AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level CHEMISTRY

Paper 2 Organic and Physical Chemistry

Monday 16 June 2025 Morning Time allowed: 2 hours

Materials

For this paper you must have:
- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

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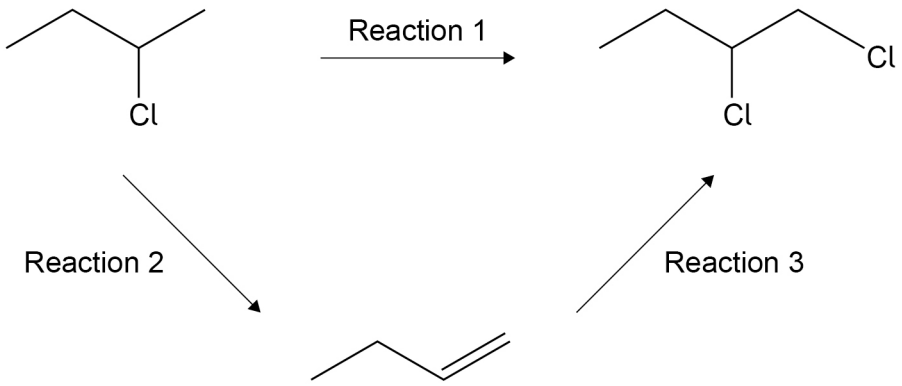
Answer **all** questions in the spaces provided.

0 1 This question is about different ways to make 1,2-dichlorobutane.



0 1 . 1 Give the name of the mechanism for reaction 1.

State **one** essential condition needed for reaction 1.

[2 marks]

Name of mechanism _____

Essential condition _____

0 1 . 2 Give equations to show **three** essential steps in the mechanism for reaction 1.

[3 marks]

Do not write outside the box

0 1 . 3 Suggest **two** reasons why using reaction 1 is likely to give a low yield of 1,2-dichlorobutane.

[2 marks]

Reason 1 _____

_____

Reason 2 _____

_____

0 1 . 4 Give a suitable reagent and conditions needed for reaction 2.

[2 marks]

Reagent _____

Conditions _____

0 1 . 5 Identify the reagent and name the mechanism for reaction 3.

[2 marks]

Reagent _____

Name of mechanism _____

0 1 . 6 Use of the reagent for reaction 2 followed by the reagent for reaction 3 gives another organic product.

Give the structure of the other organic product.

[1 mark]

12

Turn over ►

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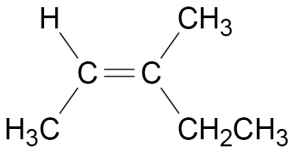
0 2 This question is about isomerism.

Compound **L** has this structure.



0 2 . 1 Use IUPAC rules to name **L**.

Explain why **L** exists as stereoisomers.

[3 marks]

Name _____

Explanation _____

_____

_____

0 2 . 2 Compound **M** has the same carbon chain as **L** but the double bond is in a different position.

M also exists as stereoisomers.

Draw the structural formula of **M**.

Explain why **M** exists as stereoisomers.

[2 marks]

Structural formula

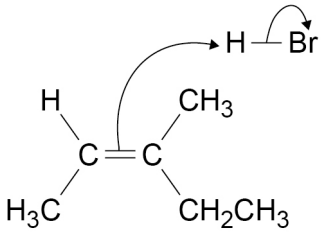
Explanation _____

_____

Do not write outside the box

0 2 . 3 **Figure 1** shows part of the mechanism when **L** reacts with hydrogen bromide.

Figure 1



Complete **Figure 1** to show the next step in the mechanism that gives the major product.

[2 marks]

7

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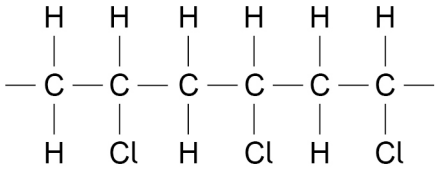
0 3 This question is about polymers.

0 3 . 1 A section of the polymer PVC is shown.



Name the monomer used to make PVC.

Draw the structure of the monomer used to make PVC.

[2 marks]

Monomer name _____

Structure

0 3 . 2 State why PVC is **not** biodegradable.

[1 mark]

_____

_____

0 3 . 3 Diisobutyl phthalate (DIBP) is a plasticiser added to PVC to modify its properties.

State how the properties of PVC are modified by the addition of DIBP.

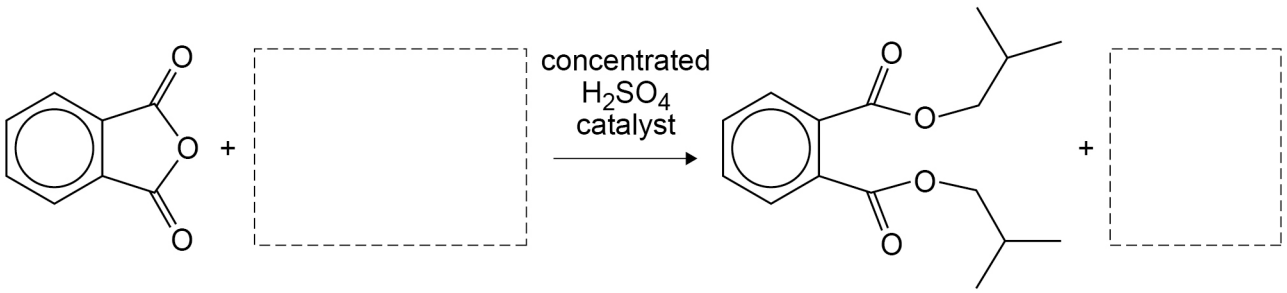
[1 mark]

_____

_____

Do not write outside the box

0 3 . 4 An incomplete equation for the reaction used to make DIBP is shown.



DIBP

Complete the equation.

Give the name of the mechanism for this reaction.

Deduce the empirical formula of DIBP.

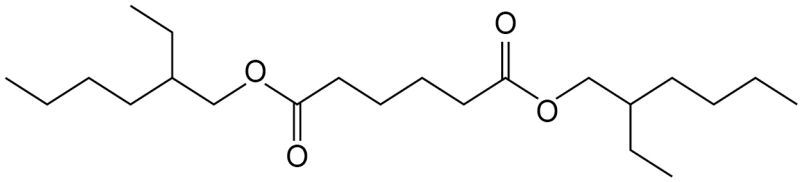
[4 marks]

Name of mechanism _____

Empirical formula of DIBP _____

0 3 . 5 A different plasticiser, DEHA, is added to PVC used for food packaging.

The structure of DEHA is



Identify the organic compound that would react with hexanedioic acid to form DEHA.

[1 mark]

_____

_____

Question 3 continues on the next page

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0 3 . 6 DEHA can be absorbed into food from PVC packaging.

In an investigation, 1 kg samples of three different foods are stored in PVC packaging for 30 days.

Table 1 shows the water content, fat content and mass of DEHA in each type of food after 30 days.

Table 1

Food	Water content (%)	Fat content (%)	Mass of DEHA in food after 30 days / mg
Milk	87	3	2.83
Cheese	45	26	10.88
Butter	16	80	24.56

Use your knowledge of intermolecular forces to explain these results.

[3 marks]

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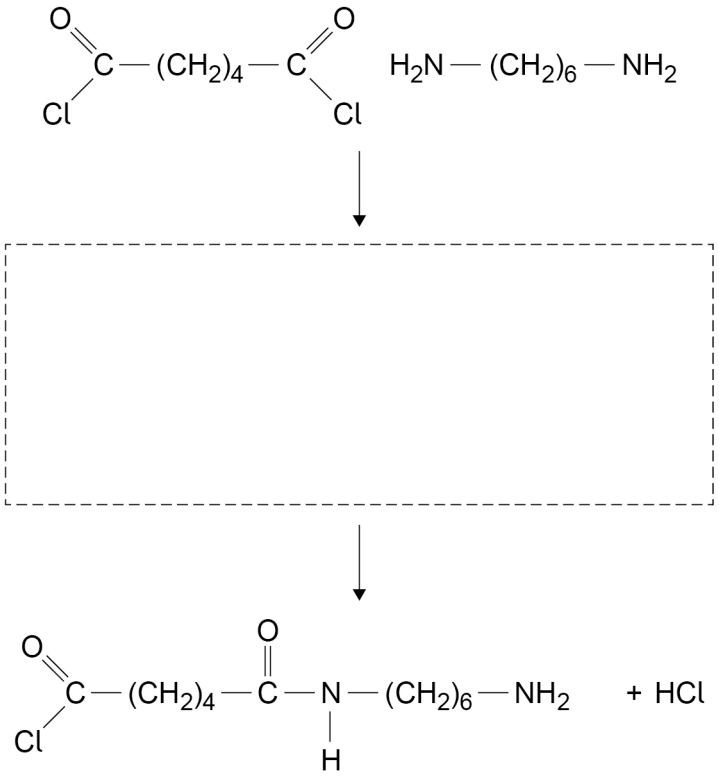
0 3 . 7 The polymer nylon 6,6 can be made from hexanedioyl dichloride and hexane-1,6-diamine.

Figure 2 shows an incomplete mechanism for the first steps in this reaction.

Figure 2



Draw the missing intermediate in the box in **Figure 2**.

Complete **Figure 2** by adding the curly arrows and any relevant lone pairs of electrons involved in these steps in the mechanism.

[4 marks]

Question 3 continues on the next page

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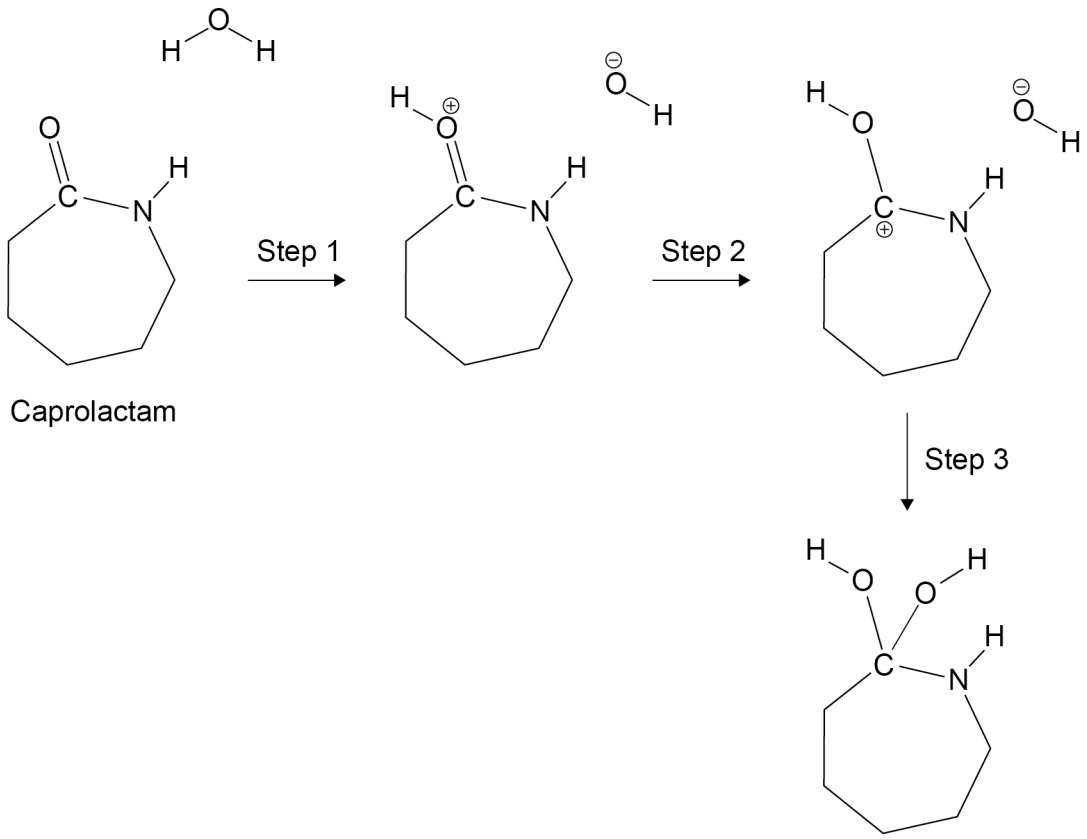
0 3 . 8 The polymer nylon 6 can be made by heating caprolactam with water.

Figure 3 shows the species involved in the first three steps of the mechanism for this reaction.

Figure 3



Complete **Figure 3** by adding the curly arrows and any relevant lone pairs of electrons involved in these steps in the mechanism.

[4 marks]

20

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 4 Hexanedioic acid is an important compound used in organic synthesis.

Hexanedioic acid can be prepared from cyclohexanol.

The equation for the reaction is

$$C_6H_{11}OH(l) + 2\,HNO_3(aq) \longrightarrow HOOC(CH_2)_4COOH(s) + N_2O(g) + 2\,H_2O(l)$$

Method

Step 1 Add 5 cm^3 of concentrated nitric acid to a boiling tube.

Step 2 Place the boiling tube in a beaker of water at 85 °C

Step 3 Add 2 cm^3 of cyclohexanol dropwise to the boiling tube.

Step 4 Leave the reaction mixture for 10 minutes.

Step 5 Cool the boiling tube in a beaker of cold water for a further 10 minutes.

Step 6 Filter the contents of the boiling tube and collect the impure solid.

Step 7 Recrystallise the impure solid using methanol.

Step 8 Wash the purified crystalline product with some ice-cold distilled water, and dry.

Step 9 Measure the melting point of the hexanedioic acid.

0 4 . 1 Suggest why the apparatus should be set up in a fume cupboard.

[1 mark]

0 4 . 2 Deduce the role of the concentrated nitric acid in the reaction.

[1 mark]

Do not write outside the box

0 4 . 3 Outline how **Steps 7** and **8** should be done to obtain the purified crystalline product.

[5 marks]

0 4 . 4 In **Step 8**, the distilled water must be ice-cold.

Suggest why using water at room temperature lowers the recorded yield of product.

[1 mark]

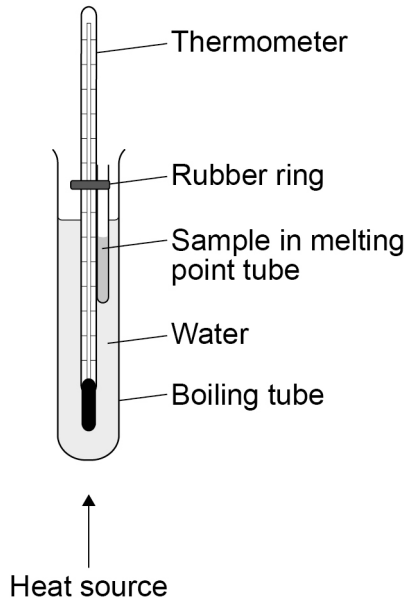
Question 4 continues on the next page

Do not write outside the box

0 4 . 5 **Figure 4** shows how a student set up the apparatus for measuring the melting point of hexanedioc acid in **Step 9** (data book value 152 °C).

The apparatus is supported by clamps but these are not shown.

Figure 4



Identify **two** mistakes the student made in setting up this apparatus.

State the problem caused by each mistake.

[4 marks]

Mistake 1 _____

_____

Problem caused _____

_____

Mistake 2 _____

_____

Problem caused _____

_____

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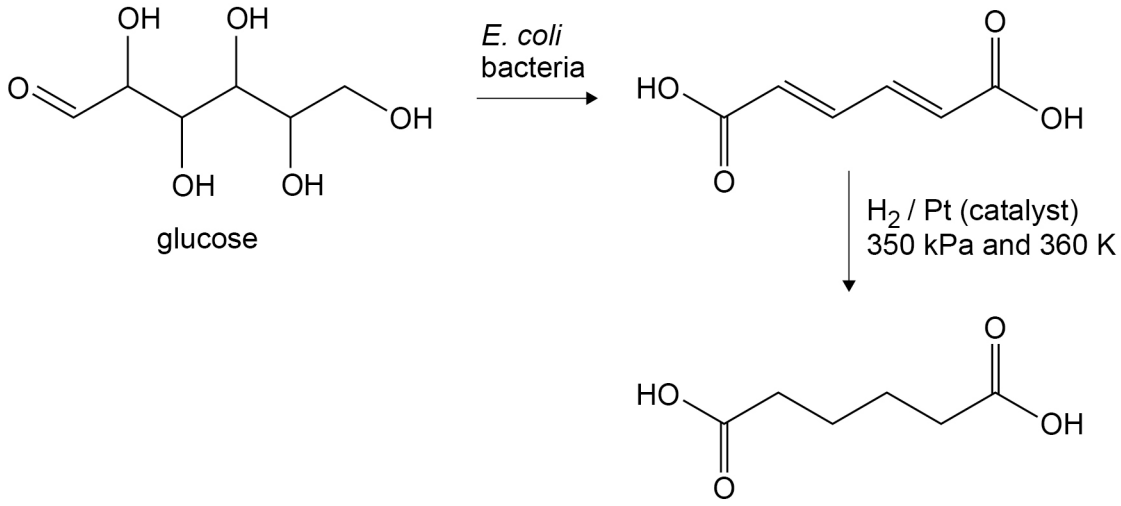
Figure 5 shows an alternative process to make hexanedioic acid.

Figure 5



0 4 . 6 Scientists disagree about whether this alternative process is more sustainable or less sustainable than the process starting from cyclohexanol.

Use the information given in **Figure 5** to provide a justification for each point of view.

[2 marks]

Justification for alternative process being more sustainable _____

_____

_____

Justification for alternative process being less sustainable _____

_____

_____

14

Turn over ►

Do not write outside the box

0 5 This question is about making the explosive 2-methyl-1,3,5-trinitrobenzene, commonly known as TNT.

TNT can be made by reacting methylbenzene with concentrated nitric acid in the presence of concentrated sulfuric acid.

0 5 . 1 Give the overall equation for the reaction between methylbenzene and nitric acid.

[2 marks]

0 5 . 2 The yield of TNT in this reaction is 42.5%.

Calculate the mass, in g, of TNT (M_r = 227.0) obtained from 1050 cm^3 of methylbenzene.

Methylbenzene has density = 0.867 g cm^{-3} and M_r = 92.0

[4 marks]

Mass of TNT _____ g

Do not write outside the box

0 5 . 3 In the mechanism for this reaction, concentrated nitric acid reacts with concentrated sulfuric acid to produce the nitronium ion O_2N^+

Give an equation for the reaction to produce the nitronium ion.

State the role of the nitronium ion in the reaction with methylbenzene.

Outline the mechanism for the reaction of the nitronium ion with methylbenzene to give 2-methyl-1-nitrobenzene.

[5 marks]

Equation

Role of nitronium ion

Mechanism

11

Turn over for the next question

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0 6 GHK is a natural tripeptide found in human blood plasma.

The amino acid sequence of GHK is Lys-His-Gly

Each amino acid is represented by a three-letter abbreviation.

Lys = lysine His = histidine Gly = glycine

Glycine has the structure H_2NCH_2COOH

0 6 . 1 D_2O is used as the solvent when obtaining a ^1H NMR spectrum for lysine.

Give **one** reason why D_2O is used rather than CCl_4 and **one** reason why D_2O is used rather than water.

[2 marks]

D_2O rather than CCl_4 _____

_____

D_2O rather than water _____

_____

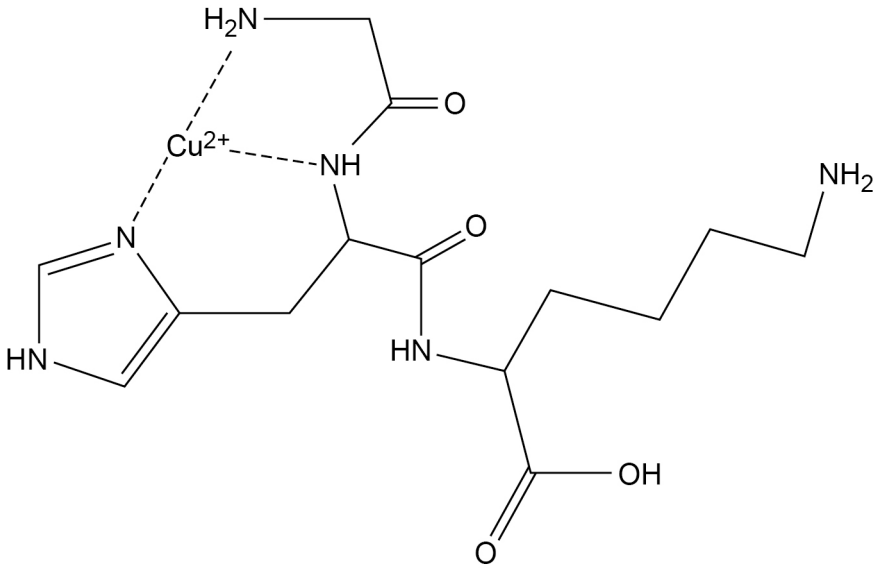
Do not write outside the box

GHK is commonly used in cosmetics as part of anti-ageing treatments.

GHK binds to copper(II) ions in the body to form GHK–Cu

Figure 6 shows the structure of GHK–Cu

Figure 6



0 6 . 2 Use **Figure 6** to determine the structure of the amino acid histidine, His

[1 mark]

Question 6 continues on the next page

Turn over ►

Do not write outside the box

Lysine molecules can polymerise to give poly(lysine).

0 6 . 3 Increasing the temperature of an alkaline solution of poly(lysine) changes the type of secondary structure in poly(lysine), as shown.

Name the type of secondary structure before and after heating.

[2 marks]

Type of secondary structure before heating _____

Type of secondary structure after heating _____

5

Do not write outside the box

0 7 This question is about spectroscopy.

0 7 . 1 Compound **P** is a hydrocarbon with only one peak (a singlet) in its ^{1}H NMR spectrum.

P has a precise M_r of 84.09396

Carbon has a precise A_r of 12.00000

Hydrogen has a precise A_r of 1.00783

Use this information to deduce the molecular formula of **P**. Show your working.

Suggest **two** possible structures for **P**.

Explain how **P** can be identified using its infrared spectrum above 1500 cm^{-1}

Use **Table A** in the Data Booklet to help you to answer this question.

[5 marks]

Molecular formula _____

Structure 1

Structure 2

Explanation _____

_____

_____

_____

Question 7 continues on the next page

Turn over ►

Do not write outside the box

0 7 . 2 Compound **Q** has the molecular formula $C_5H_8O_2$

Figure 7 shows the ^{13}C NMR spectrum of compound **Q**.

Figure 8 shows the ^{1}H NMR spectrum of compound **Q**.

Figure 7

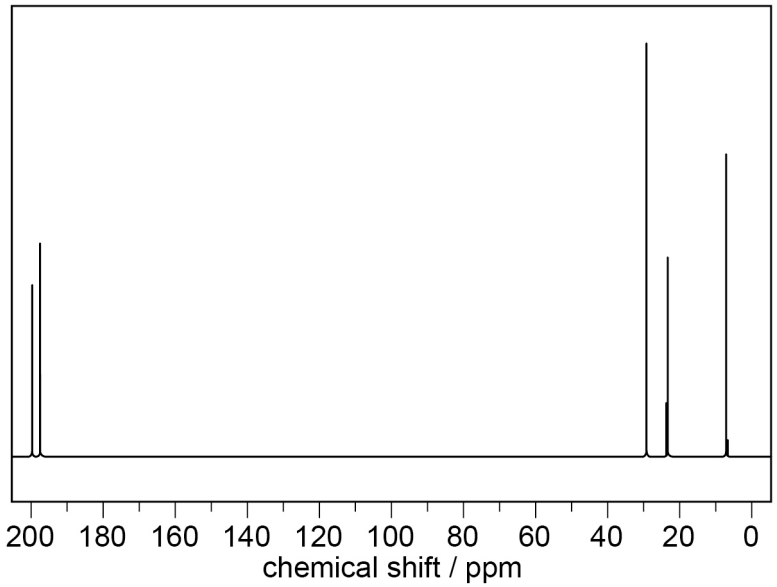
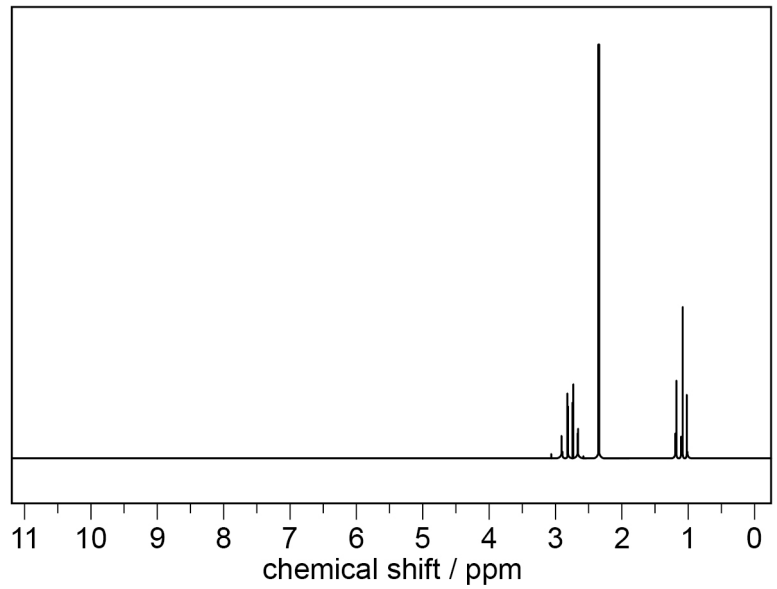


Figure 8



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Explain what you can deduce about the structure of compound **Q**.

In your answer you should refer to

- the peaks in the ^{13}C NMR spectrum
- the chemical shift values for the peaks in the ^{1}H NMR spectrum
- the splitting pattern for the peaks in the ^{1}H NMR spectrum.

Give the structure of compound **Q**.

[7 marks]

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12

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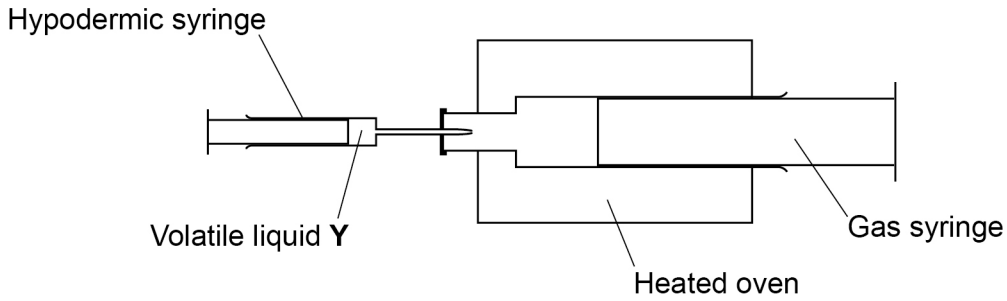
0 8 This question is about gas volumes.

Figure 9 shows some of the apparatus needed to determine an experimental value for the M_r of an unknown volatile liquid **Y**.

Figure 9



A student uses this method to determine an experimental value for the M_r of **Y**.

1. Record the volume of air in a gas syringe.
2. Collect a sample of **Y** in a hypodermic syringe.
3. Record the mass of the hypodermic syringe and **Y**.
4. Push the needle of the hypodermic syringe through the rubber cap on the gas syringe.
5. Inject a small amount of **Y** into the gas syringe.
6. Remove the hypodermic syringe from the gas syringe.
7. Record the mass of the hypodermic syringe and the remaining **Y**.
8. Record the volume of gas in the gas syringe.
9. Record the temperature in the oven and the atmospheric pressure.

Results

Initial volume of air in the gas syringe	5 cm^3
Mass of hypodermic syringe and **Y** before injection	3.873 g
Mass of hypodermic syringe and **Y** after injection	3.471 g
Final volume of gas in the gas syringe	110 cm^3
Temperature	155 °C
Pressure	101 kPa

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0 8 . 1 Use the results to determine an experimental value for the M_r of **Y**.

The gas constant, $R = 8.31$ J K^{-1} mol^{-1}

Show your working.

[5 marks]

M_r _____

Question 8 continues on the next page

Do not write outside the box

0 8 . 2 The percentage uncertainty in the volume of **Y** in the gas syringe is 0.95%

The percentage uncertainty in the temperature is 0.12%

The uncertainty in each balance reading is ± 0.0005 g

Assume that the uncertainty in the value for pressure is negligible.

Calculate the percentage uncertainty in the use of the balance in this experiment.

Use your answer and the percentage uncertainties for volume and temperature to calculate a range of values for the M_r of **Y**.

(If you were unable to calculate an experimental value for the M_r of **Y** in Question **08.1**, assume it is 141. This is not the correct answer.)

[3 marks]

Percentage uncertainty for balance _____

M_r range _____

Do not write outside the box

0 8 . 3 A teacher suggests placing a seal over the needle of the hypodermic syringe after collecting the sample of liquid **Y**, and then replacing the seal after injecting the liquid **Y** into the gas syringe.

Give a reason why the teacher's suggestion will improve the experiment.

[1 mark]

0 8 . 4 A mixture of methane and propane has a volume of 40 cm^3

This mixture needs exactly 170 cm^3 of oxygen for complete combustion.

The equations for these reactions are

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

Calculate the volume

- of methane in the original mixture
- of propane in the original mixture.

All volumes are measured at the same temperature and pressure.

[4 marks]

Volume of methane _____ cm^3

Volume of propane _____ cm^3

13

Turn over ►

Do not write outside the box

0 9 This question is about rates of reaction.

The rate of hydrolysis of a bromoalkane (RBr) is investigated using this method.

- A boiling tube has a cross drawn onto it.
- An aqueous solution of silver nitrate is added to an ethanolic solution of RBr in the boiling tube in a warm water bath.
- The time is recorded for the cross on the boiling tube to become invisible.

The method is repeated at different temperatures.

0 9 . 1 State why the cross on the boiling tube becomes invisible.

[1 mark]

0 9 . 2 The volume and concentration of each substance used at each temperature is kept constant.

Identify **one** other variable that should be kept constant to ensure that the investigation is fair.

[1 mark]

Do not write outside the box

0 9 . 3 The reaction between the bromoalkane RBr and an aqueous solution of KOH is investigated.

The rate constant k for this reaction is determined at a series of temperatures T.

The Arrhenius equation can be written in this form.

$$\ln k = -\frac{E_a}{RT} + \ln A$$

Table 2 shows an incomplete set of results for this investigation.

Table 2

T / °C	$\frac{1}{T}$ / K^{-1}	k / $mol^{-1}\ dm^3\ s^{-1}$	ln k
39.5	3.20×10^{-3}	0.432	–0.84
44.5	3.15×10^{-3}	0.741	–0.30
52.2		1.65	0.50
60.3	3.00×10^{-3}	3.74	1.32
71.8	2.90×10^{-3}	10.8	2.38

Complete **Table 2**.

[1 mark]

Question 9 continues on the next page

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0 9 . 4 The results in **Table 2** can be used to plot a graph to determine the activation energy E_a for this reaction.

Complete the *x*-axis in **Figure 10** by adding an appropriate scale.

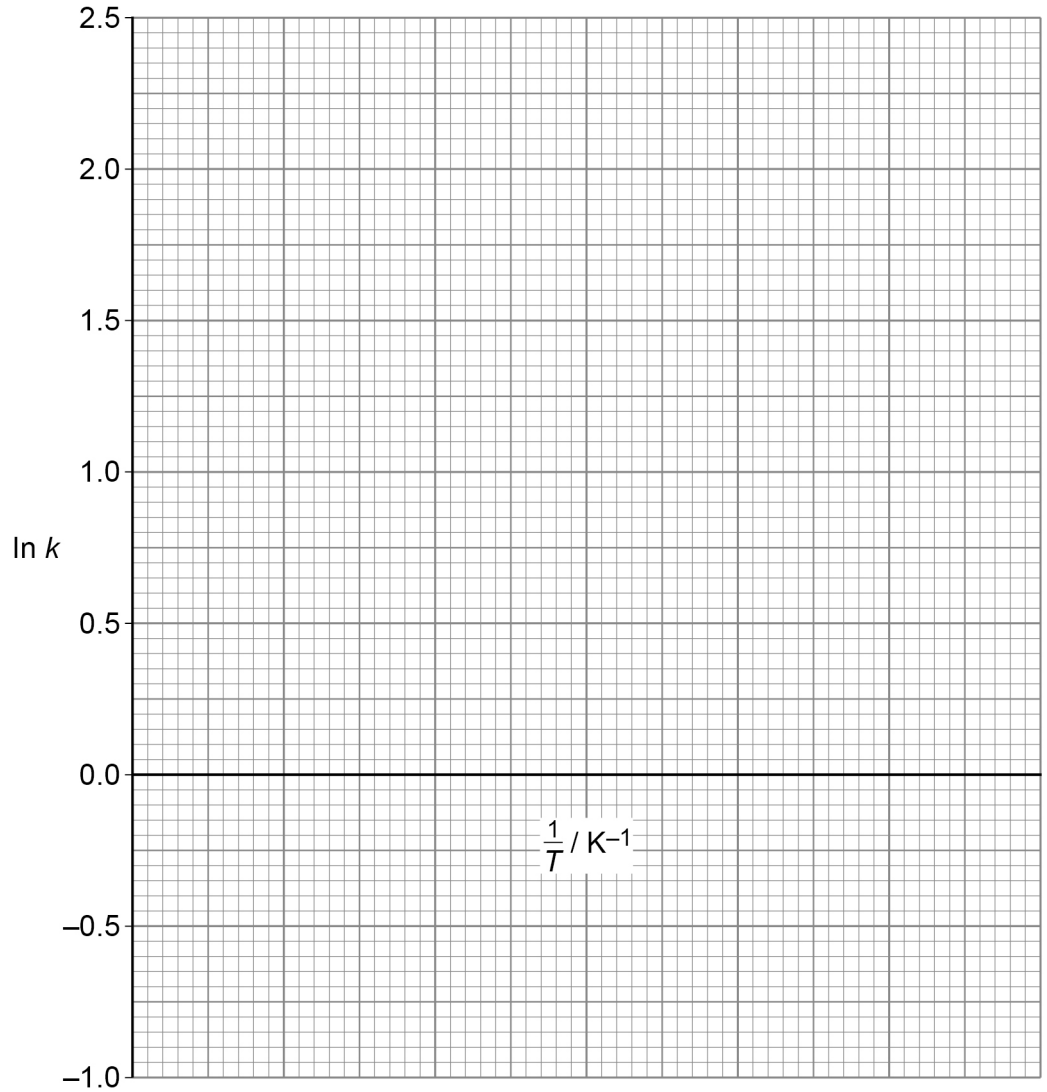
Plot the graph on the grid in **Figure 10**.

Use your graph to determine a value, in kJ mol^{-1}, for the activation energy E_a

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[5 marks]

Figure 10



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E_a _____ kJ mol^{-1}

Question 9 continues on the next page

Do not write outside the box

0 9 . 5 The rate equation for the reaction between a different bromoalkane (R_2CHBr) and an aqueous solution of KOH is

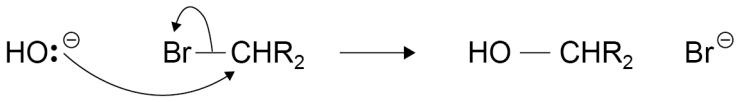
$$\text{rate} = k\,[R_2CHBr]$$

Which of these is a correct mechanism for the reaction between R_2CHBr and KOH?

[1 mark]

Tick (✓) **one** box.

A



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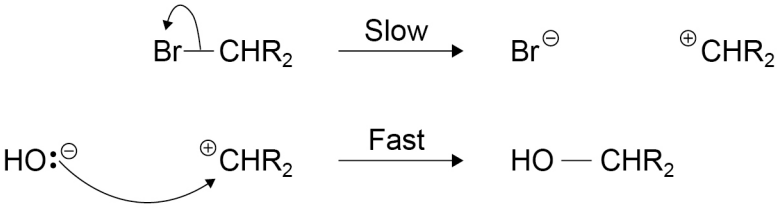

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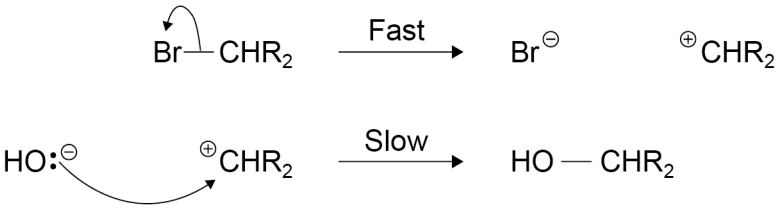

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0 9 . 6 Explain, in terms of bond polarity, why R_2CHBr and KOH react together.

[2 marks]

11

END OF QUESTIONS

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