculate the maximum temperature change and record it below your graph. [4]

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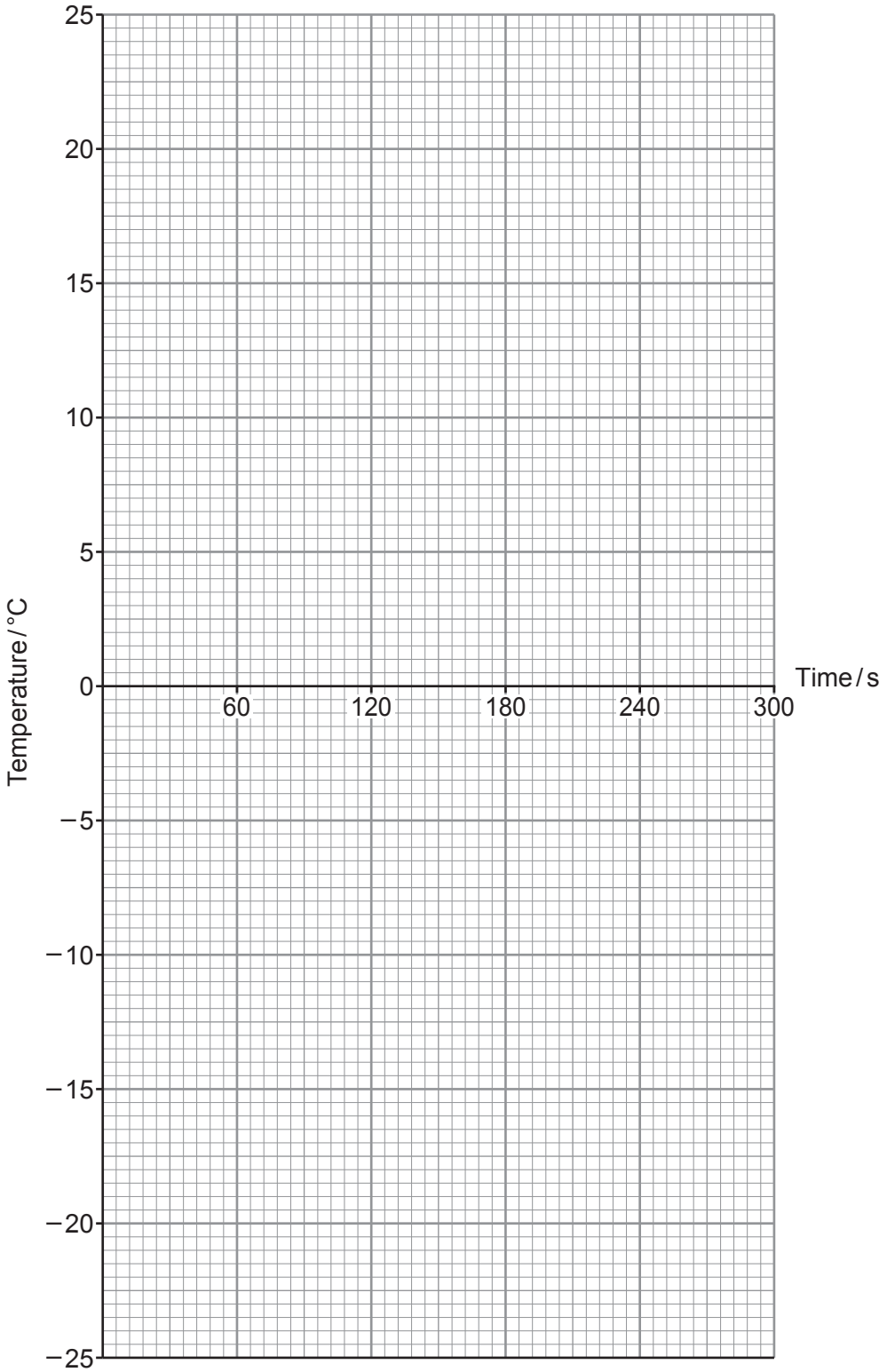

Maximum temperature change = ... °C

Turn over.

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(ii) Use the balanced equation to calculate the mass of water released during this reaction. Give your answer to an **appropriate** number of significant figures. [3]

$$Ba(OH)_2.8H_2O + 2NH_4Cl \longrightarrow BaCl_2.2H_2O + 8H_2O + 2NH_3$$

M_r 315

Mass of water = ... g

(iii) Use the mass of water from part (ii) and the maximum temperature change from part (i) to calculate the enthalpy change of reaction per mole of hydrated barium hydroxide. Give your answer in **kJ mol^{-1}**.

Assume that the specific heat capacity of the reaction mixture is 1.13 J g^{-1} K^{-1}. [2]

Enthalpy change = ... kJ mol^{-1}

Examiner only

(d) (i) Explain why the experimental value calculated in part (c)(iii) is much lower than the theoretical value calculated in part (b)(ii). [1]

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(ii) Suggest a possible change to the method that would improve the accuracy of the experimentally determined value. [1]

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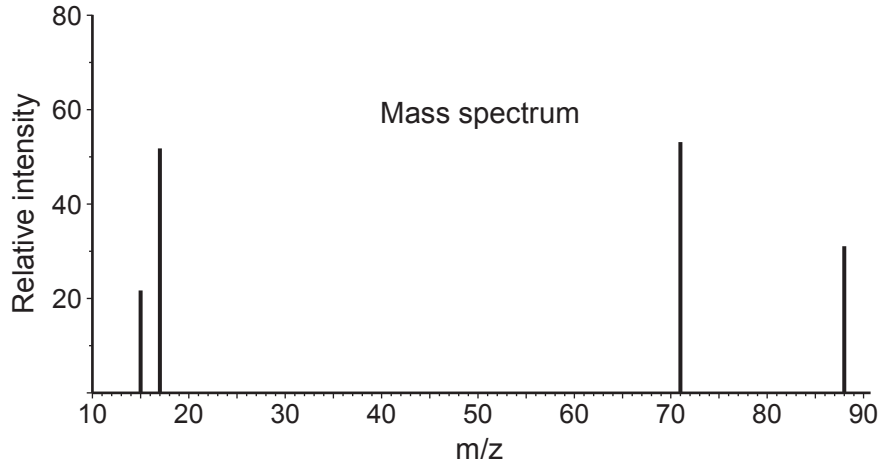
17

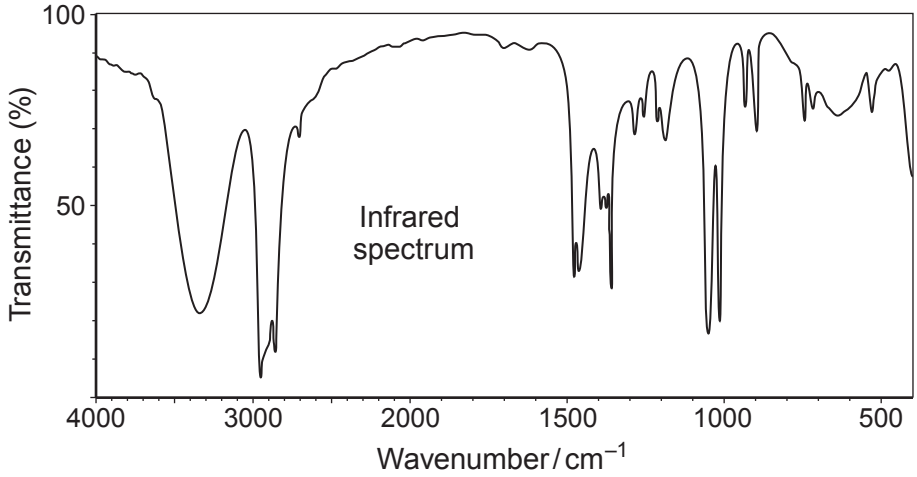
Turn over.

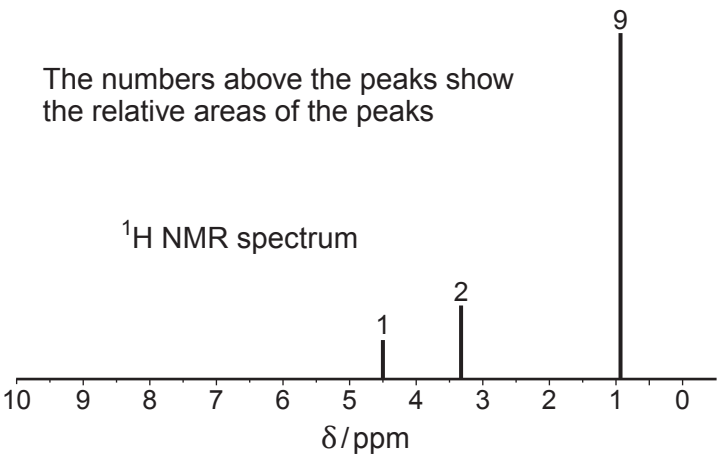
9. (a) Compound **A** contains carbon, hydrogen and oxygen only.

Elemental analysis of compound **A** indicates that it is composed of 68.09 % carbon and 18.16 % oxygen by mass.

Simplified forms of the mass spectrum, infrared spectrum, ^{1}H NMR spectrum and ^{13}C NMR spectrum are shown below.







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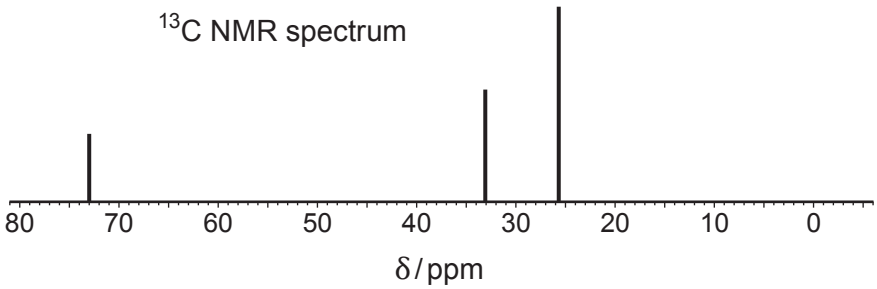

Determine the identity of compound **A**. Explain your answer using information from **all** of the data sources provided. [10]

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(b) Propan-1-ol can be oxidised to propanoic acid in the presence of sulfuric acid.

(i) Give a solution which acts as an oxidising agent for this reaction in acidic conditions. [1]

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(ii) Give the balanced equation for this reaction. [1]

..... + ... [O] ⟶ ..... + H_2O

(iii) The oxidation of propan-1-ol requires the presence of a strong acid. Hydrochloric acid cannot be used in this reaction as the chloride ions would be oxidised.

Give the half equation for the oxidation of chloride ions. [2]

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(iv) Propanoic acid and ethanol react on heating in acidic conditions to form a sweet-smelling compound.

I. Give the products of this reaction. Clearly show the structure of the sweet-smelling compound. [2]

II. Name the sweet-smelling compound. [1]

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III. State the purpose of adding an acid to the reaction mixture. [1]

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10. 1-Bromobutane can be converted into 2-bromobutane using a two-step synthesis.

(a) The first step in this synthesis is an elimination reaction between 1-bromobutane and sodium hydroxide to form but-1-ene.

(i) Give the conditions needed for this elimination reaction. [2]

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(ii) State the molecule **eliminated** from 1-bromobutane. [1]

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(iii) The but-1-ene formed during this reaction is then used to form 2-bromobutane by reaction with hydrogen bromide, HBr.

Draw the mechanism for this reaction. [3]

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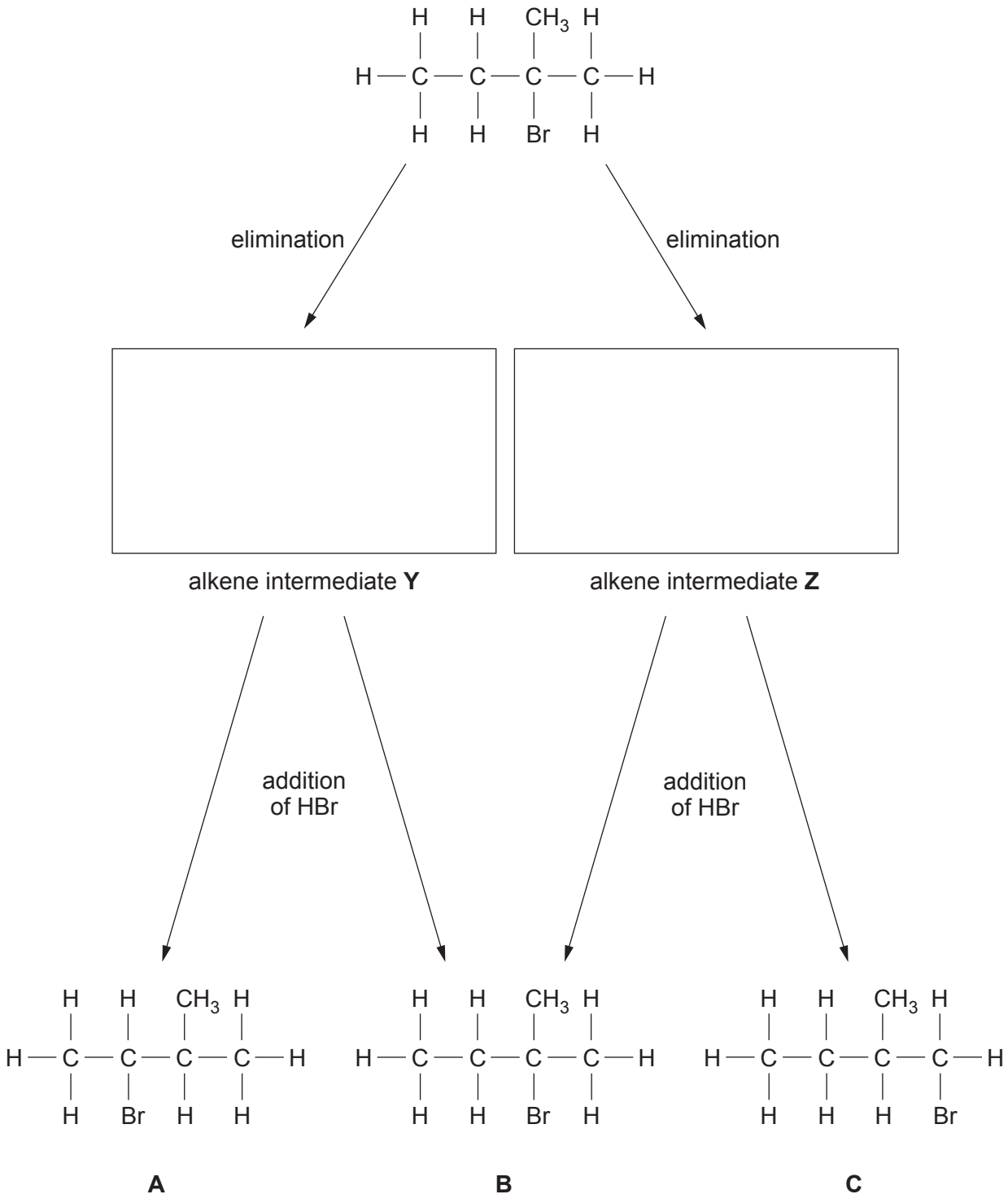
(b) A similar two-step synthesis was carried out starting from 2-bromo-2-methylbutane. The diagram below shows some of the details.



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(i) **Complete the diagram** by drawing the structures of the **two** possible alkene intermediates, **Y** and **Z**. [2]

(ii) Suggest which of the **three** possible products, **A**, **B** or **C**, would have the greatest yield.

Explain your reasoning in terms of the stability of any carbocation intermediates formed. [3]

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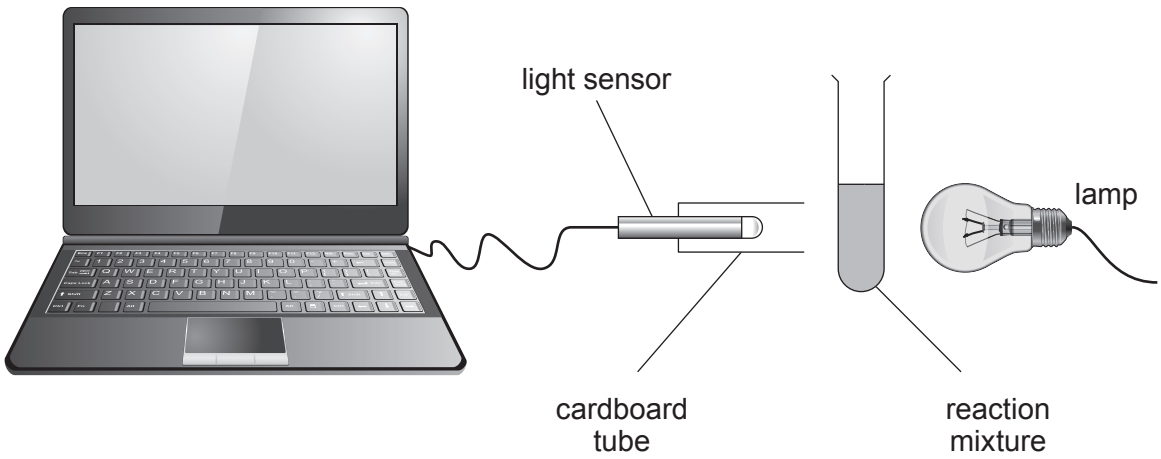
11

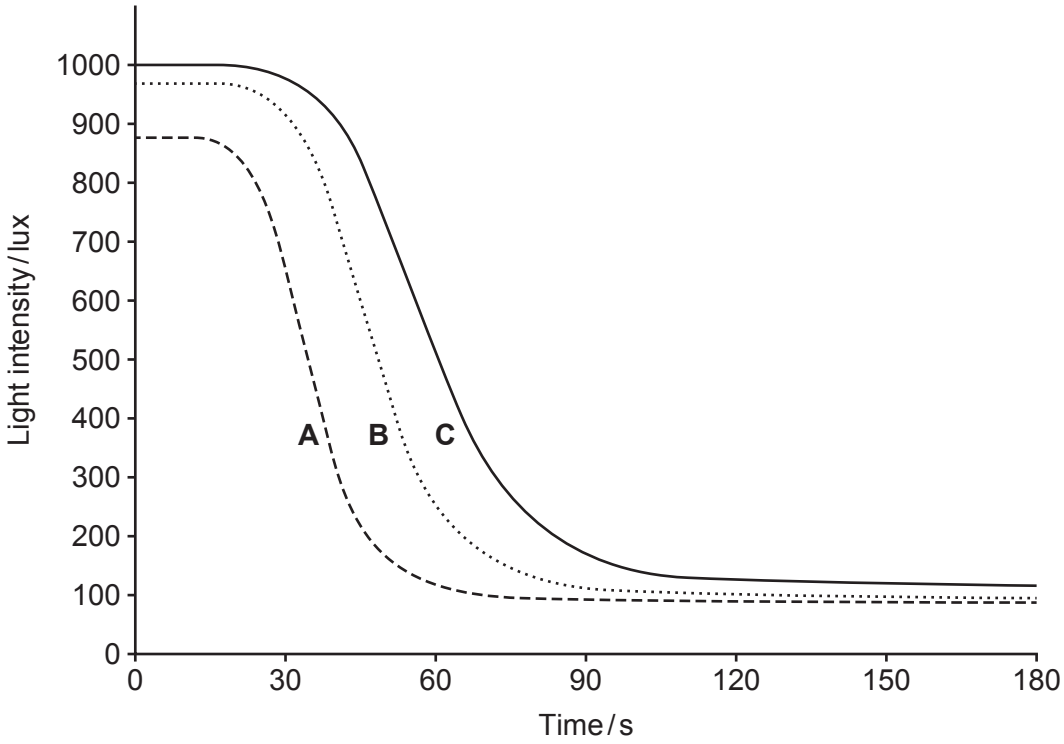
11. (a) A student was investigating the rate of hydrolysis of three different halogenoalkanes:

1-chlorobutane, 1-bromobutane and 1-iodobutane

She added 2 cm^3 of the halogenoalkane to a mixture of 6 cm^3 of sodium hydroxide dissolved in ethanol and aqueous silver nitrate solution. She then used a light sensor to measure the amount of light transmitted through the reaction mixture over time.



Her results are shown in the graphs below.



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(i) Explain why this method can be used to monitor the rate of these hydrolysis reactions. [2]

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(ii) Identify which of graphs **A-C** shows the rate of hydrolysis for 1-iodobutane.

Explain your reasoning. [3]

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(iii) Calculate the mean rate of the reaction shown by graph **B**.

Give the appropriate unit. [2]

Rate = ...

Unit .....

(iv) Using the graphs, suggest why the results of this experiment could be considered to be **not** valid. [1]

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(b) Another student investigated the effect of concentration on rate using an iodine clock reaction. This method uses a solution containing persulfate ions to oxidise iodide ions to generate iodine in a slow reaction.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-}$$

Iodine is then reduced back to iodide by thiosulfate ions in a fast reaction.

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

When the thiosulfate has been consumed, excess iodine is formed which can then be identified using an appropriate indicator.

Describe how the student could determine the effect of changing the concentration of persulfate ions on the rate of the reaction.

You should

- give a brief method (specific quantities are **not** required)
- state how persulfate solutions of different concentrations are prepared from a stock solution
- state how the data collected is used to determine the rate of the reaction

[6 QER]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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