A

AQA

Surname _____

Other Names _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level
CHEMISTRY

Paper 2 Organic and Physical Chemistry

7405/2

Time allowed: 2 hours

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

JUN217405201

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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.**
- **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

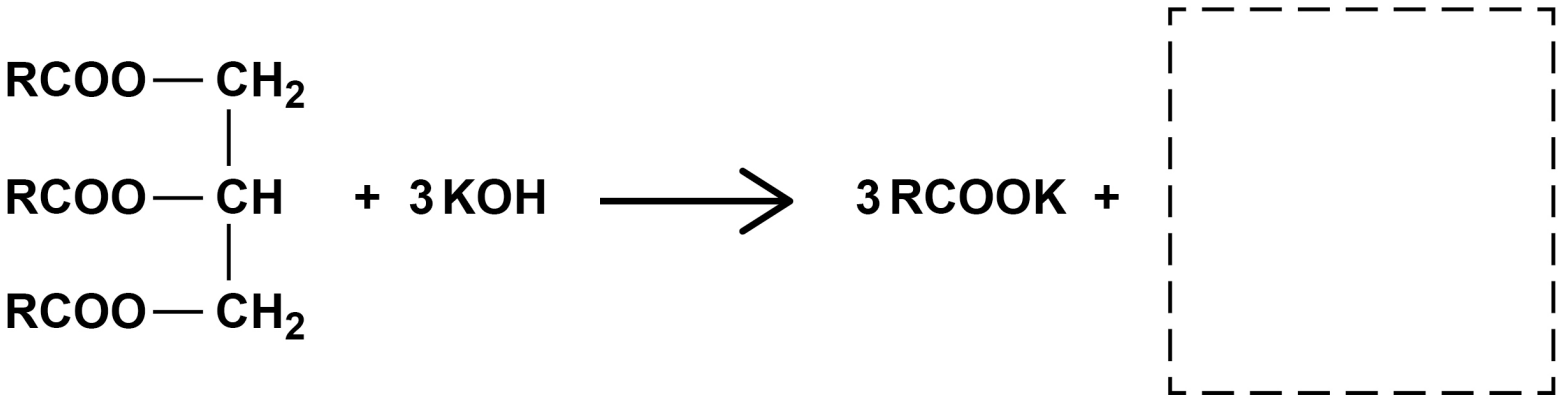
- **The marks for questions are shown in brackets.**
- **The maximum mark for this paper is 105.**

DO NOT TURN OVER UNTIL TOLD TO DO SO

Answer ALL questions in the spaces provided.

0 1

Coconut oil contains a triester with three identical R groups.
This triester reacts with potassium hydroxide.



4

0 1 . 1

Complete the equation by drawing the structure of the other product of this reaction in the box.

Name the type of compound shown by the formula RCOOK

Give ONE use for this type of compound. [3 marks]

Type of compound _____

Use _____

[Turn over]

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0 1 . 2

The triester in coconut oil has a relative molecular mass, M_r = 638.0

In the equation shown at the start of Question 01, R represents an alkyl group that can be written as $CH_3(CH_2)_n$

Deduce the value of n in $CH_3(CH_2)_n$

Show your working. [3 marks]

n _____

[Turn over]

0 1 . 3

A 1.450 g sample of coconut oil is heated with 0.421 g of KOH in aqueous ethanol until all of the triester is hydrolysed.
The mixture is cooled.
The remaining KOH is neutralised by exactly 15.65 cm^3 of 0.100 mol dm^{-3} HCl

Calculate the percentage by mass of the triester (M_r = 638.0) in the coconut oil. [6 marks]

Percentage by mass _____

[Turn over]

0 1 . 4

Suggest why aqueous ethanol is a suitable solvent when heating the coconut oil with KOH.

Give a safety precaution used when heating the mixture.
Justify your choice. [3 marks]

Reason _____

_____

_____

Safety precaution _____

_____

_____

Justification _____

_____

_____

15

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[Turn over]

0 2

This question is about fuels.

0 2 . 1

The petrol fraction obtained from crude oil can be used as fuel in cars.

State the meaning of fraction, as used in the term petrol fraction. [1 mark]

0 2 . 2

Hexadecane ($C_{16}H_{34}$) can be cracked at high temperature to form petrol.

Complete the equation, on the opposite page, to show the cracking of one molecule of hexadecane to form hexane and cyclopentane only.

Give the name of a catalyst used in this cracking reaction. [3 marks]

$C_{16}H_{34} \longrightarrow$ _____ + _____

Catalyst _____

_____

0 2 . 3

Carbon dioxide is formed when petrol is burned. Carbon dioxide acts as a greenhouse gas when it absorbs infrared radiation.

Give a reason why carbon dioxide absorbs infrared radiation. [1 mark]

_____

_____

_____

_____

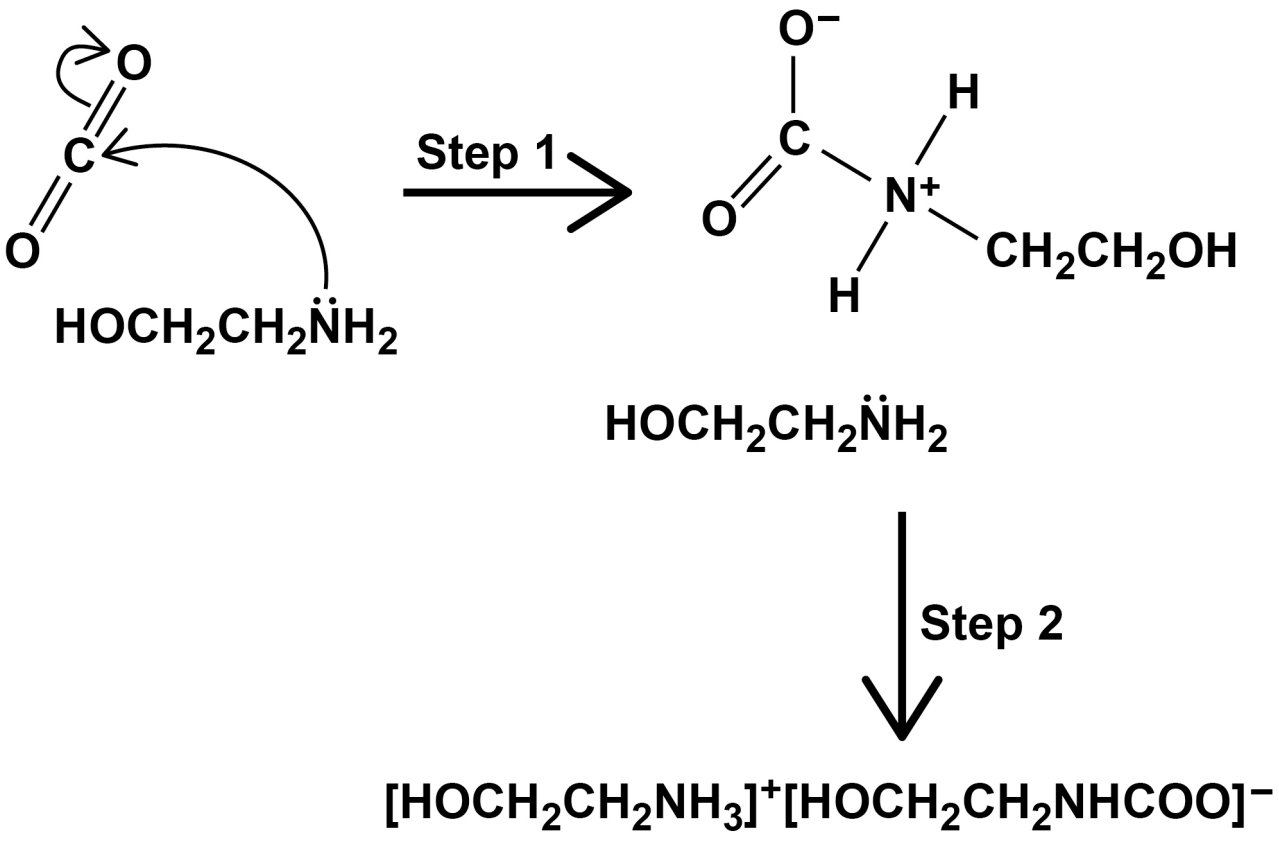
[Turn over]

0 2 . 4

Compound Z ($HOCH_2CH_2NH_2$) can be used to remove carbon dioxide from the mixture of waste gases produced in some power stations.

FIGURE 1 shows part of a suggested mechanism for the reaction of Z with carbon dioxide.

FIGURE 1



Draw TWO curly arrows to complete the mechanism in FIGURE 1.

Name compound Z ($HOCH_2CH_2NH_2$)

Deduce the role of Z in step 2 of the mechanism.
[4 marks]

Name _____

Role _____

_____

_____

[Turn over]

0 2 . 5

$HOCH_2CH_2NH_2$ can be represented as XNH_2
$[HOCH_2CH_2NH_3]^+$ can be represented as $[XNH_3]^+$

Draw the shape of XNH_2 and of $[XNH_3]^+$

State whether the H–N–H bond angle in XNH_2 is greater than, the same as, or smaller than that in $[XNH_3]^+$

Explain your answer. [4 marks]

Shape of XNH_2

Shape of $[XNH_3]^+$

Bond angle _____

_____

Explanation _____

_____

_____

[Turn over]

0 2 . 6

Bioethanol is used as an alternative to fossil fuels.

This statement appeared on a website.

"The fact that bioethanol is a carbon-neutral fuel outweighs the environmental disadvantages of producing bioethanol."

Evaluate this statement.

In your answer you should include:

- **an outline of how bioethanol is produced**
- **relevant equations**
- **analysis of the environmental impacts.**

[6 marks]

[Turn over]

[Turn over]

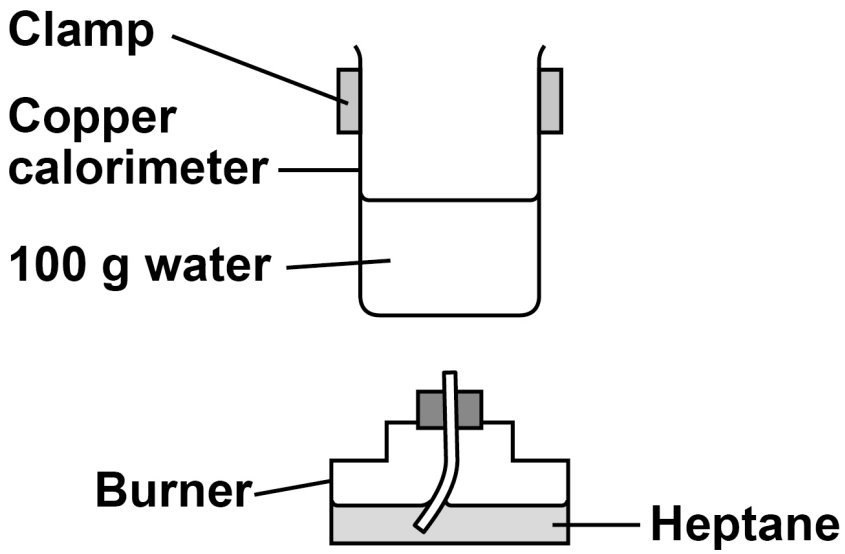
[Turn over]

19

0 3

A student does an experiment to determine a value for the enthalpy of combustion of heptane.
FIGURE 2 shows some of the apparatus used.

FIGURE 2



0 3 . 1

Design a table to record all the readings necessary to determine an experimental value for the enthalpy of combustion for heptane in this experiment. [2 marks]

[Turn over]

0 3 . 2

The student considered using a glass beaker on a tripod and gauze instead of the clamped copper calorimeter.

Suggest TWO disadvantages of using a glass beaker on a tripod and gauze. [2 marks]

Disadvantage 1 _____

_____

_____

Disadvantage 2 _____

_____

_____

0 3 . 3

Suggest TWO reasons why the value of enthalpy of combustion from this experiment is less exothermic than a data book value. [2 marks]

Reason 1 _____

_____

_____

Reason 2 _____

_____

_____

0 3 . 4

Suggest ONE addition to this apparatus that would improve the accuracy of the enthalpy value obtained. [1 mark]

_____

_____

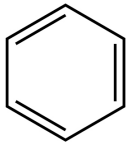
_____

[Turn over]

7

0 4

Kekulé suggested this structure for benzene.



Benzene is now represented by this structure.

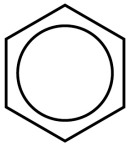
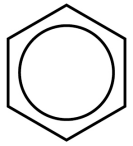


FIGURE 3, on the opposite page, shows the relative stability of



compared to

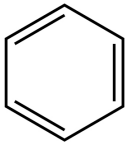
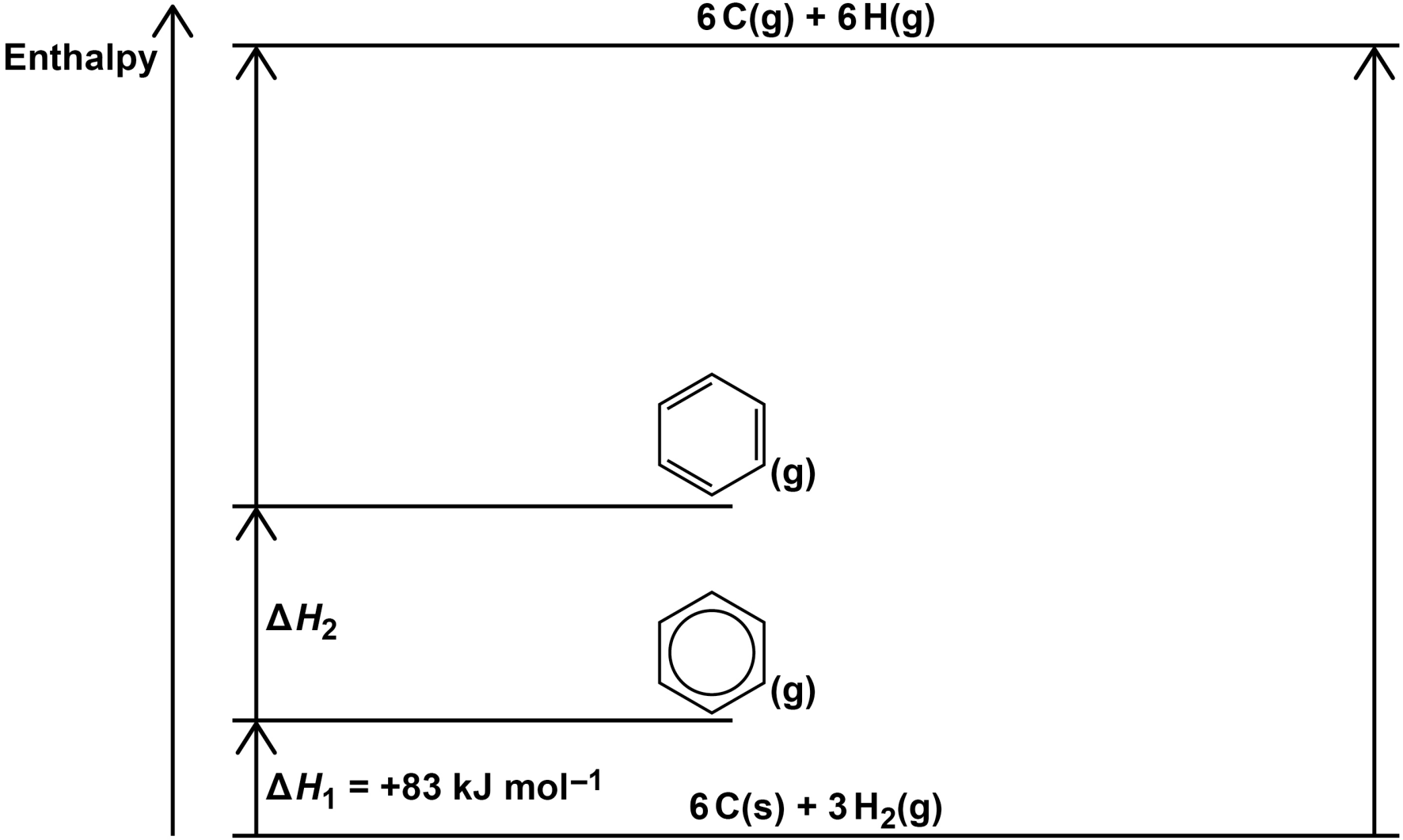


FIGURE 3



[Turn over]

0 4 . 1

Use FIGURE 3 and the data shown in TABLE 1 to calculate ΔH_2 [3 marks]

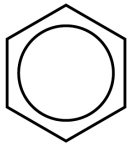
TABLE 1

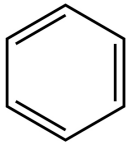
	ΔH / kJ mol^{-1}
Enthalpy of atomisation for carbon	+715
Enthalpy of atomisation for hydrogen	+218
Bond enthalpy (C–C)	+348
Bond enthalpy (C=C)	+612
Bond enthalpy (C–H)	+412

ΔH_2 _____ kJ mol^{-1}

[Turn over]

0 4 . 2

Explain, in terms of structure and bonding, why 

is more thermodynamically stable than 

[1 mark]

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[Turn over]

0 4 . 3

A mixture of concentrated nitric acid and concentrated sulfuric acid reacts with benzene.

FIGURE 4, on pages 36 and 37, shows the incomplete mechanism for this reaction.

Name the mechanism.

Complete the mechanism in FIGURE 4, on pages 36 and 37, by adding

- **any lone pairs of electrons involved in each step**
- **TWO curly arrows in step 1**
- **a curly arrow in step 2**
- **a curly arrow in step 3**
- **a curly arrow in step 4.**

[5 marks]

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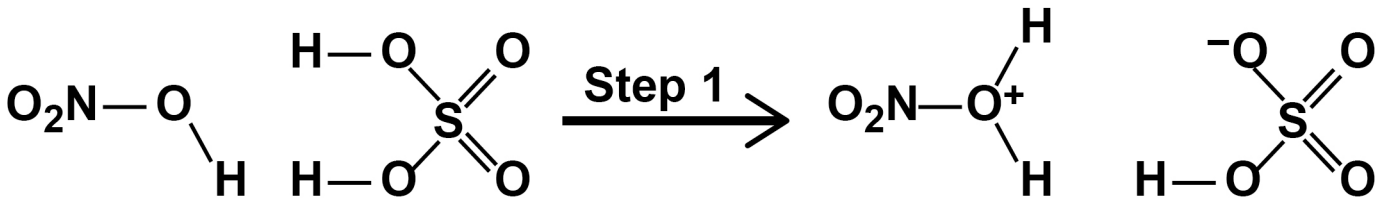
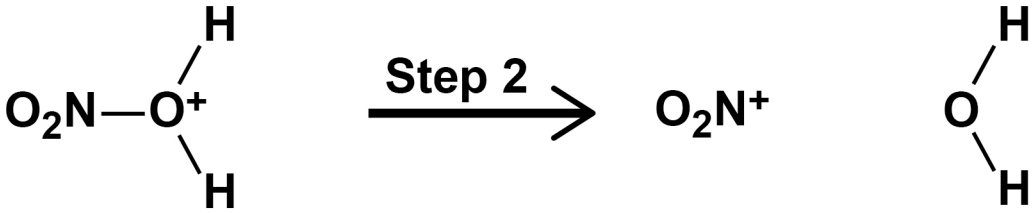
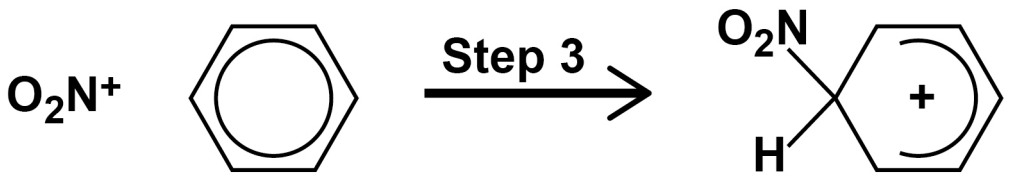
[Turn over]

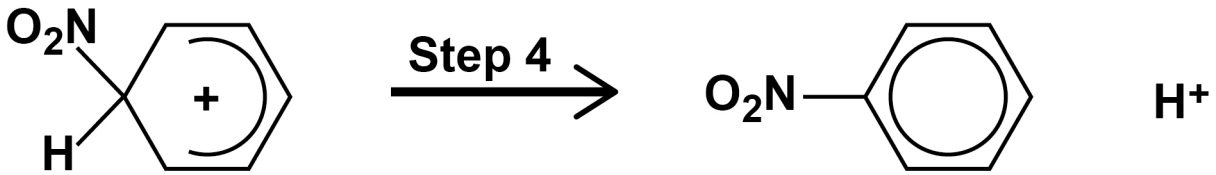
Name of mechanism _____

FIGURE 4









[Turn over]

9

0 5

This question is about equilibrium.

0 5 . 1

1 mol of a diester with molecular formula $C_7H_{12}O_4$ is added to 1 mol of water in the presence of a small amount of catalyst.

The mixture is left to reach equilibrium at a constant temperature.

$$C_7H_{12}O_4(l) + 2\,H_2O(l) \rightleftharpoons$$

$$2\,CH_3COOH(l) + HO(CH_2)_3OH(l)$$

At equilibrium, x mol of ethanoic acid are present in the mixture.

Complete TABLE 2, on the opposite page, by deducing the amounts, in terms of x, of the diester, water and diol present in the equilibrium mixture. [3 marks]

TABLE 2

Amount in the mixture / mol				
	Diester	**Water**	**Acid**	**Diol**
At the start	**1**	**1**	**0**	**0**
At equilibrium			x	

0 5 . 2

Deduce the structure of the diester in Question 05.1
[1 mark]

[Turn over]

0 5 . 3

A new equilibrium mixture of the substances from Question 05.1 is prepared at a different temperature.

$$C_7H_{12}O_4(l) + 2\ H_2O(l) \rightleftharpoons$$

$$2\ CH_3COOH(l) + HO(CH_2)_3OH(l)$$

TABLE 3 shows the amount of each substance in this new equilibrium mixture.

TABLE 3

Amount in the mixture / mol				
	Diester	**Water**	**Acid**	**Diol**
At equilibrium	**0.971**	**To be calculated**	**0.452**	**0.273**

The value of the equilibrium constant, K_c is 0.161 at this temperature.

Calculate the amount of water, in mol, in this new equilibrium mixture.

Show your working. [3 marks]

Amount of water _____ **mol**

[Turn over]

7

0 6

This question is about isomers with the molecular formula $C_5H_{10}O$

0 6 . 1

Draw the skeletal formula of a branched chain aldehyde with molecular formula $C_5H_{10}O$ that is optically active.

[1 mark]

0 6 . 2

Describe how you distinguish between separate samples of the two enantiomers of the branched chain aldehyde $C_5H_{10}O$ [2 marks]

0 6 . 3

Draw the *E* and *Z* forms of a structural isomer of $C_5H_{10}O$ that shows BOTH optical and geometric isomerism. [2 marks]

***E* isomer**	***Z* isomer**

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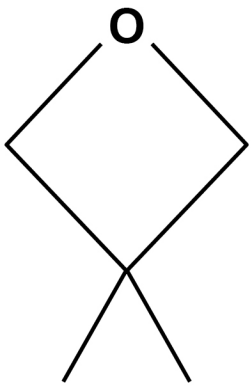
[Turn over]

0 6 . 4

Isomer J is cyclic and has an ether functional group (C–O–C)
Isomer J has only three peaks in its ^{13}C NMR spectrum.

Isomer J



Draw TWO other cyclic isomers of $C_5H_{10}O$ that have an ether functional group and only three peaks in their ^{13}C NMR spectra. [2 marks]

[Turn over]

7

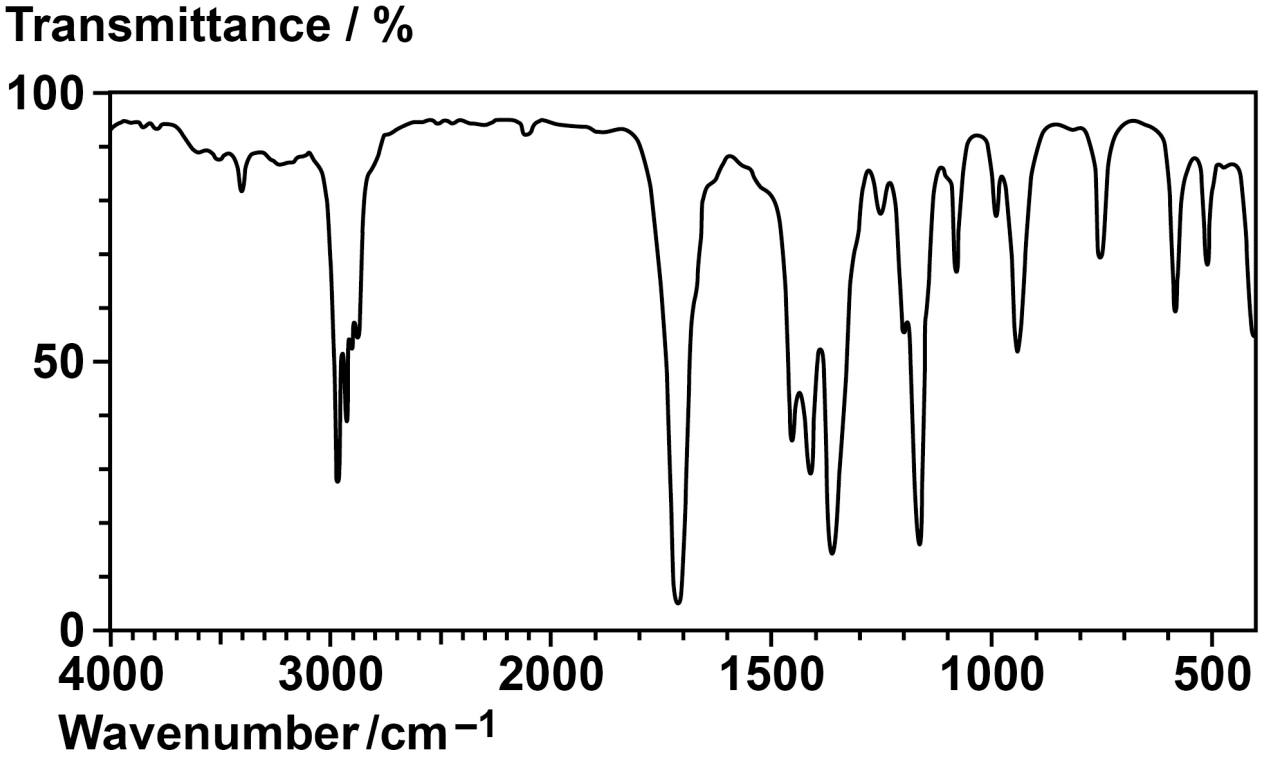
0 7

This question is about spectroscopy.

0 7 . 1

Compound K has molecular formula C_4H_8O
FIGURE 5 shows the infrared spectrum of K.

FIGURE 5



Which functional group does K contain? [1 mark]

Tick (✓) ONE box.

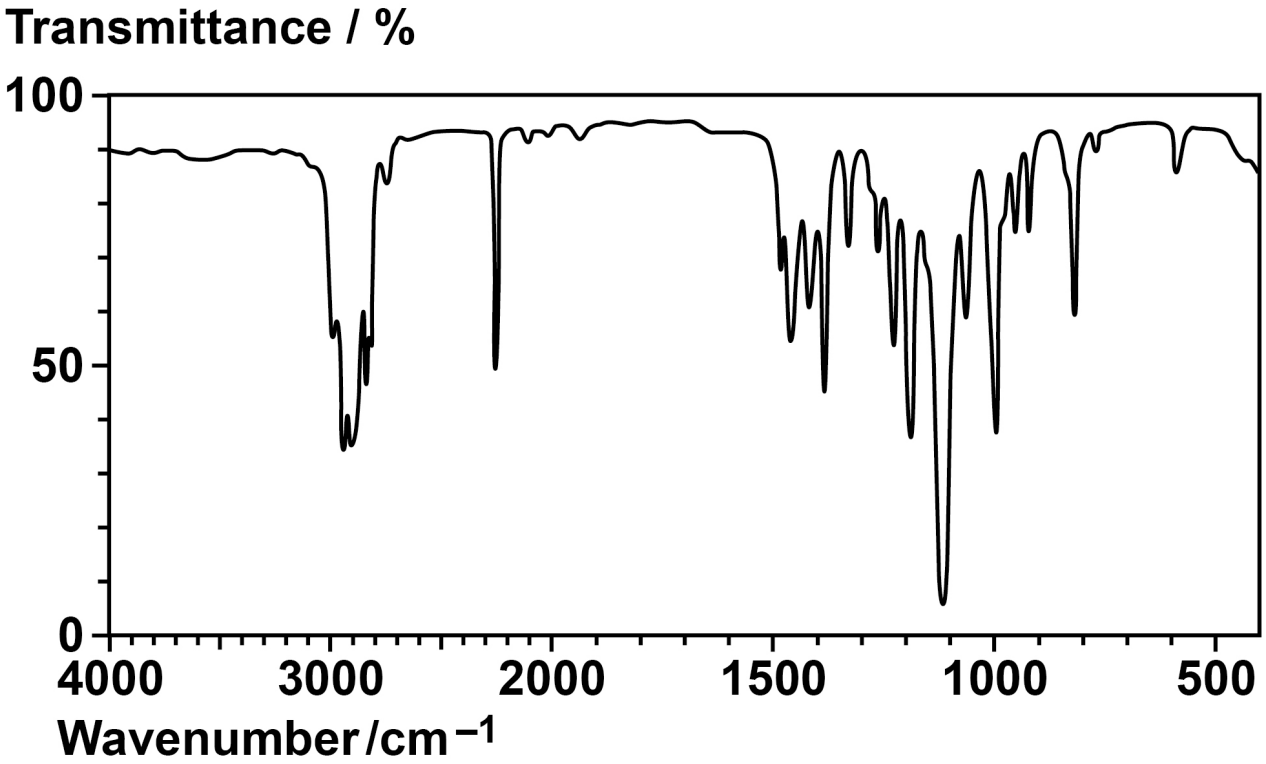
Functional Group				
alcohol	**alkene**	**amine**	**carbonyl**	**nitrile**

[Turn over]

0 7 . 2

Compound L has molecular formula C_4H_7NO
FIGURE 6 shows the infrared spectrum of L.

FIGURE 6



L reacts with H_2 in the presence of a nickel catalyst to give compound M.

Suggest THREE ways in which the infrared spectrum of M is different from the infrared spectrum of L. [3 marks]

1 _____

_____

_____

2 _____

_____

_____

3 _____

_____

_____

[Turn over]

0 7 . 3

FIGURE 7 shows the ^{1}H NMR spectrum of Q, C_3H_7ClO

FIGURE 7

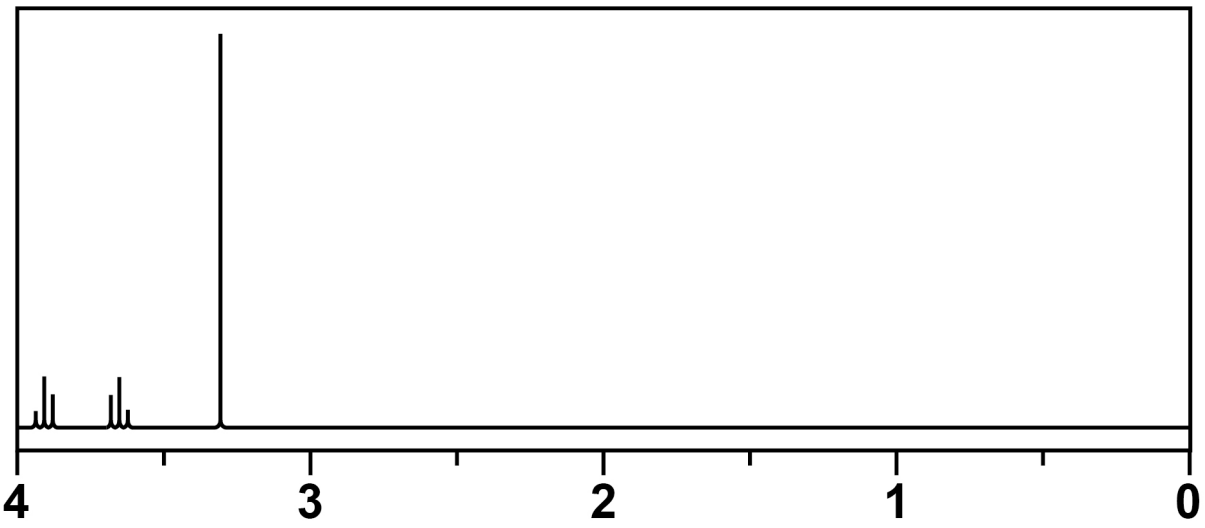


TABLE 4 shows the chemical shifts (δ values) and integration values for each peak.

TABLE 4

δ value / ppm	3.95	3.65	3.35
Integration value	0.6	0.6	0.9

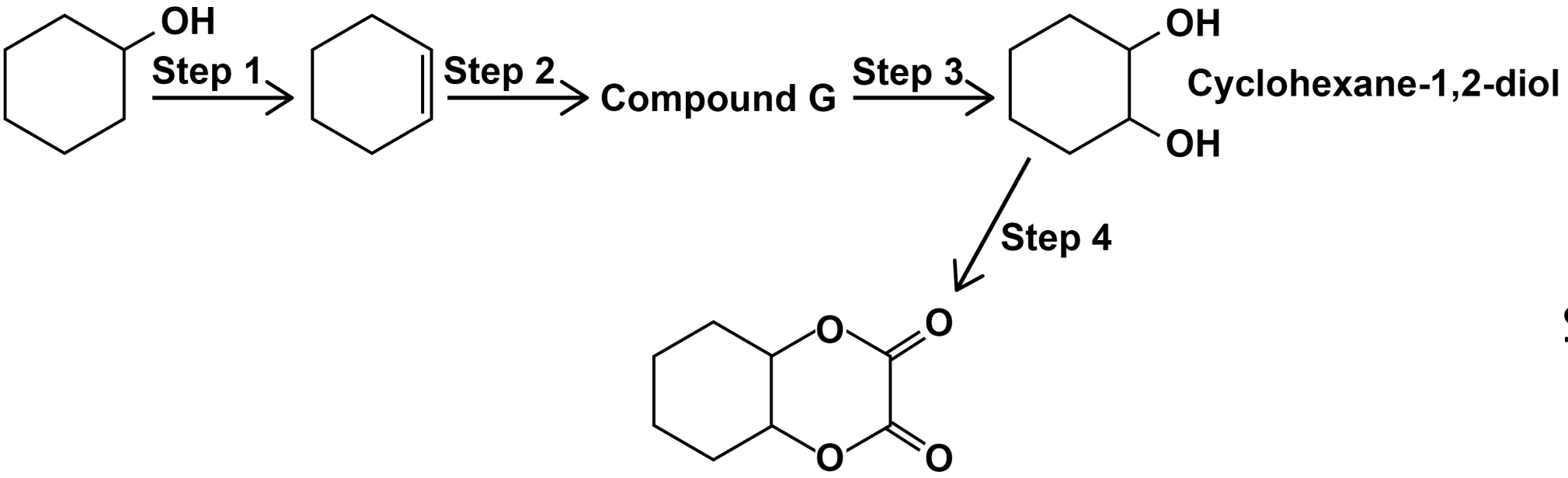
Deduce the structure of Q.

Explain your answer. [5 marks]

9

0 8

This question is about making a diester from cyclohexanol.



0 8 . 1

State the type of reaction in step 1.

Give the name of the reagent needed for step 1. [2 marks]

Type of reaction _____

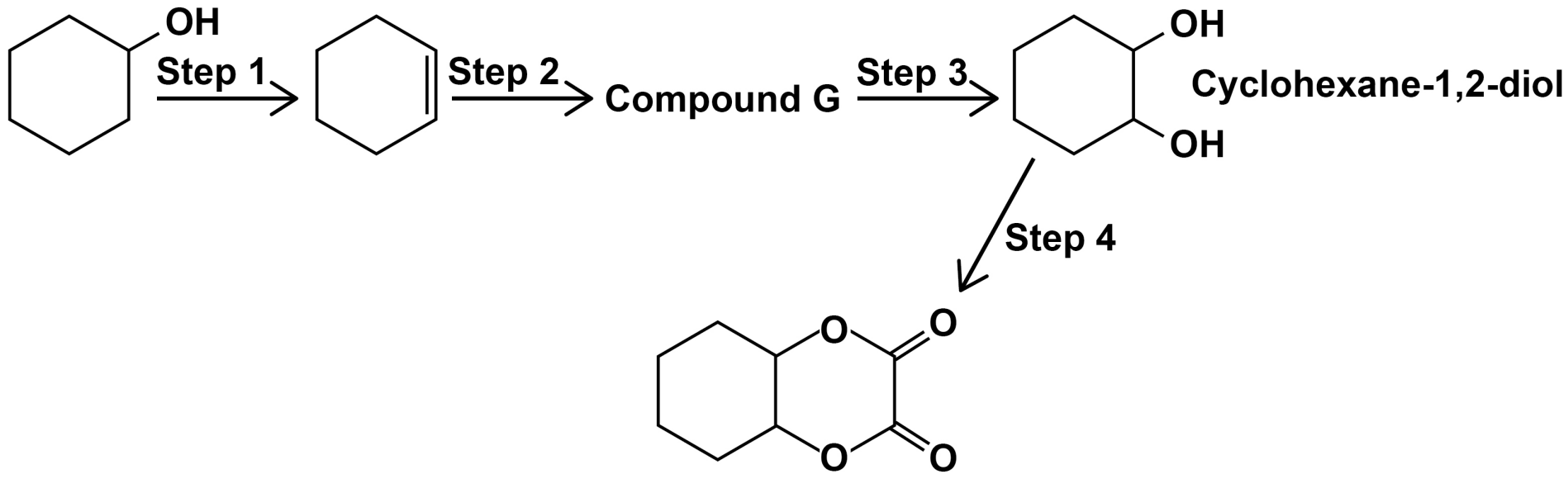
_____

Reagent _____

_____

[Turn over]

REPEAT OF DIAGRAM



0 8 . 2

State the reagents needed and give equations for step 2 and step 3.

Show the structure of Compound G in your equations. [4 marks]

Step 2 reagent _____

_____

Step 2 equation

Step 3 reagent _____

Step 3 equation

[Turn over]

0 8 . 3

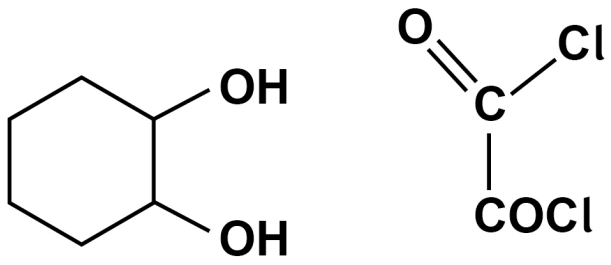
Cyclohexane-1,2-diol reacts with ethanedioyl dichloride.

Give the name of the mechanism for this reaction.

Complete the mechanism to show the formation of ONE ester link in the first step of this reaction. [5 marks]

Mechanism name _____

Mechanism



0 8 . 4

Suggest why chemists usually aim to design production methods

- **with fewer steps**
- **with a high percentage atom economy.**

[2 marks]

Fewer steps _____

_____

_____

_____

High percentage atom economy _____

_____

_____

_____

[Turn over]

13

0 9

This question is about the ozone layer in the upper atmosphere.

0 9 . 1

State why the ozone layer is beneficial for living organisms. [1 mark]

0 9 . 2

State how chlorofluorocarbons (CFCs) form chlorine atoms in the upper atmosphere. [1 mark]

0 9 . 3

Give equations to show how chlorine atoms catalyse the decomposition of ozone. [2 marks]

_____

_____

[Turn over]

0 9 . 4

Hydrochlorofluorocarbons (HCFCs) have been used in place of CFCs.
In the mechanism to make an HCFC from a fluoroalkane, two incomplete steps are shown.

Complete each step in the mechanism.

Give the name of the type of step shown by both these equations. [3 marks]

$$\underline{\qquad\qquad\qquad} \longrightarrow \bullet CHF_2 + HCl$$

$$\bullet CHF_2 + Cl_2 \longrightarrow \underline{\qquad\qquad\qquad}$$

Type of step _____

7

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[Turn over]

1 0

This question is about rates of reaction.

Iodine and propanone react together in an acid-catalysed reaction

$$CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_3COCH_2I(aq) + HI(aq)$$

A student completed a series of experiments to determine the order of reaction with respect to iodine.

Method

- **Transfer 25 cm^3 of 1.0 mol dm^{-3} propanone solution into a conical flask.**
- **Add 10 cm^3 of 1.0 mol dm^{-3} HCl(aq)**
- **Add 25 cm^3 of 5.0×10^{-3} mol dm^{-3} $I_2(aq)$ and start a timer.**
- **At intervals of 1 minute, remove a 1.0 cm^3 sample of the mixture and add each sample to a separate beaker containing an excess of $NaHCO_3(aq)$**
- **Titrate the contents of each beaker with a standard solution of sodium thiosulfate and record the volume of sodium thiosulfate used.**

1 0 . 1

Suggest why the 1.0 cm^3 portions of the reaction mixture are added to an excess of $NaHCO_3$ solution.

[2 marks]

[Turn over]

1 0 . 2

Suggest why the order of this reaction with respect to propanone can be ignored in this experiment. [2 marks]

BLANK PAGE

[Turn over]

The volume of sodium thiosulfate solution used in each titration is proportional to the concentration of iodine in each beaker.

TABLE 5 shows the results of the experiment.

TABLE 5

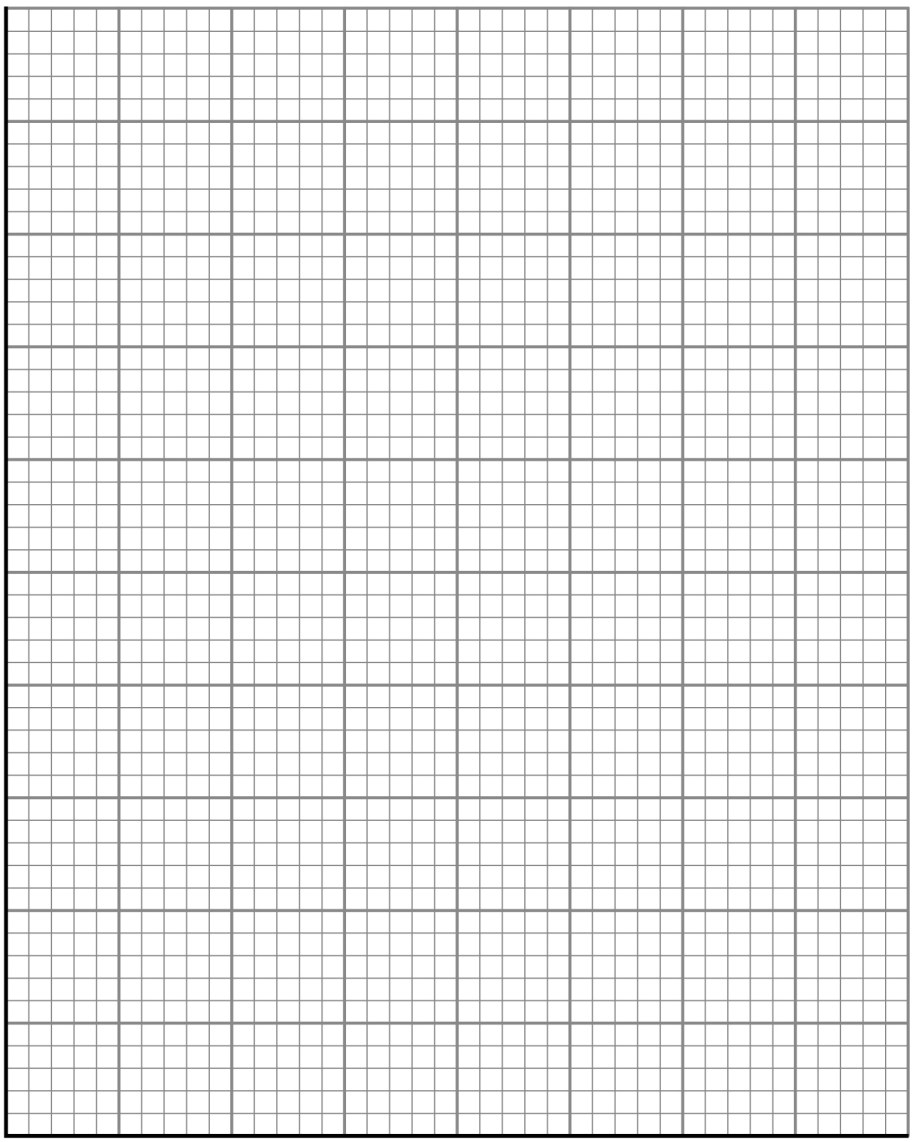
Time / minutes	Volume of sodium thiosulfate solution / cm^3
1	41
2	35
3	24
4	22
5	16
6	10

1 0 . 3

Use the results in TABLE 5 to draw a graph of volume of sodium thiosulfate solution against time.

Draw a line of best fit. [3 marks]

Volume of sodium thiosulfate solution / cm^3



Time / minutes

[Turn over]

1 0 . 4

Explain how the graph shows that the reaction is zero-order with respect to iodine in the reaction between propanone and iodine. [2 marks]

1 0 . 5

The Arrhenius equation can be written as

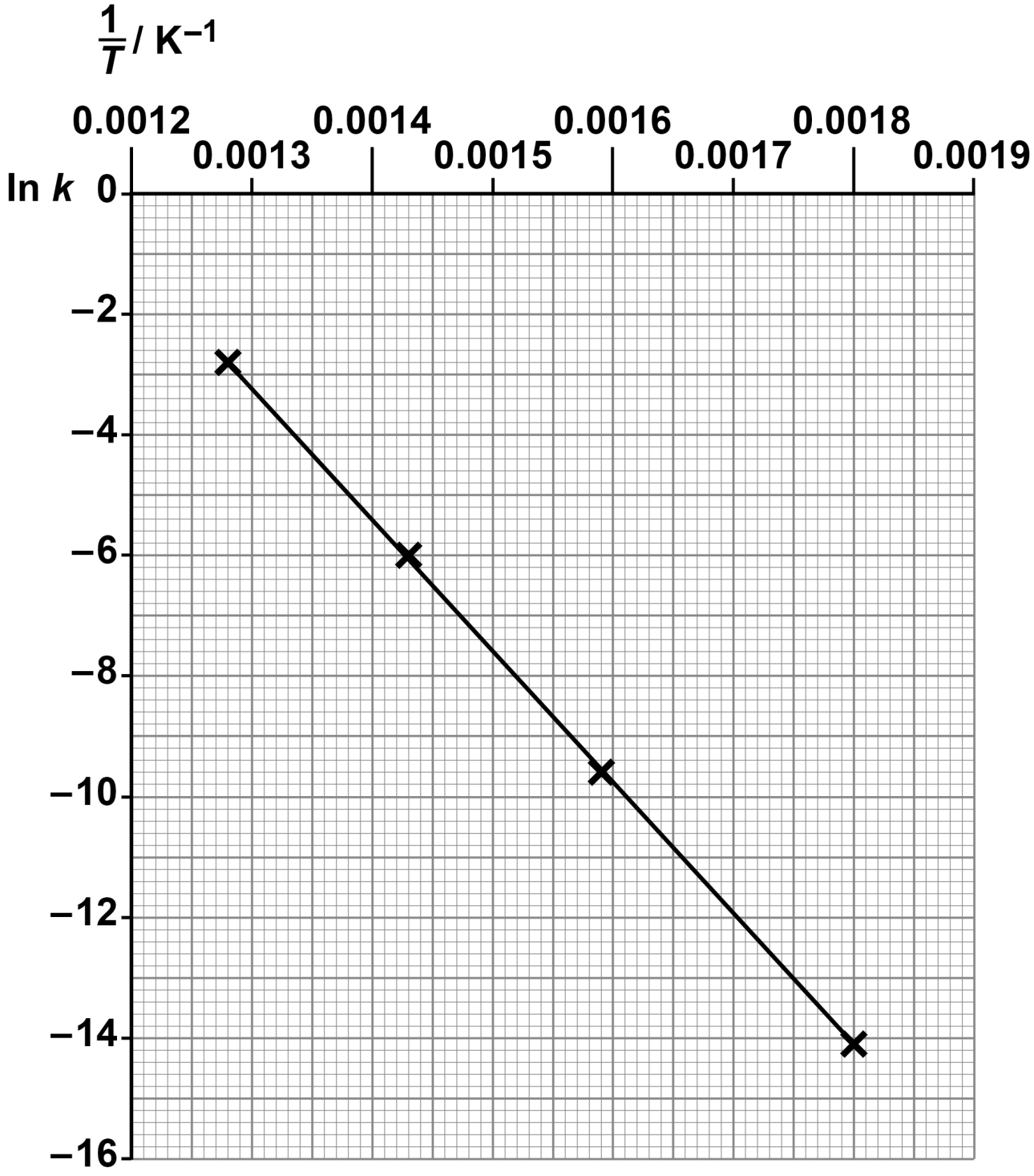
$$\ln k = \frac{-E_a}{RT} + \ln A$$

FIGURE 8, page 72, shows a graph of ln *k* against $\frac{1}{T}$ for the reaction

$2\,HI(g) \longrightarrow H_2(g) + I_2(g)$

[Turn over]

FIGURE 8


1/T / K⁻¹
0.0012
0.0013
0.0014
0.0015
0.0016
0.0017
0.0018
0.0019
ln k
0
−2
−4
−6
−8
−10
−12
−14
−16

Use FIGURE 8 to calculate a value for the activation energy (E_a), in kJ mol^{-1}, for this reaction.

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

[3 marks]

E_a _____ **kJ mol^{-1}**

END OF QUESTIONS

12

Additional page, if required.
Write the question numbers in the left-hand margin.

Additional page, if required.
Write the question numbers in the left-hand margin.

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For Examiner's Use	
Question	Mark
1	
2	
3	
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9	
10	
TOTAL	

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