



Surname _____

Forename(s) _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level

CHEMISTRY

Paper 2 Organic and Physical Chemistry

7405/2

Monday 19 June 2023

Afternoon

Time allowed: 2 hours

[Turn over]



At the front of this book, write your surname and forename(s), your centre number, your candidate number and add your signature.

MATERIALS

For this paper you must have:

- **the Periodic Table/Data Sheet, 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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do NOT write 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.**

DO NOT TURN OVER UNTIL TOLD TO DO SO



Answer ALL questions in the spaces provided.

0	1
----------	----------

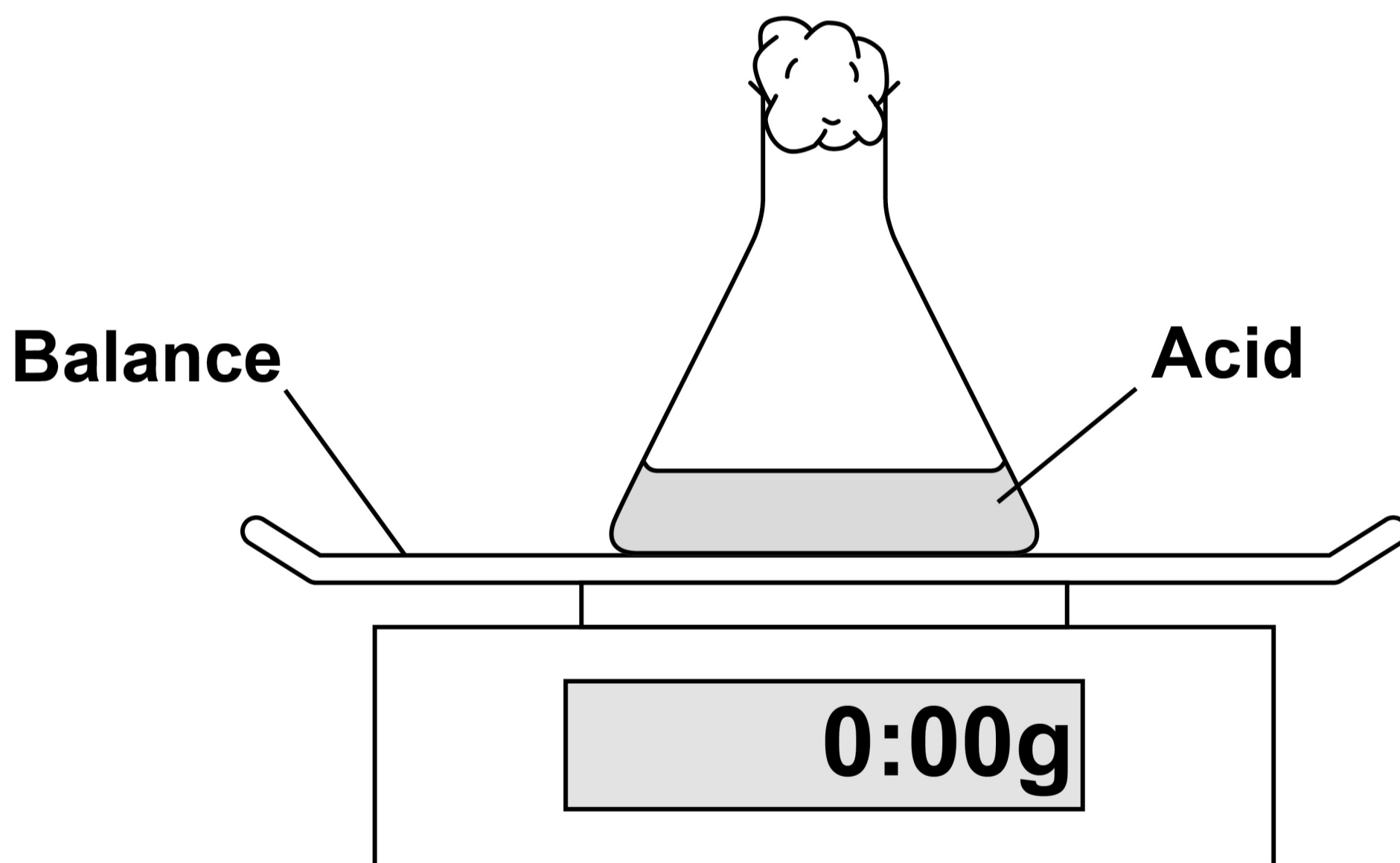
This question is about rates of reaction.

FIGURE 1, on the opposite page, shows apparatus used to measure the rate of reaction when an acid reacts with an excess of solid sodium hydrogencarbonate, NaHCO_3

When different monoprotic organic acids are used, the rates at which gas escapes can be used to compare the strengths of the acids.

A timer is started when the NaHCO_3 is added to the acid and the mass of CO_2 gas lost is recorded at regular intervals. (It is assumed that any change in mass is due to the loss of CO_2)

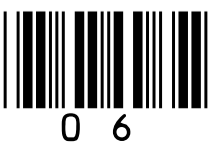
FIGURE 1



[Turn over]



BLANK PAGE



0	1	.	1
---	---	---	---

Suggest a reason why using a conical flask instead of a beaker would give more accurate results in this experiment.
[1 mark]

FIGURE 2, on page 8, shows the results of this experiment when 25.0 cm^3 of a 2.23 mol dm^{-3} solution of ethanoic acid reacts with an excess of NaHCO_3

[Turn over]



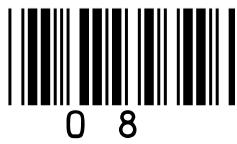
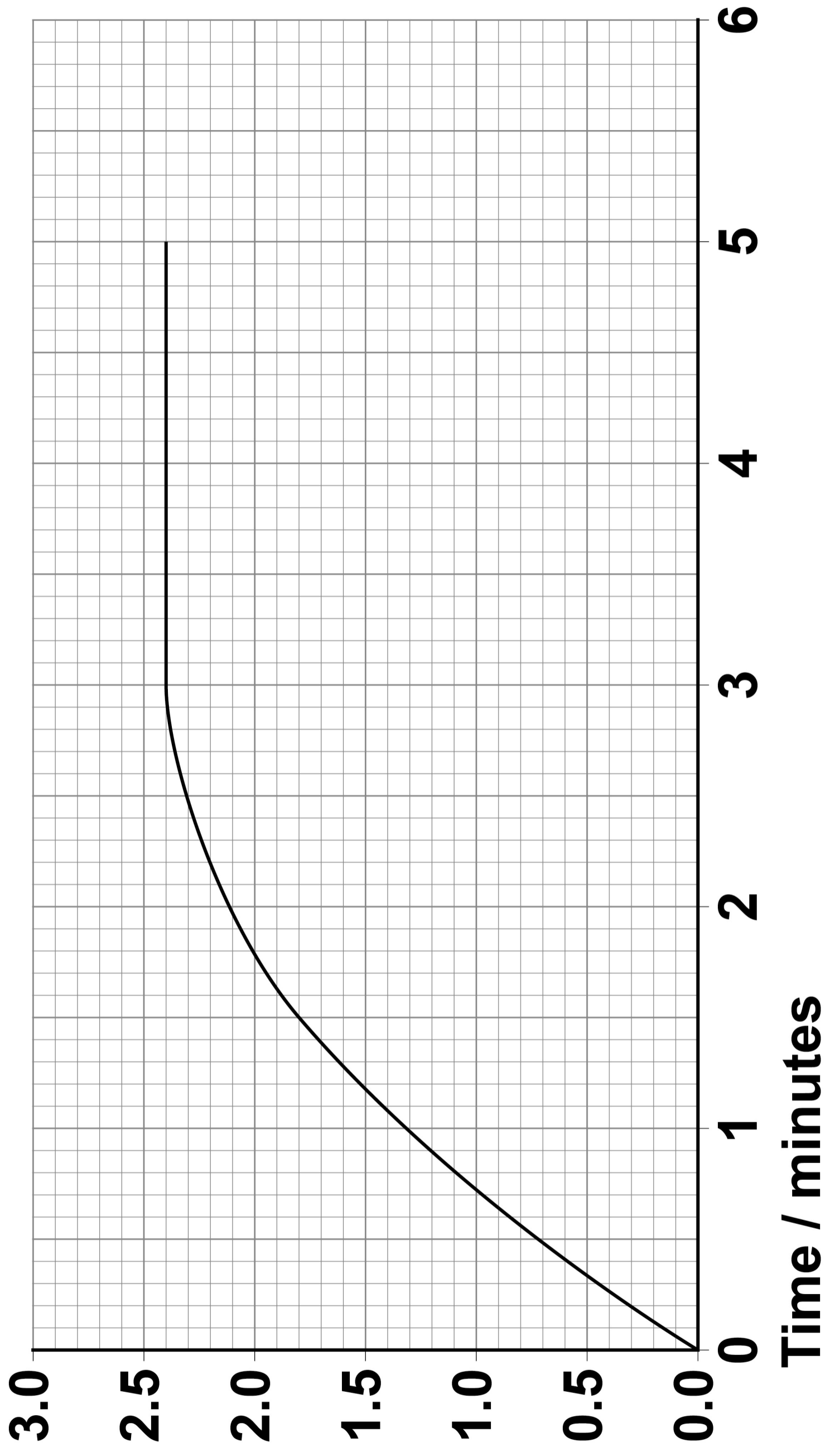
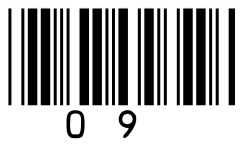


FIGURE 2

Mass of CO₂
lost / g





0 1 . 2

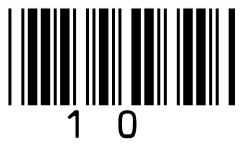
Use FIGURE 2 to calculate the rate of reaction at 2 minutes.

Deduce the units of your calculated rate. [3 marks]

9

Rate _____ **Units** _____

[Turn over]



0 1 . 3

Chloroethanoic acid is a stronger acid than ethanoic acid.

Sketch, on FIGURE 2 on page 8, the curve you would expect when 25.0 cm³ of a 2.23 mol dm⁻³ solution of chloroethanoic acid reacts with an excess of NaHCO₃

Suggest why chloroethanoic acid is a stronger acid than ethanoic acid. [3 marks]

10

7



1 1

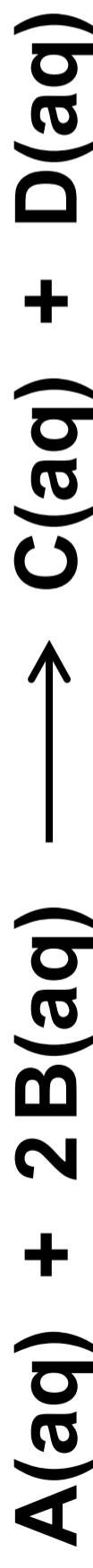
BLANK PAGE

[Turn over]



0	2
---	---

A and B react together in the presence of an acid catalyst.



The rate equation for this reaction is

$$\text{rate} = k[\text{B}]^2[\text{H}^+]$$

12

TABLE 1, on the opposite page, shows how the values of the relative initial rate vary with different concentrations of each reagent at the same temperature.

**TABLE 1**

Experiment	[A] / mol dm⁻³	[B] / mol dm⁻³	[H⁺] / mol dm⁻³	Relative initial rate
1	0.40	0.20	0.10	1.00
2	0.50	0.20	0.10	
3	0.40		0.10	0.64
4	0.50	0.30	0.06	

13**0 2 . 1**

**Complete TABLE 1 by calculating the missing values.
[3 marks]**

[Turn over]

02.2

A suggested mechanism for the reaction is shown.



Deduce the rate-determining step for this reaction.

Give a reason for your answer. [2 marks]

Rate-determining step _____

Reason _____



[Turn over]

<hr/>
5

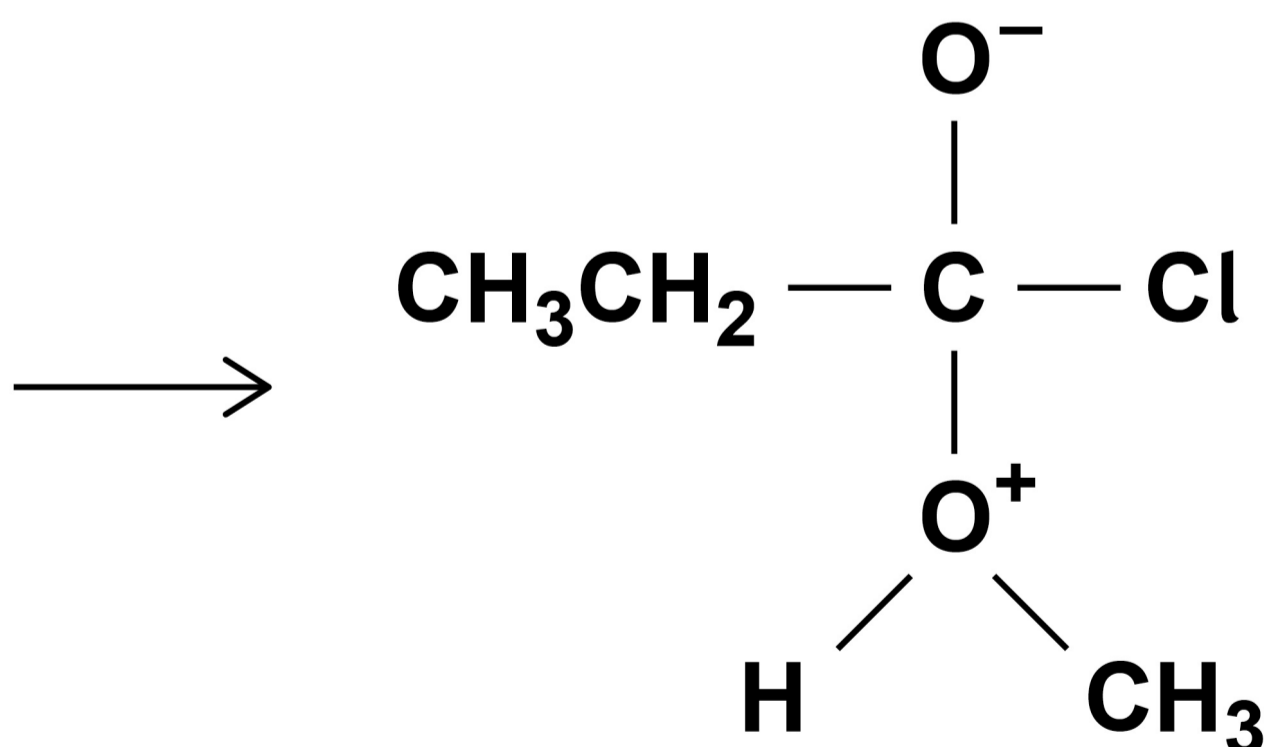


03

This question is about intermediates in reaction mechanisms.

03.1

FIGURE 3 shows an intermediate formed in the first step of a nucleophilic addition–elimination mechanism.

FIGURE 3

Complete FIGURE 3, on the opposite page, to show the structures of the two reactant species with curly arrows and relevant lone pairs of electrons involved in the formation of the intermediate.

Draw curly arrows and relevant lone pairs of electrons on the intermediate to show how the final products are formed.
[4 marks]

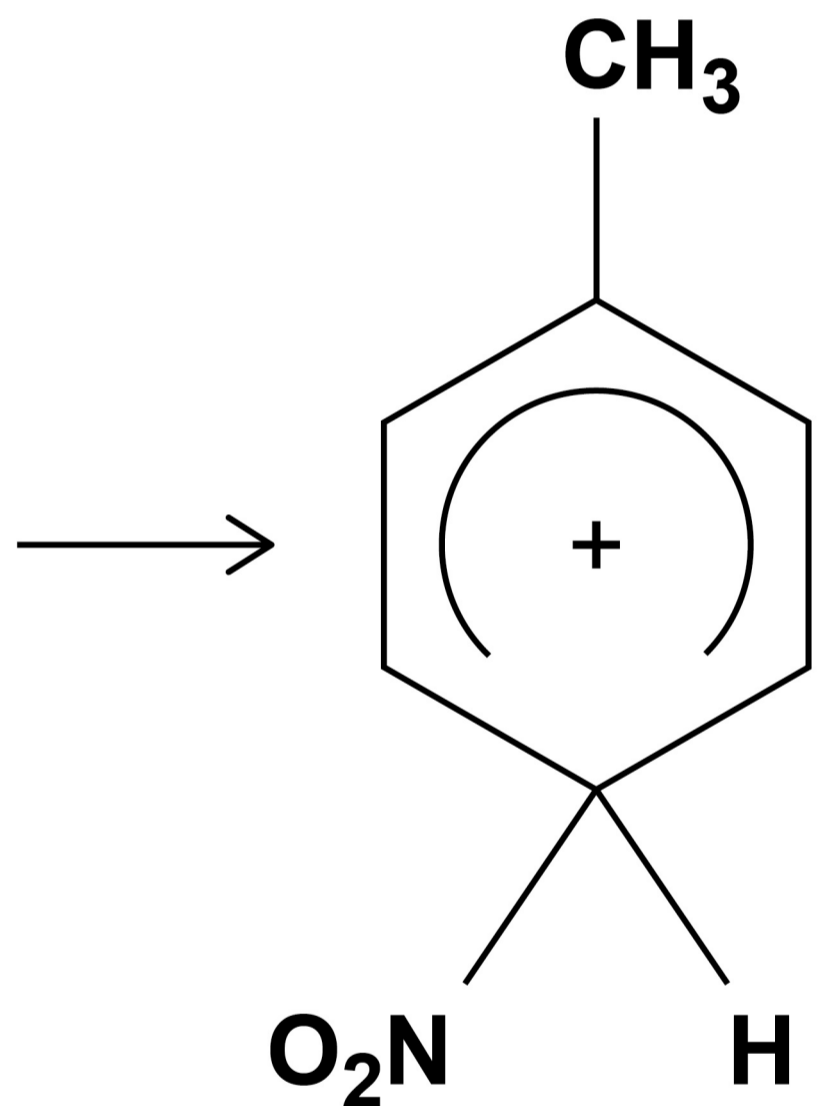
[Turn over]



03.2

FIGURE 4 shows an intermediate formed in the first step of a reaction mechanism of methylbenzene.

FIGURE 4



Complete FIGURE 4, on the opposite page, to show the reactant species and any curly arrows involved in the formation of the intermediate.

Draw a curly arrow on the intermediate to show how the product is formed.

Give the name of the reaction mechanism. [4 marks]

Name of mechanism _____

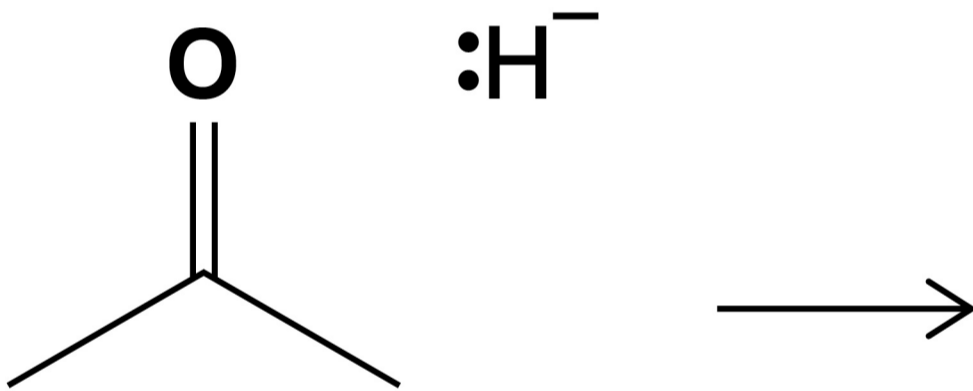
[Turn over]



0	3	.	3
---	---	---	---

FIGURE 5 shows the reactant species involved in the first step of a mechanism.

FIGURE 5



Complete FIGURE 5, on the opposite page, to show the structure of the intermediate formed with curly arrows involved in its formation.

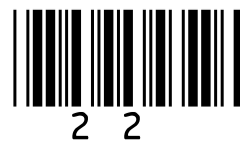
Give the name of the reaction mechanism. [4 marks]

Name of mechanism _____

[Turn over]

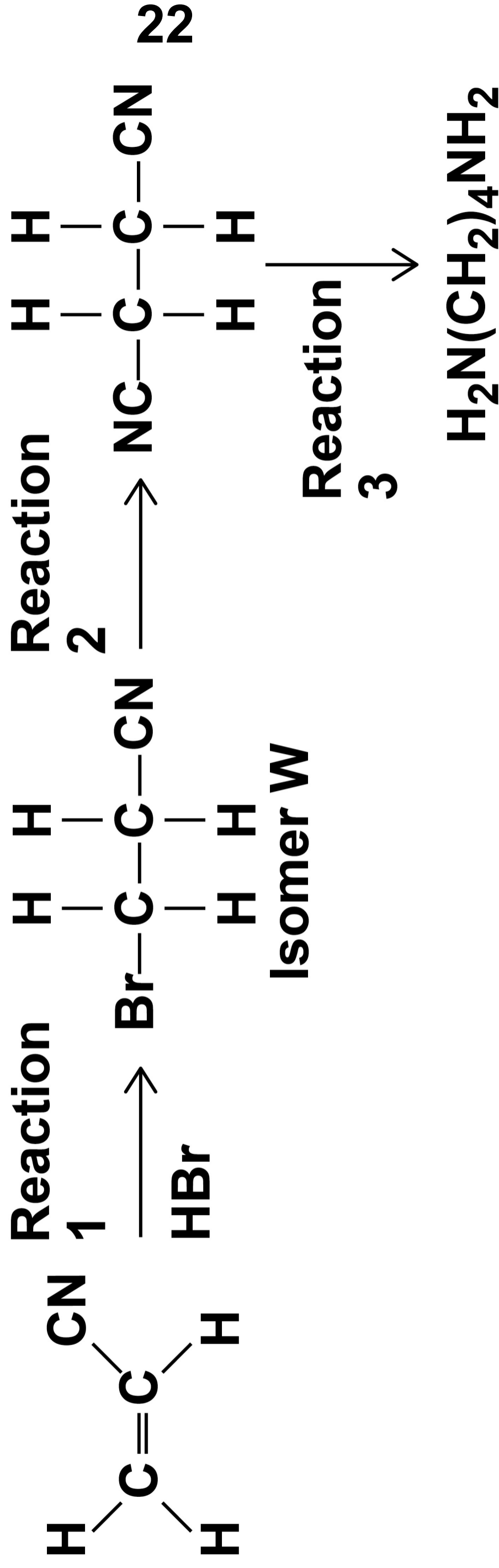
<hr/>
12





0	4
---	---

Acrylonitrile, $\text{H}_2\text{C}=\text{CHCN}$, can be used as a starting material for the synthesis of butane-1,4-diamine, as shown in this reaction scheme.





04.1

Use IUPAC rules to name isomer W. [1 mark]

[Turn over]



04.2

Reaction 1, on page 22, produces a mixture of W and two other isomers.

Draw the structures of the two other isomers.

Explain, by considering the mechanism of this reaction, why all three isomers are formed. [6 marks]

[Turn over]



Vertical lines for writing.

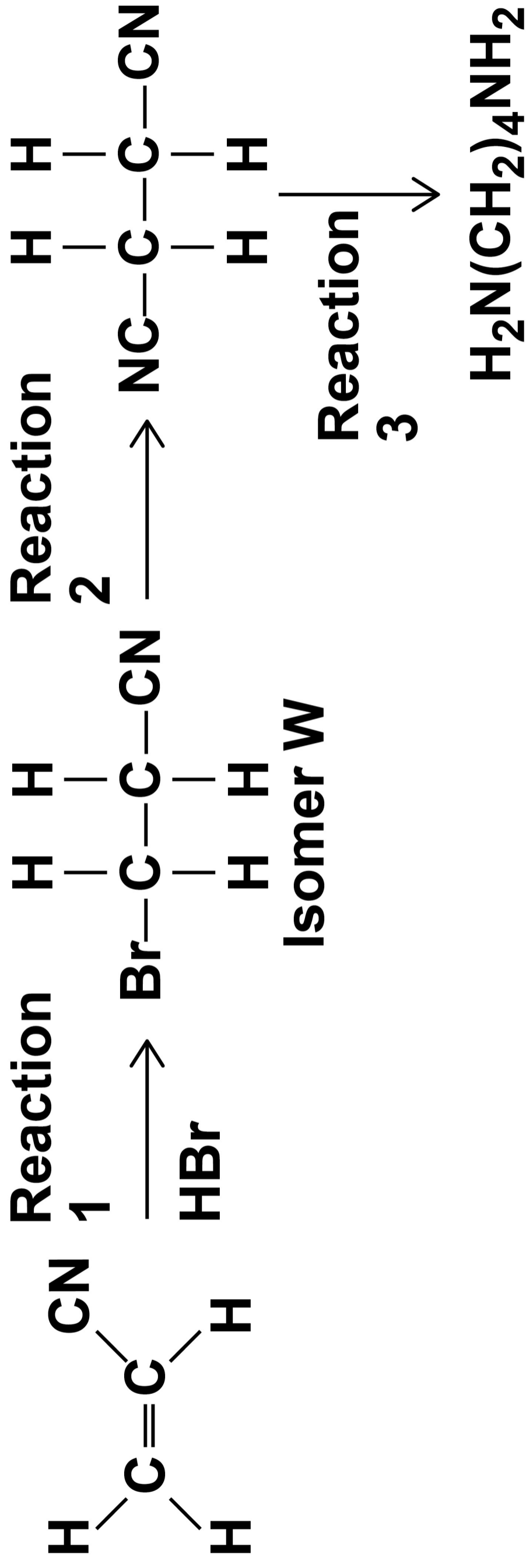


[Turn over]





The reaction scheme is repeated here.





04.3

Identify the reagent that is warmed with isomer W in reaction 2.

State the other reaction condition needed. [2 marks]

Reagent _____

Condition _____

29

[Turn over]



04.4

State the reagent and reaction conditions needed for reaction 3, on page 28.

Give an equation for reaction 3. [2 marks]

Reagent and conditions _____

Equation _____



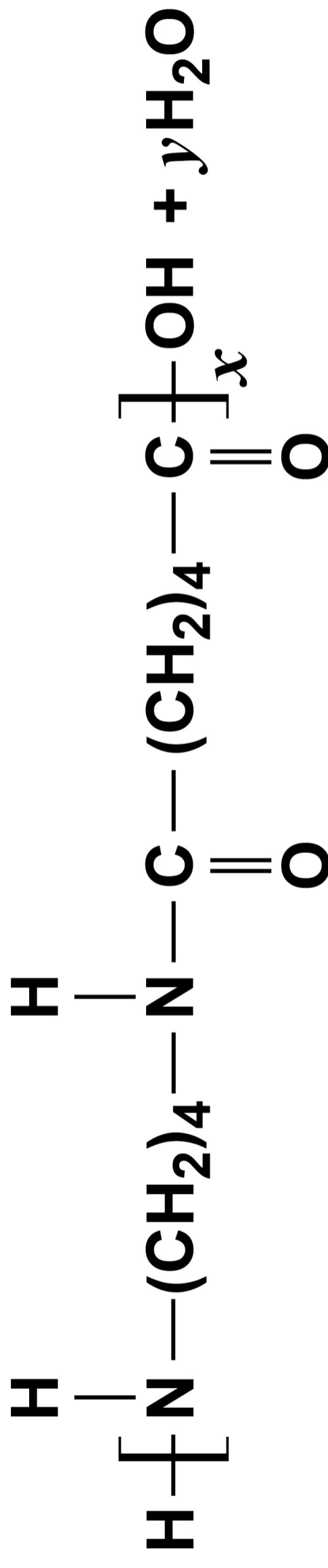
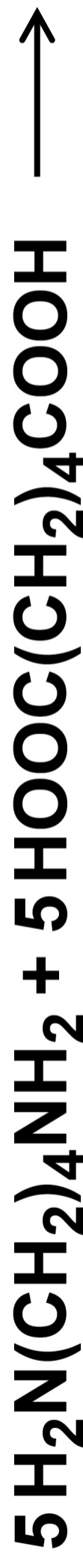
BLANK PAGE

[Turn over]



0	4	.	5
---	---	---	---

An incomplete equation for the formation of nylon 4,6 from five molecules of butane-1,4-diamine and five molecules of hexanedioic acid is shown.





Deduce the values of x and y in this equation. [2 marks]

33

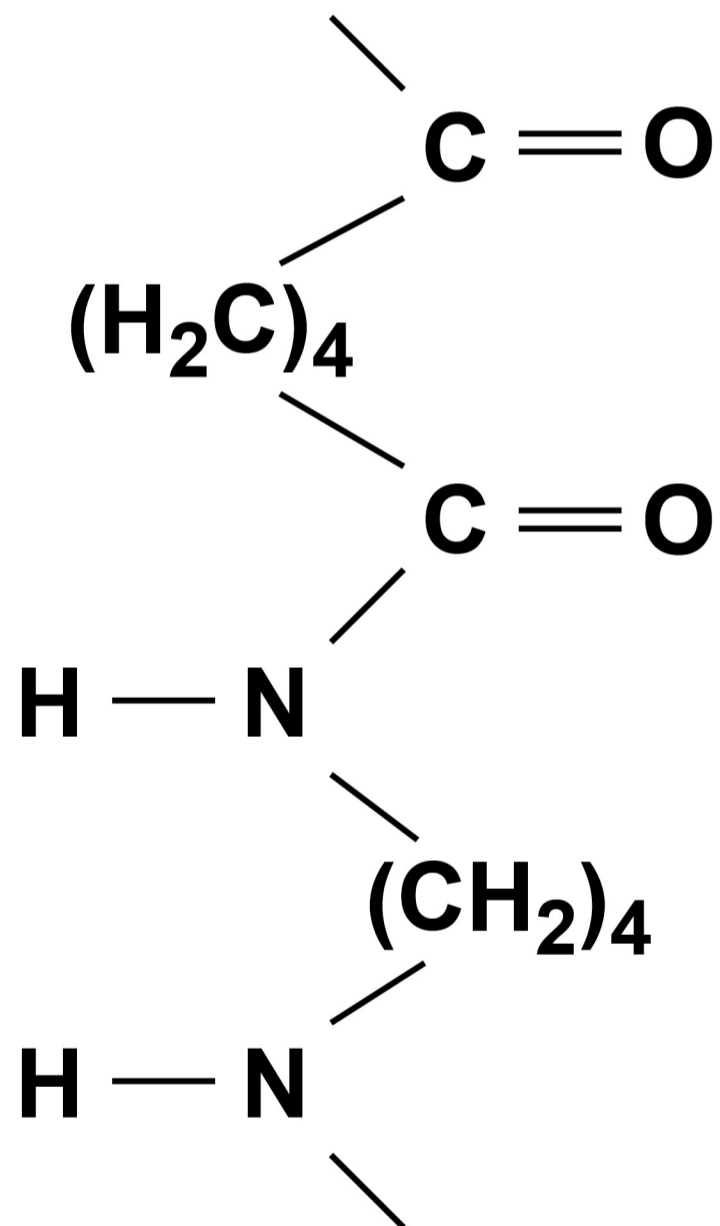
$$x \quad \underline{\hspace{2cm}} \quad y \quad \underline{\hspace{2cm}}$$

[Turn over]

04.6

FIGURE 6 shows a section of the nylon 4,6 polymer molecule.

FIGURE 6



Draw, on FIGURE 6, on the opposite page, another section of nylon 4,6 polymer showing two hydrogen bonds between the two sections. [2 marks]

[Turn over]

<hr/>
15





05

This question is about compound Z, with molecular formula $C_7H_{12}O_3$

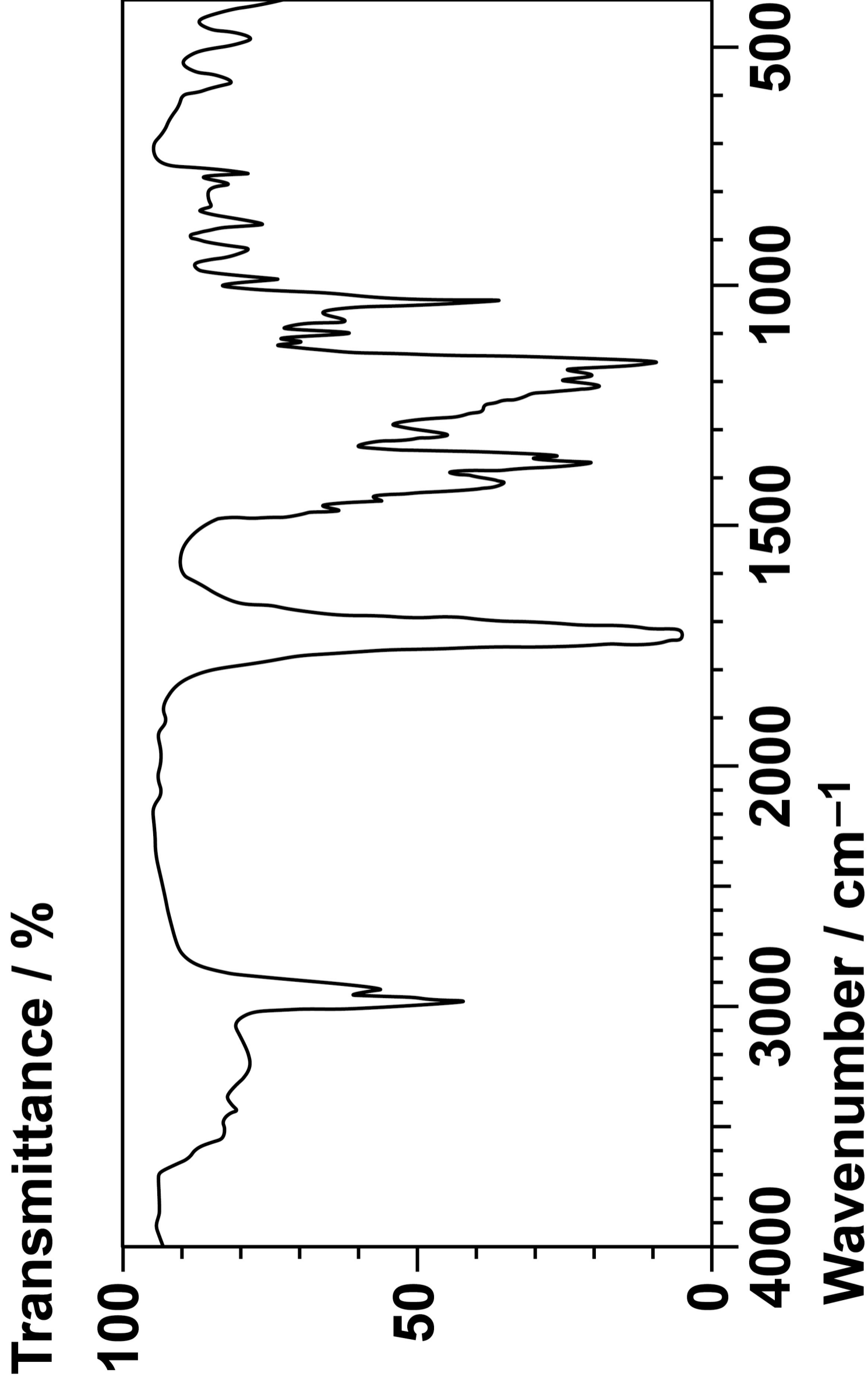
FIGURE 7, on the opposite page, shows the infrared spectrum of Z.

05.1

Identify the bond that causes the absorption at 1725 cm^{-1}
[1 mark]



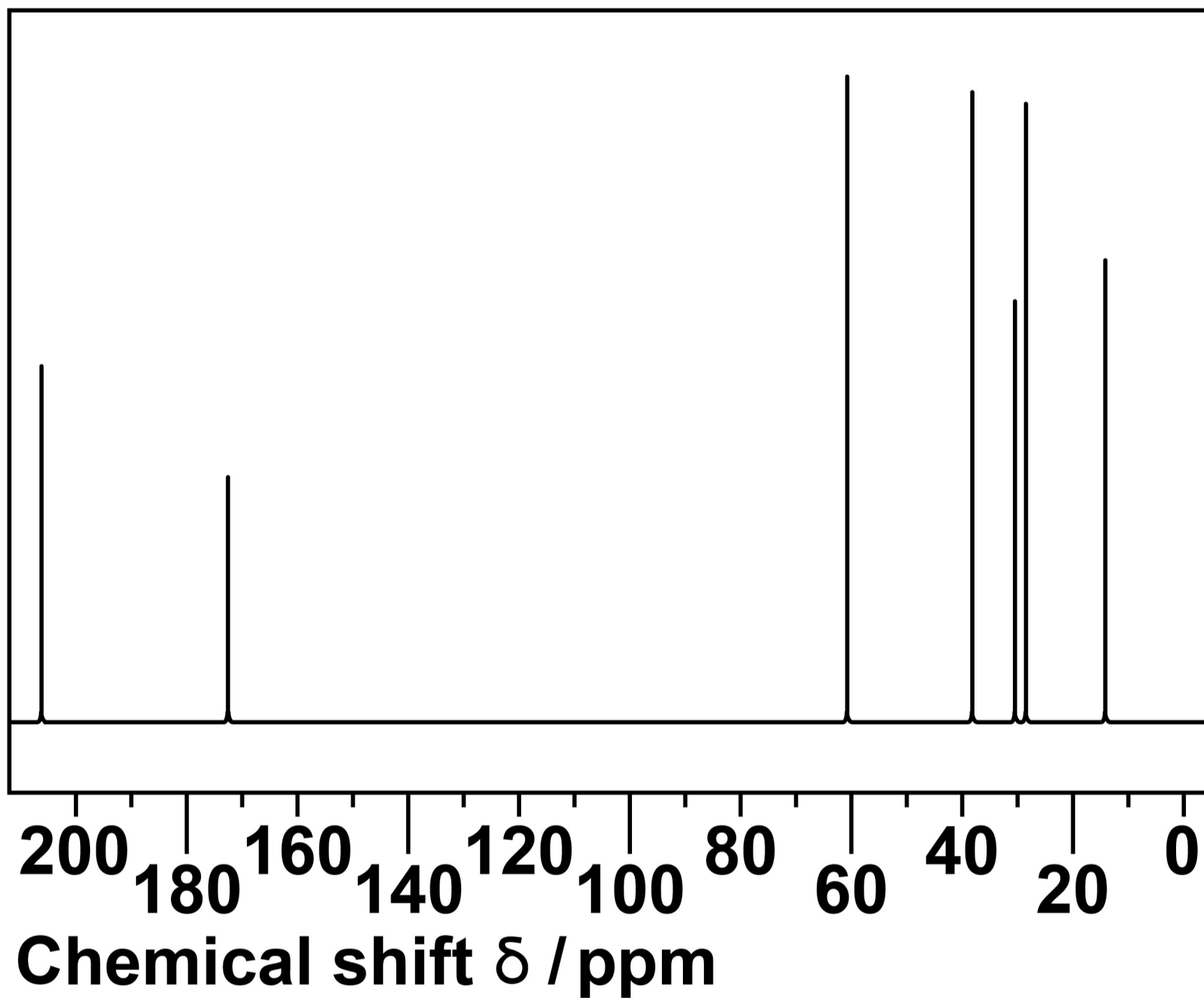
FIGURE 7



[Turn over]

FIGURE 8 shows the ^{13}C NMR spectrum of **Z**.

FIGURE 8



0 5 . 2

How many different carbon environments are there in a molecule of Z? [1 mark]

	5	6	7	8
Tick (✓) ONE box				

0 5 . 3

State the type of carbon environment that causes the peak at $\delta = 174$ ppm

Use TABLE C in the Data Booklet to help you answer this question. [1 mark]

[Turn over]





05.4

TABLE 2 shows data from the ^1H NMR spectrum for compound Z.

TABLE 2

Chemical shift δ / ppm	4.10	2.60	2.56	2.19	1.26
Integration ratio	2	2	2	3	3
Splitting pattern	quartet	triplet	triplet	singlet	triplet



Explain what can be deduced from the splitting patterns and chemical shift values for the peaks at $\delta = 4.10$ ppm and at $\delta = 1.26$ ppm

Deduce the part of the structure of Z that causes the peaks at $\delta = 4.10$ ppm and $\delta = 1.26$ ppm

Use TABLE B in the Data Booklet to help you answer this question. [5 marks]

Peak at $\delta = 4.10$ ppm _____

[Turn over]



Peak at $\delta = 1.26$ ppm

Part of structure



05.5

Deduce the part of the structure of Z that causes the peak at $\delta = 2.19$ ppm [1 mark]

Part of structure

[Turn over]



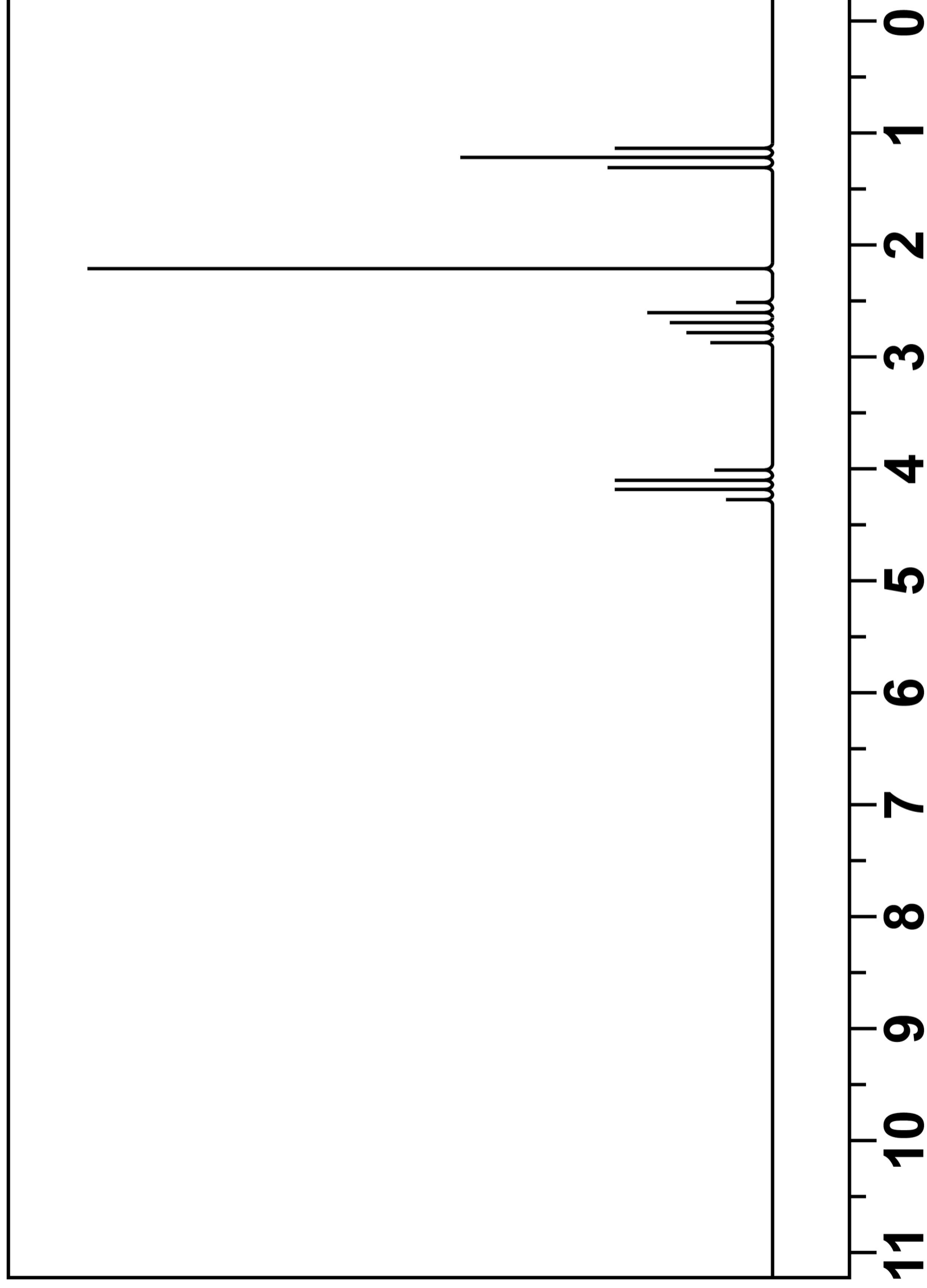
FIGURE 9, on the opposite page, shows the ^1H NMR spectrum of compound Z.

0 5 . 6

Suggest why it would be difficult to determine the structure of Z using the spectrum in FIGURE 9 without the information in TABLE 2 on page 40. [1 mark]



FIGURE 9



Chemical shift δ / ppm

[Turn over]



0 5 . 7

Deduce the structure of Z. [1 mark]

46

11



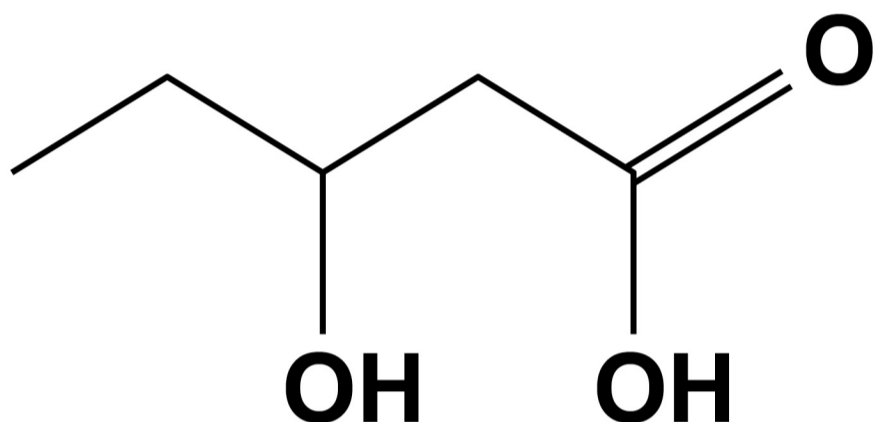
4 7

BLANK PAGE

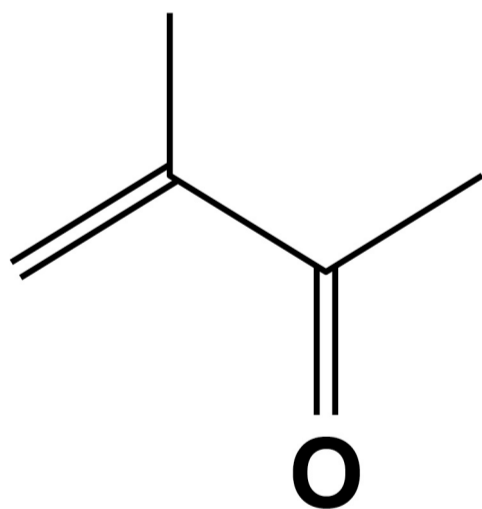
[Turn over]

0	6
---	---

A student plans a series of chemical tests to confirm the identities of four organic liquids.

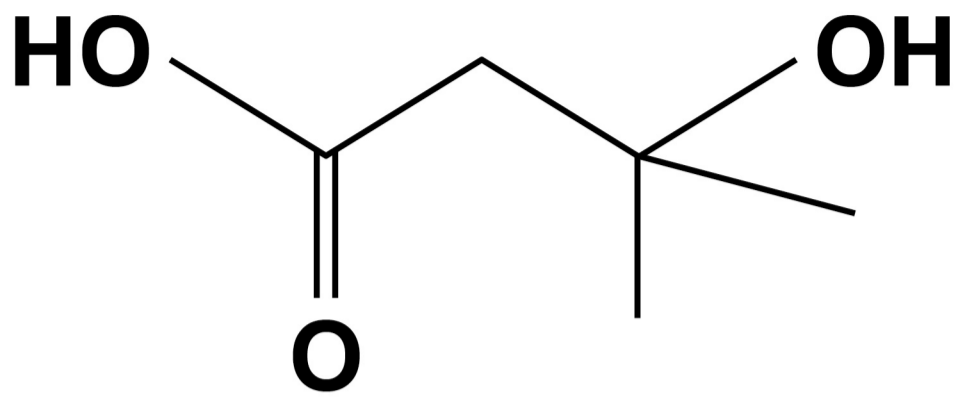


Liquid J

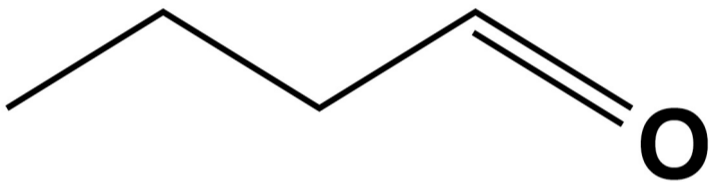


Liquid K





Liquid L



Liquid M

[Turn over]



This is the student's method.

To separate test tubes containing samples of each liquid:

TEST 1 add potassium dichromate(VI) solution and warm gently

TEST 2 add Fehling's solution and cool in iced water

TEST 3 add sodium hydrogencarbonate solution and test any gas produced with a lighted splint

TEST 4 add bromine water and shake at room temperature.



06.1

Identify the missing reagent needed in TEST 1. [1 mark]

[Turn over]



06.2

In addition to the missing reagent in TEST 1, on page 50, there is a mistake in the method for TWO of the other tests.

State the TWO mistakes.

Suggest how each of the mistakes should be corrected. [2 marks]

Mistake 1 _____

Suggestion _____

Mistake 2 _____



Suggestion _____

[Turn over]



0	6	.	3
---	---	---	---

The missing reagent is added and the mistakes are corrected.

Identify the liquid(s), J, K, L and M, that would react in each test.

State the expected observation for each reaction. [8 marks]

Liquid(s) that react in TEST 1 _____

Expected observation _____

Liquid(s) that react in TEST 2 _____



Expected observation _____

Liquid(s) that react in TEST 3 _____

Expected observation _____

Liquid(s) that react in TEST 4 _____

Expected observation _____

[Turn over]



06.4

FIGURE 10, on page 58, shows the apparatus that is used to separate a mixture of liquids K and M using fractional distillation.

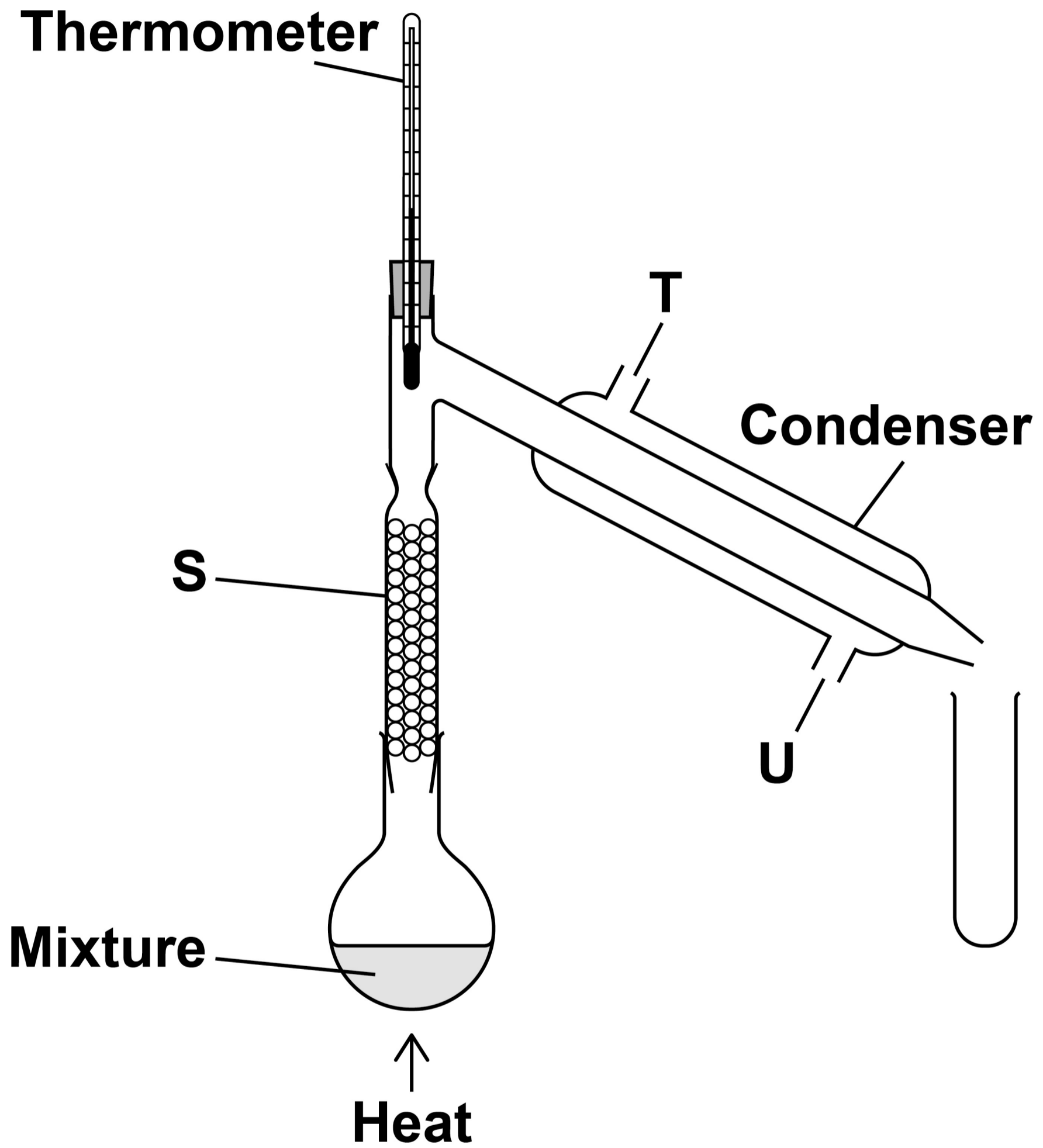


BLANK PAGE

[Turn over]



FIGURE 10



Suggest labels that should be added to positions S, T and U in FIGURE 10.

Explain why fractional distillation is preferred to simple distillation to separate liquids K and M. [3 marks]

Label S _____

Label T _____

Label U _____

Explanation _____

[Turn over]



0	7
---	---

A gas syringe that does not have any graduations is calibrated using a known mass of propanone (boiling point = 56.2 °C).

The sealed gas syringe contains 0.146 g of propanone ($M_r = 58.0$) at a temperature of 95 °C and a pressure of 103 kPa

0	7	.	1
---	---	---	---

Calculate the volume, in cm^3 , of propanone in the gas syringe.

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
[4 marks]



Volume of propanone _____ cm^3

[Turn over]



07.2

The gas syringe is then cooled to 75 °C, without changing the pressure.

Calculate the decrease in volume.

(If you were unable to calculate the volume in Question 07.1, you should use the volume 89 cm³. This is not the correct answer.) [2 marks]

Decrease in volume _____ cm³



BLANK PAGE

[Turn over]



07.3

The total uncertainty in using the balance to measure the mass of propanone in Question 07.1 is ± 0.001 g

On the opposite page, calculate the uncertainty that this causes in the volume, in cm^3 , of propanone calculated in Question 07.1.

(If you were unable to calculate the volume in Question 07.1, you should use the volume 89 cm^3 . This is not the correct answer.) [2 marks]



Uncertainty _____ **cm³**

[Turn over]





07.4

A 600 cm³ sample of propanone is mixed with 2800 cm³ of oxygen in a container at 60 °C and 100 kPa. The mixture is ignited.

When the reaction is complete, the remaining mixture of gases is cooled to 60 °C at 100 kPa



On the opposite page, calculate the total volume of the remaining gas mixture. [2 marks]



Volume _____ cm³

10

[Turn over]



08

This question is about biofuels.

Palmitic acid, $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$, can be made by hydrolysis of the triester in palm oil under acidic conditions.

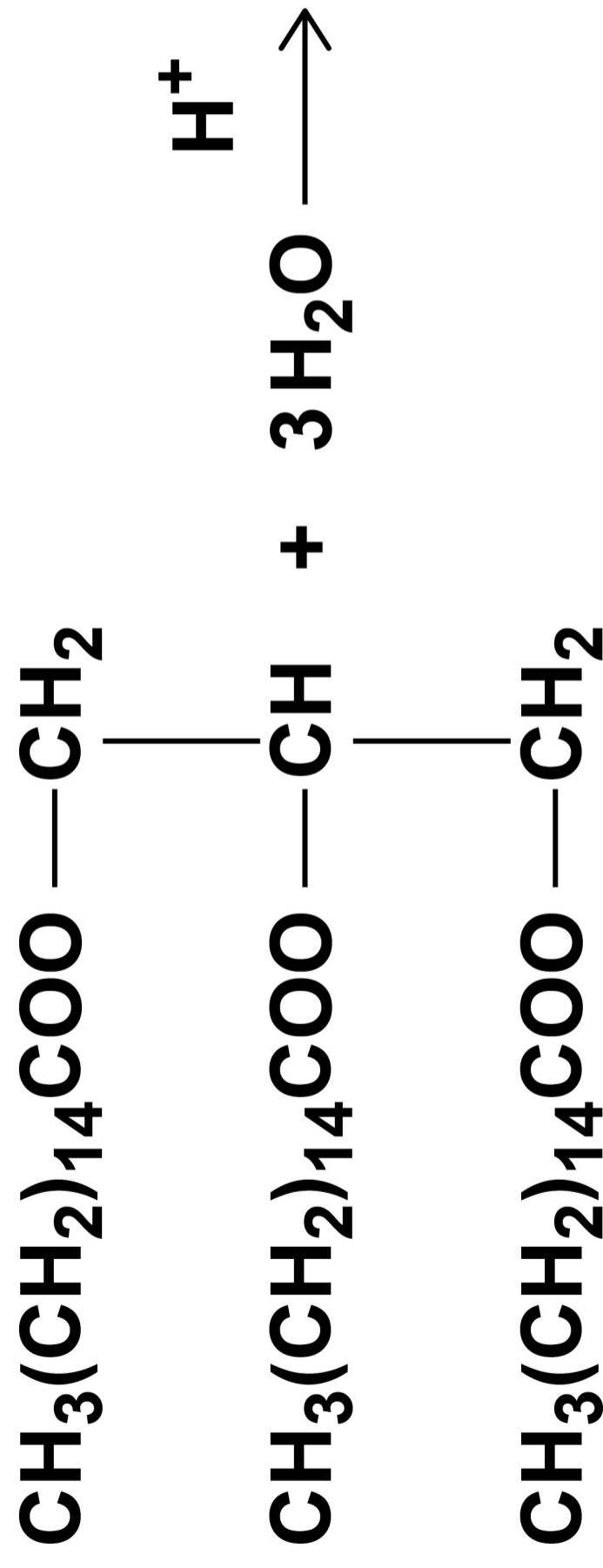
Palmitic acid can be used as a biofuel.



6 9

08.1

Complete the equation for the hydrolysis of the triester in palm oil under acidic conditions. [2 marks]



69

[Turn over]

08.2

Palmitic acid burns in air.

In a calorimetry experiment, combustion of 387 mg of palmitic acid increases the temperature of 0.150 kg of water from 23.9 °C to 37.5 °C

On the opposite page, calculate a value, in kJ mol^{-1} , for the enthalpy of combustion of palmitic acid in this experiment.

Give your answer to the appropriate number of significant figures.

The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$ [5 marks]



Enthalpy of combustion

kJ mol⁻¹

[Turn over]



08.3

State how the value calculated in Question 08.2 is likely to differ from data book values.

Give one reason, other than heat loss, for this difference. [2 marks]

Difference _____

Reason _____



08.4

A sample of a different biofuel, made from sewage sludge, is found to contain 37.08% carbon, 5.15% hydrogen and 24.72% oxygen by mass.

The rest of the sample is sulfur.

Calculate the empirical formula of this biofuel. [3 marks]

Empirical formula _____

[Turn over]



08.5

Complete combustion of the biofuel made from sewage sludge produces the greenhouse gas carbon dioxide.

Suggest ONE other possible environmental problem with the complete combustion of this biofuel.

State the formula of the pollutant responsible for this problem. [2 marks]

Environmental problem _____

Formula _____

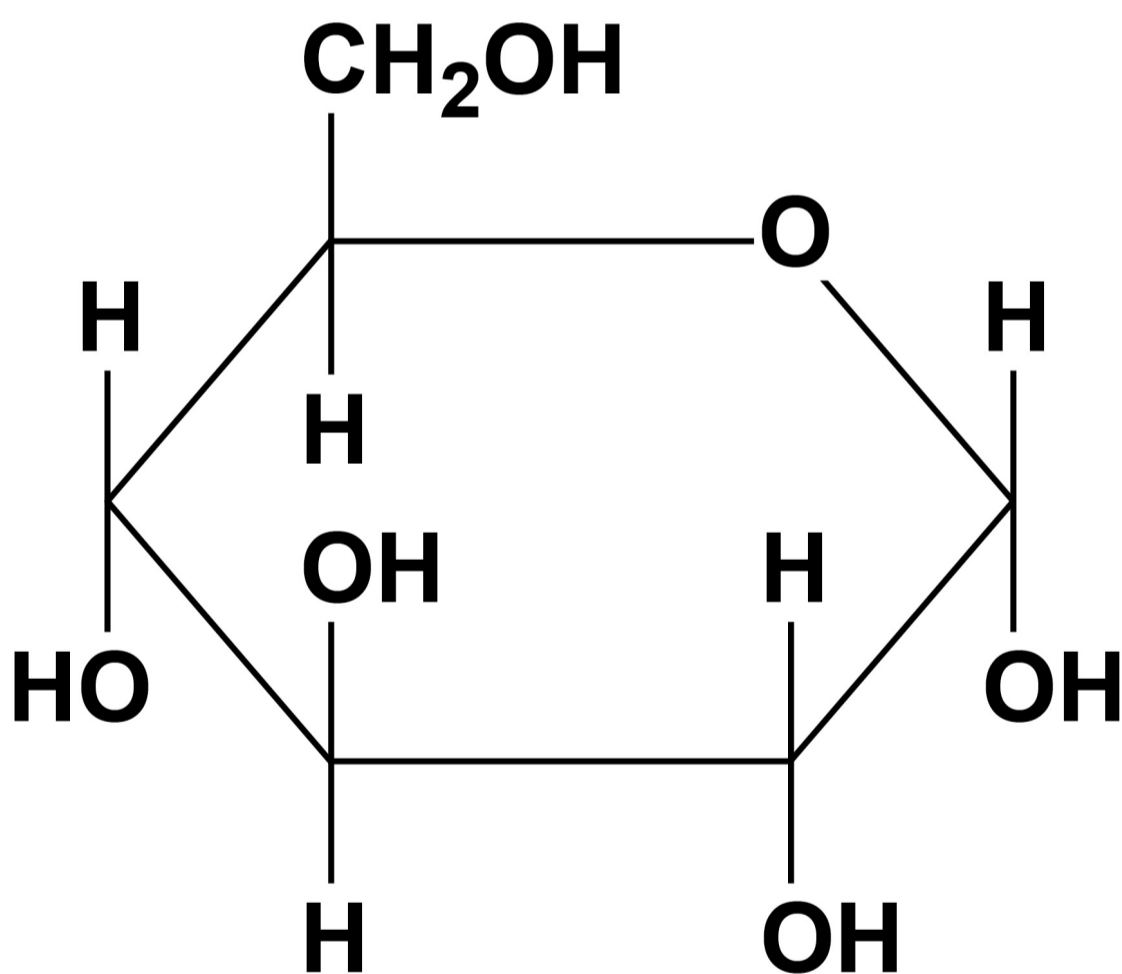


08.6

Ethanol is a biofuel that can be produced by the fermentation of glucose.



Glucose has the structural formula shown.



[Turn over]



TABLE 3 shows some mean bond enthalpy values.

TABLE 3

	C–H	C–C	C–O	C=O	O–H
Mean bond enthalpy / kJ mol⁻¹	412	348	360	805	463

Use the equation and the data in TABLE 3 to calculate an approximate value of ΔH for the fermentation of glucose. For this calculation you should assume that all the substances are in the gaseous state. [3 marks]



ΔH _____ kJ mol^{-1}

[Turn over]





The carbon dioxide produced from fermentation can be reacted with steam to make more ethanol.

The equation for this reaction is



78

TABLE 4 shows some standard enthalpies of formation.

TABLE 4

	$\text{CO}_2(\text{g})$	$\text{O}_2(\text{g})$	$\text{C}_2\text{H}_5\text{OH}(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-394	0	-235	-242



Use the data in TABLE 4 to calculate a standard enthalpy change value for this reaction. [2 marks]

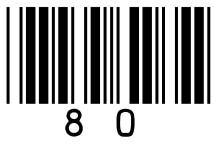
79

Standard enthalpy change

_____ kJ mol⁻¹

[Turn over]

19

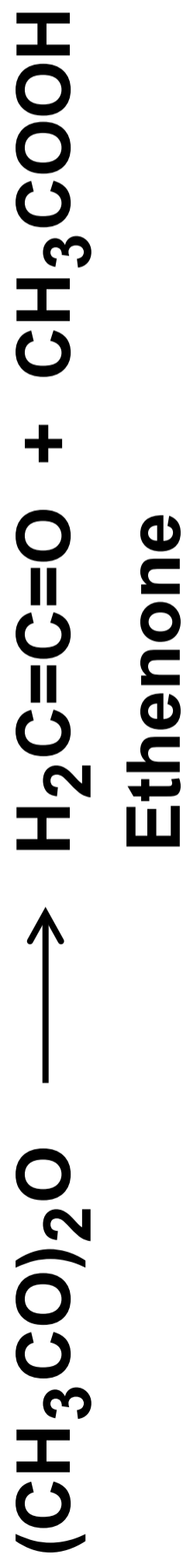


0	9
---	---

This question is about ethanoic anhydride.

In the gas phase, ethanoic anhydride $(\text{CH}_3\text{CO})_2\text{O}$ decomposes to form ethenone.

The equation is





8 1

09.1

Ethenone is the simplest member of the ketene homologous series.

Ketenes all contain one C=C double bond and one C=O double bond.

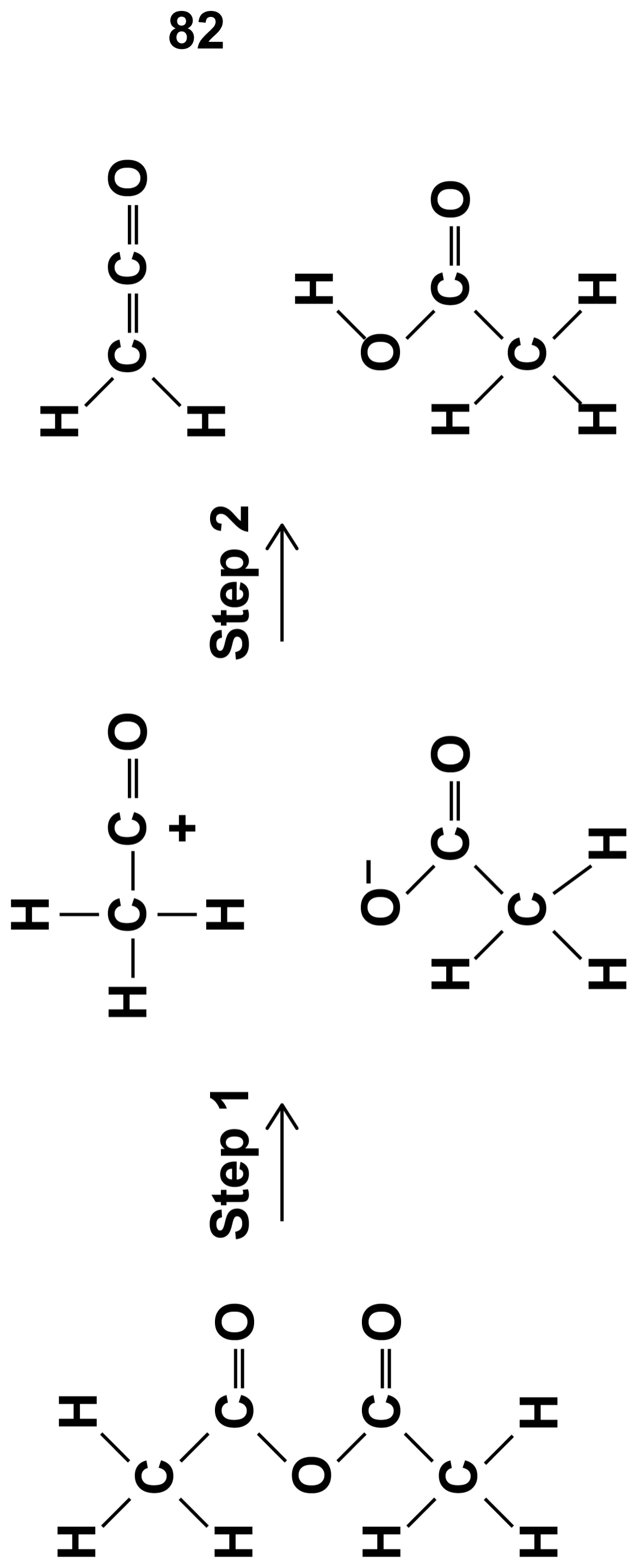
Deduce the general formula for the ketene homologous series. [1 mark]

[Turn over]



FIGURE 11 shows an incomplete suggested mechanism for the decomposition of ethanoic anhydride.

FIGURE 11





Complete the mechanism in FIGURE 11, on the opposite page, by adding three curly arrows and any relevant lone pairs of electrons. [3 marks]

[Turn over]

0 9 . 3

For a chemical reaction the relationship between the rate constant, k , and the temperature, T , is shown by the Arrhenius equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

For the decomposition of gaseous ethanoic anhydride

the activation energy, $E_a = 34.5 \text{ kJ mol}^{-1}$

the Arrhenius constant, $A = 1.00 \times 10^{12} \text{ s}^{-1}$

At temperature T_1 the rate constant,

$$k = 2.48 \times 10^8 \text{ s}^{-1}$$

Calculate T_1

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

[3 marks]



T_1

K



[Turn over]



09.4

On the opposite page, sketch the Maxwell–Boltzmann distribution of molecular energies for gaseous ethanoic anhydride at temperature T_1 and at a higher temperature T_2

Include a label for each axis, and mark on the appropriate axis a typical position for the activation energy.

Explain why the rate of reaction is faster at T_2 [5 marks]





Explanation _____

END OF QUESTIONS

<hr/>
12



Additional page, if required.

Write the question numbers in the left-hand margin.



BLANK PAGE

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

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2023 AQA and its licensors. All rights reserved.

WP/M/SC/Jun23/7405/2/E6