

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

I declare this is my own work.

A-level CHEMISTRY

Paper 2 Organic and Physical Chemistry

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.

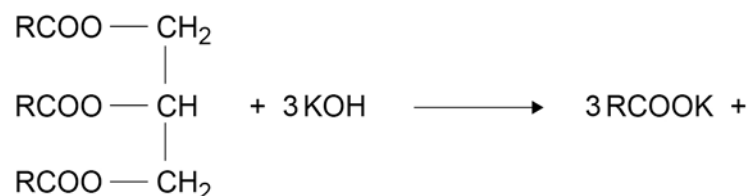
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	



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.



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 _____

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 $\text{CH}_3(\text{CH}_2)_n$

Deduce the value of n in $\text{CH}_3(\text{CH}_2)_n$
Show your working.

[3 marks]

n _____



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 cm³ 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 _____

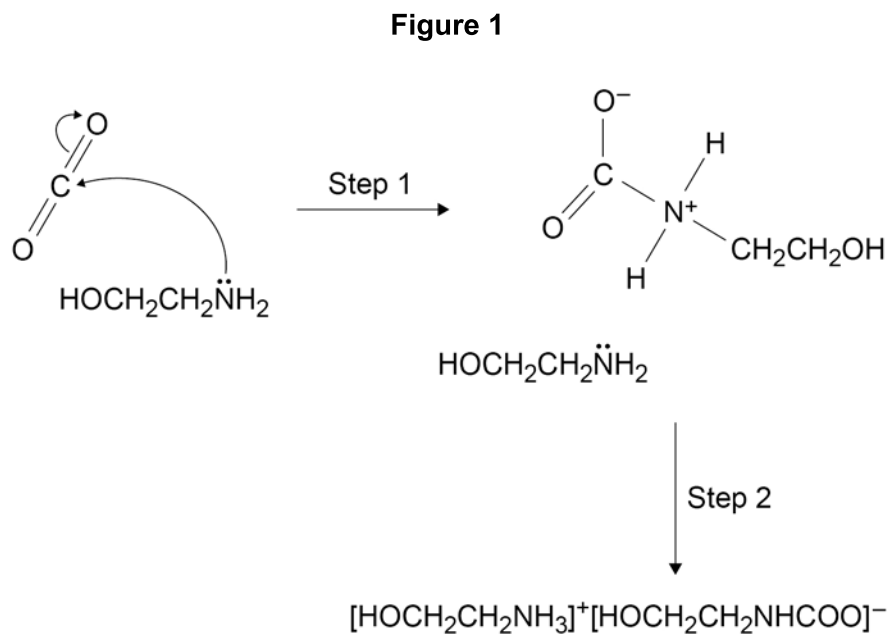
15



0 2 . 4

Compound **Z** ($\text{HOCH}_2\text{CH}_2\text{NH}_2$) 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.



Draw **two** curly arrows to complete the mechanism in **Figure 1**.

Name compound **Z** ($\text{HOCH}_2\text{CH}_2\text{NH}_2$)

Deduce the role of **Z** in step **2** of the mechanism.

[4 marks]

Name _____

Role _____



0 2 . 5

$\text{HOCH}_2\text{CH}_2\text{NH}_2$ can be represented as XNH_2
 $[\text{HOCH}_2\text{CH}_2\text{NH}_3]^+$ can be represented as $[\text{XNH}_3]^+$

Draw the shape of XNH_2 and of $[\text{XNH}_3]^+$

State whether the H–N–H bond angle in XNH_2 is greater than, the same as, or smaller than that in $[\text{XNH}_3]^+$

Explain your answer.

[4 marks]

Shape of XNH_2

Shape of $[\text{XNH}_3]^+$

Bond angle _____

Explanation _____

Question 2 continues on the next page

Turn over ►

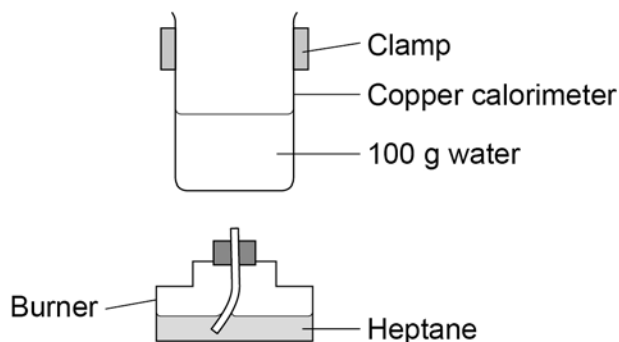


0 3

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]

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]

7**Turn over for the next question****Turn over ►**

0 4

Kekulé suggested this structure for benzene. 


Benzene is now represented by this structure. 



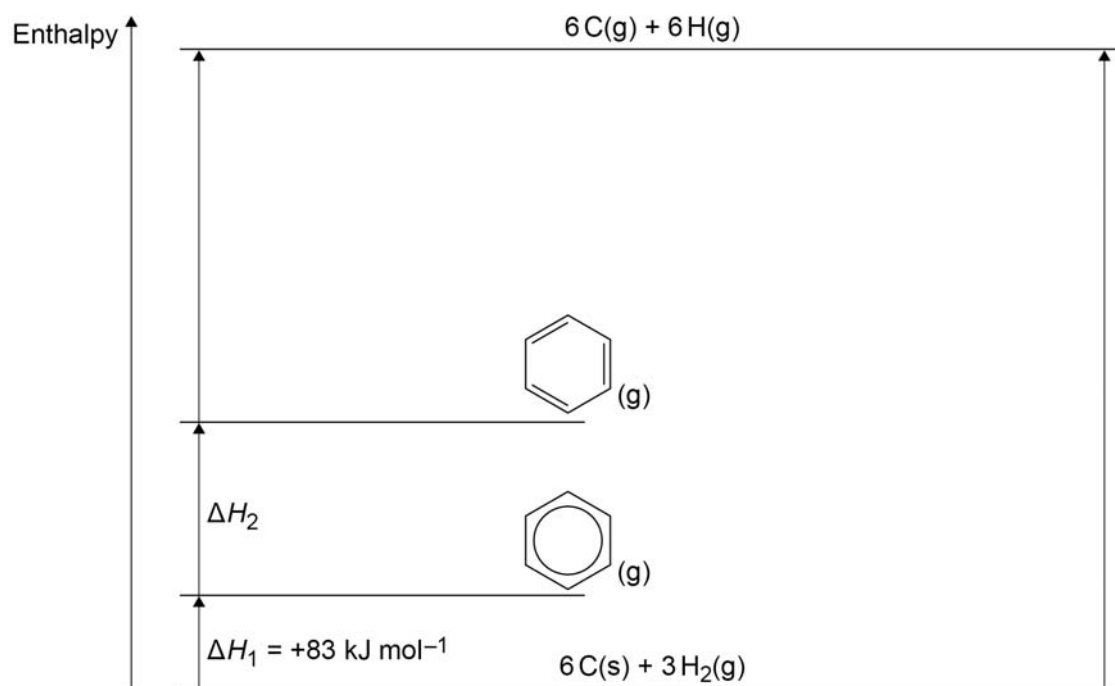
Figure 3 shows the relative stability of  compared to .

Figure 3

0 4 . 1 Use **Figure 3** and the data shown in **Table 1** to calculate ΔH_2

[3 marks]

Table 1

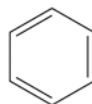
	$\Delta H / \text{kJ mol}^{-1}$
Enthalpy of atomisation for carbon	+715
Enthalpy of atomisation for hydrogen	+218
Bond enthalpy (C–C)	+348
Bond enthalpy (C=C)	+612
Bond enthalpy (C–H)	+412

ΔH_2 _____ kJ mol^{-1}

0 4 . 2 Explain, in terms of structure and bonding, why



is more thermodynamically stable than



[1 mark]

Turn over ►



0 4 . 3

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

Figure 4 shows the incomplete mechanism for this reaction.

Name the mechanism.

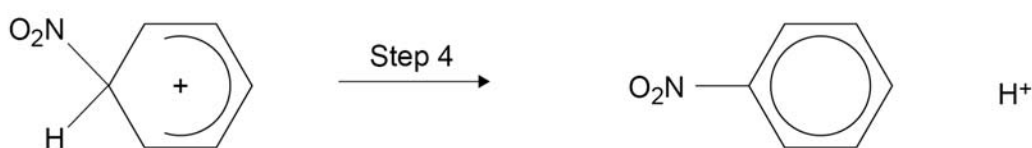
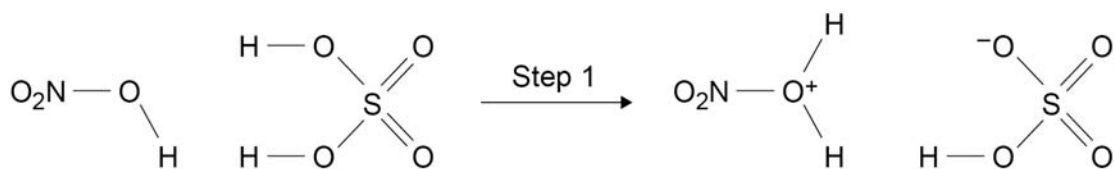
Complete the mechanism in **Figure 4** by adding

- 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]

Name of mechanism _____

Figure 4



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.



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

Complete **Table 2** 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]

Question 5 continues on the next page

Turn over ►



0 5 . 3

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

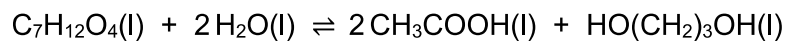


Table 3 shows the amount of each substance in this new equilibrium mixture.

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

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]

<i>E</i> isomer	<i>Z</i> isomer

Question 6 continues on the next page

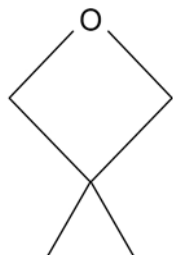
Turn over ►



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 $\text{C}_5\text{H}_{10}\text{O}$ that have an ether functional group and only three peaks in their ^{13}C NMR spectra.

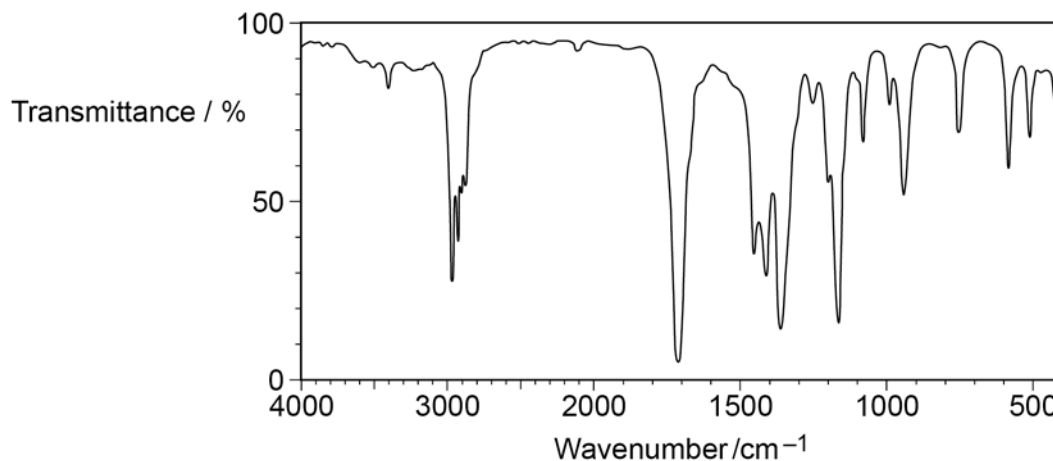
[2 marks]



0 7

This question is about spectroscopy.

0 7 . 1

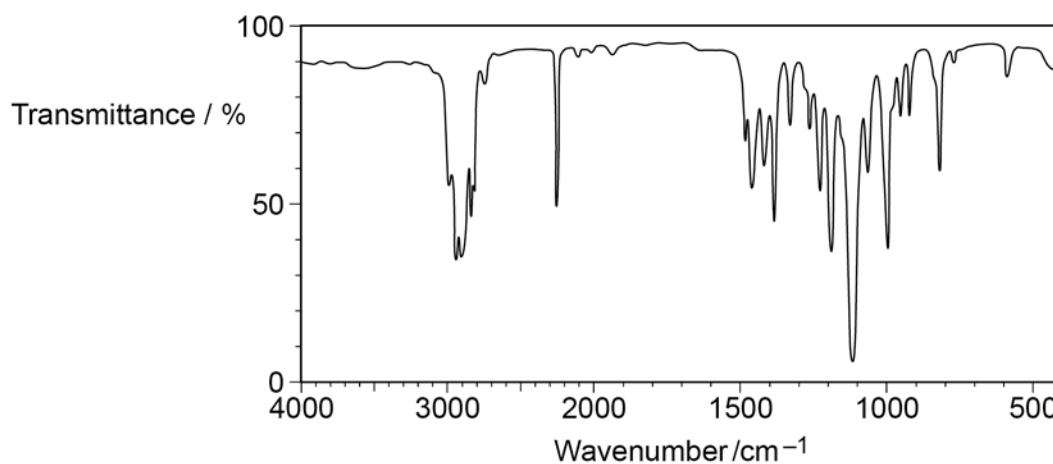
Compound **K** has molecular formula C_4H_8O **Figure 5** shows the infrared spectrum of **K**.**Figure 5**Which functional group does **K** contain?Tick (✓) **one** box.**[1 mark]**

Functional Group				
alcohol	alkene	amine	carbonyl	nitrile

Question 7 continues on the next page**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 _____



0 7 . 3

Figure 7 shows the ^1H NMR spectrum of **Q**, $\text{C}_3\text{H}_7\text{ClO}$

Figure 7

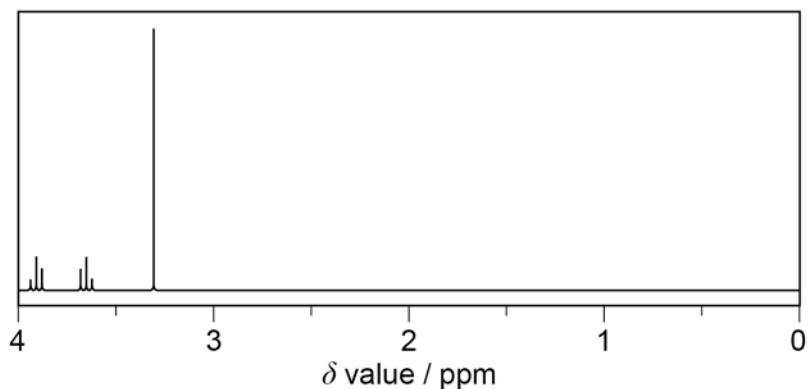
Table 4 shows the chemical shifts (δ values) and integration values for each peak.

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.

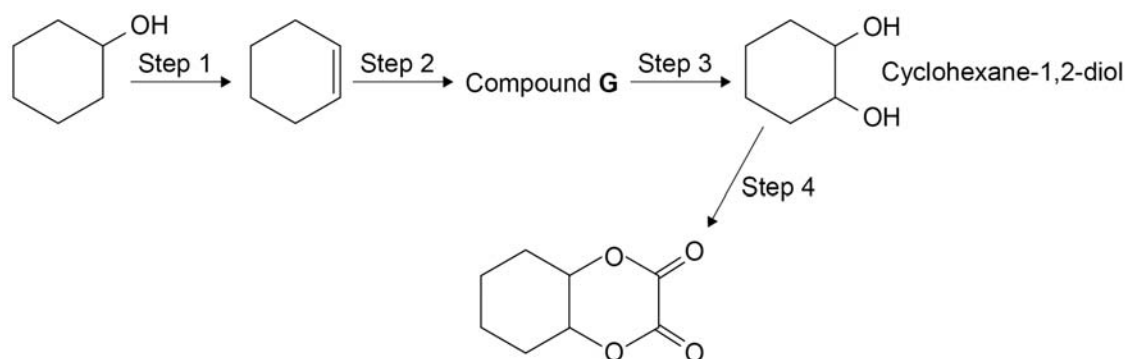
[5 marks]

Turn over ►



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 _____

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



0 8 . 3

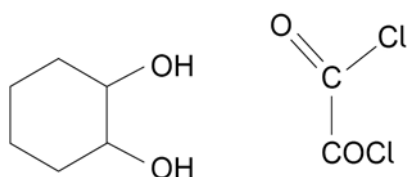
Cyclohexane-1,2-diol reacts with ethanedioyl dichloride.

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 _____

13

Turn over ►



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]

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]



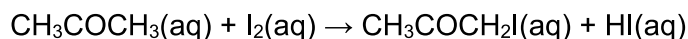
Type of step _____

7



1 0

This question is about rates of reaction.
Iodine and propanone react together in an acid-catalysed reaction



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

Method

- Transfer 25 cm³ of 1.0 mol dm⁻³ propanone solution into a conical flask.
- Add 10 cm³ of 1.0 mol dm⁻³ HCl(aq)
- Add 25 cm³ of 5.0 × 10⁻³ mol dm⁻³ I₂(aq) and start a timer.
- At intervals of 1 minute, remove a 1.0 cm³ sample of the mixture and add each sample to a separate beaker containing an excess of NaHCO₃(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 cm³ portions of the reaction mixture are added to an excess of NaHCO₃ solution.

[2 marks]

1 0 . 2

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

[2 marks]

Question 10 continues on the next 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

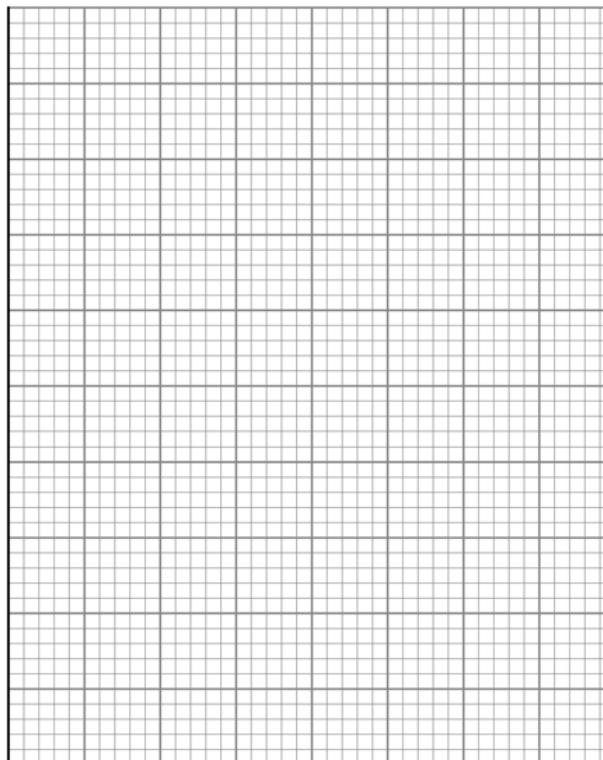
1 0 . 3

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 /
cm³



Time / minutes



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]

Question 10 continues on the next page

Turn over ►

1 0 . 5 The Arrhenius equation can be written as

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

Figure 8 shows a graph of $\ln k$ against $\frac{1}{T}$ for the reaction

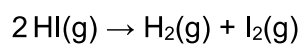
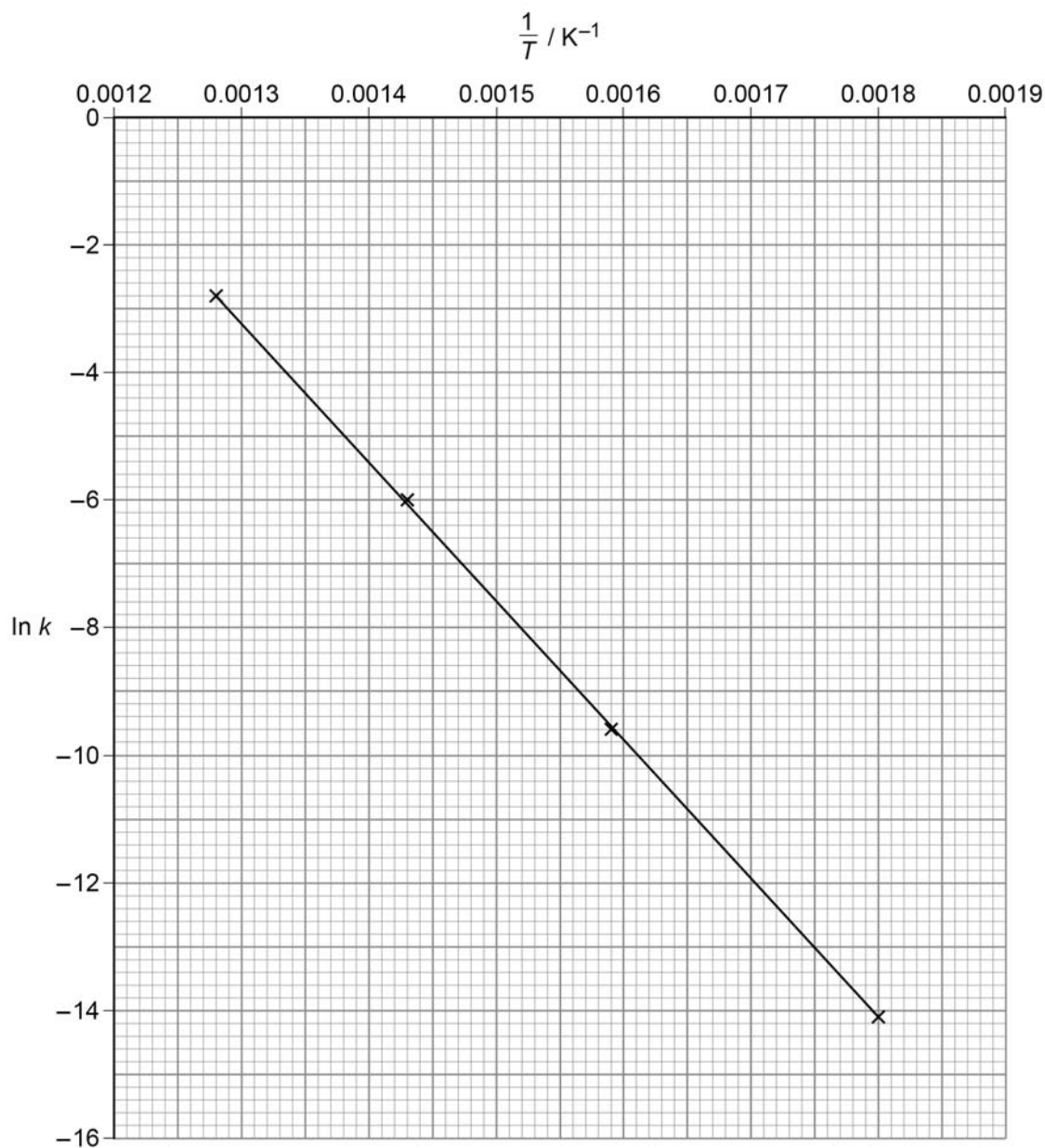


Figure 8



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

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

[3 marks]

E_a _____ kJ mol^{-1}

12

END OF QUESTIONS



There are no questions printed on this page

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outside the
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ANSWER IN THE SPACES PROVIDED**



