

Please write clearly in block capitals.

Centre number

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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.

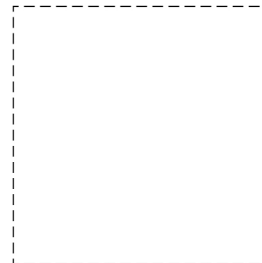
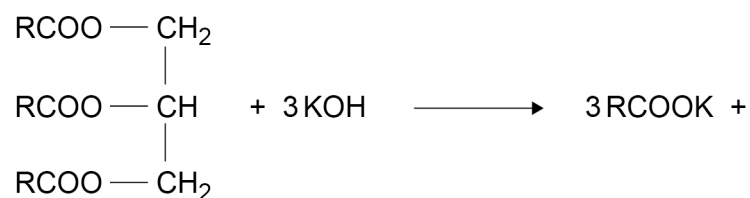
For Examiner's Use	
Question	Mark
1	
2	
3	
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8	
9	
10	
<b>TOTAL</b>	



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 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> 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** 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]**

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**0 2 . 2** Hexadecane ( $C_{16}H_{34}$ ) can be cracked at high temperature to form petrol.

Complete the equation 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]**



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]**

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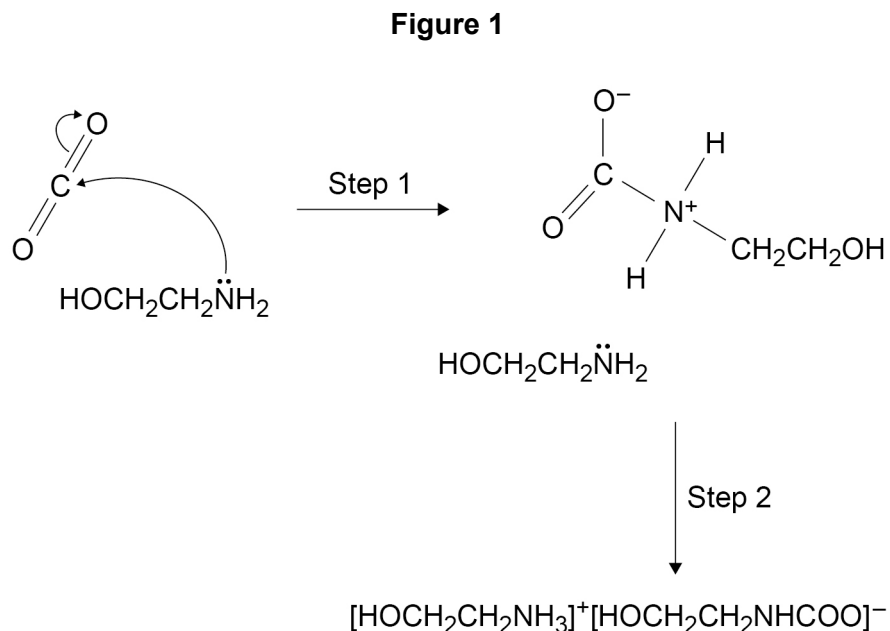
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0 2 . 4

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

HOCH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub> can be represented as XNH<sub>2</sub>  
[HOCH<sub>2</sub>CH<sub>2</sub>NH<sub>3</sub>]<sup>+</sup> can be represented as [XNH<sub>3</sub>]<sup>+</sup>

Draw the shape of XNH<sub>2</sub> and of [XNH<sub>3</sub>]<sup>+</sup>

State whether the H–N–H bond angle in XNH<sub>2</sub> is greater than, the same as, or smaller than that in [XNH<sub>3</sub>]<sup>+</sup>

Explain your answer.

**[4 marks]**

Shape of XNH<sub>2</sub>

Shape of [XNH<sub>3</sub>]<sup>+</sup>

Bond angle \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

**Question 2 continues on the next page**

**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]

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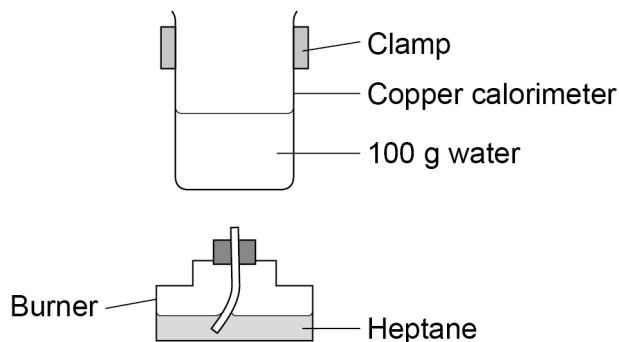


0 3

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]**


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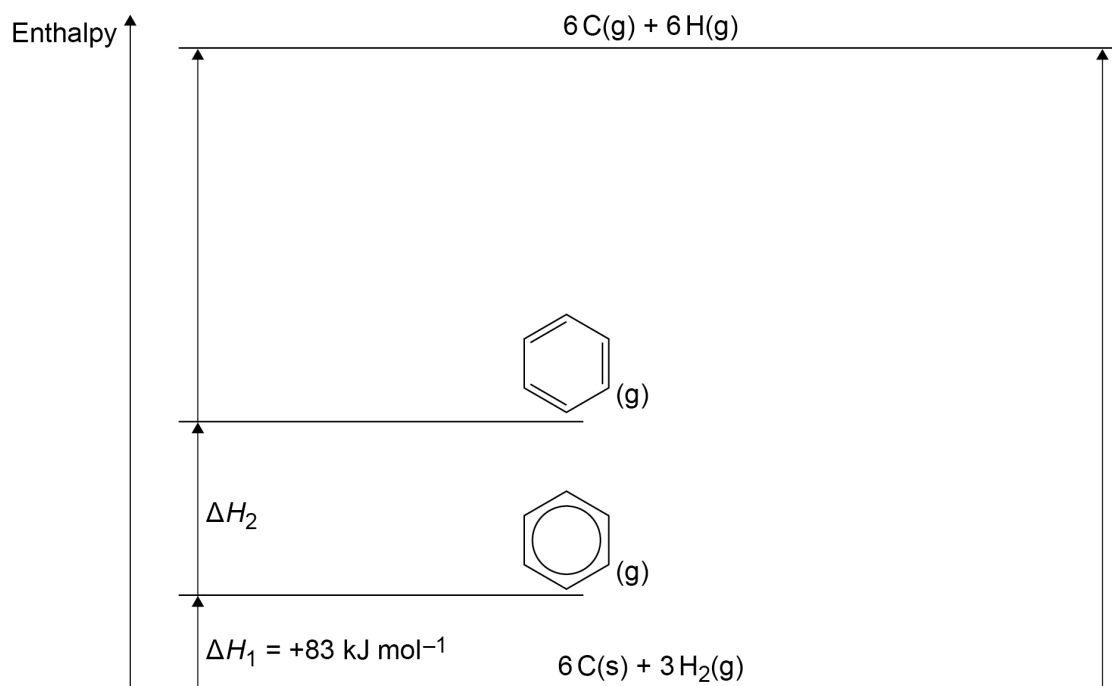
7**Turn over for the next question****Turn over ►**

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  $\Delta H_2$

[3 marks]

**Table 1**

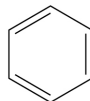
	$\Delta H / \text{kJ mol}^{-1}$
Enthalpy of atomisation for carbon	+715
Enthalpy of atomisation for hydrogen	+218
Bond enthalpy (C–C)	+348
Bond enthalpy (C=C)	+612
Bond enthalpy (C–H)	+412

$\Delta H_2$  \_\_\_\_\_  $\text{kJ mol}^{-1}$

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** shows the incomplete mechanism for this reaction.

Name the mechanism.

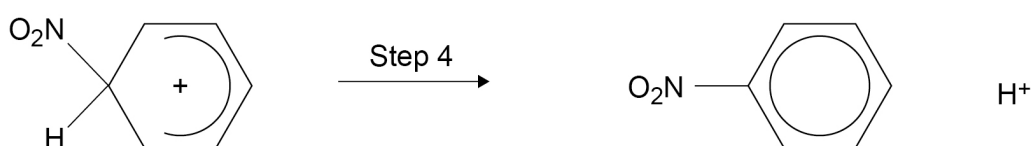
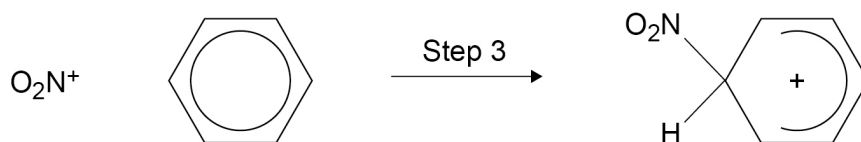
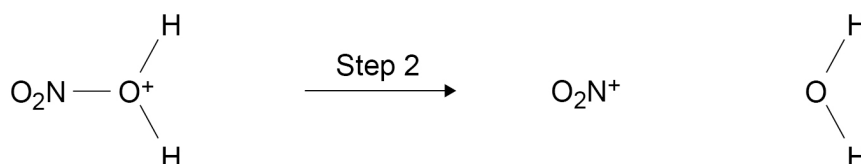
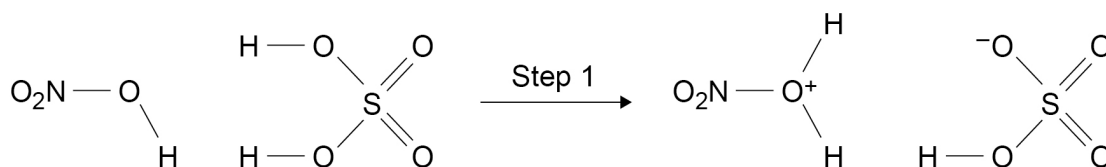
Complete the mechanism in **Figure 4** by adding

- 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**



9



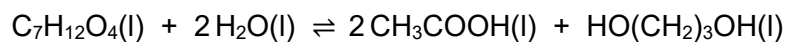
0 5

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.



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.

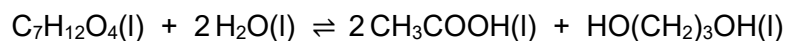


Table 3 shows the amount of each substance in this new equilibrium mixture.

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]**


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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

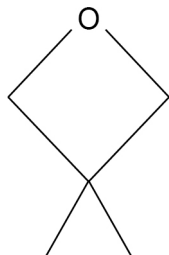
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0 6 . 4

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

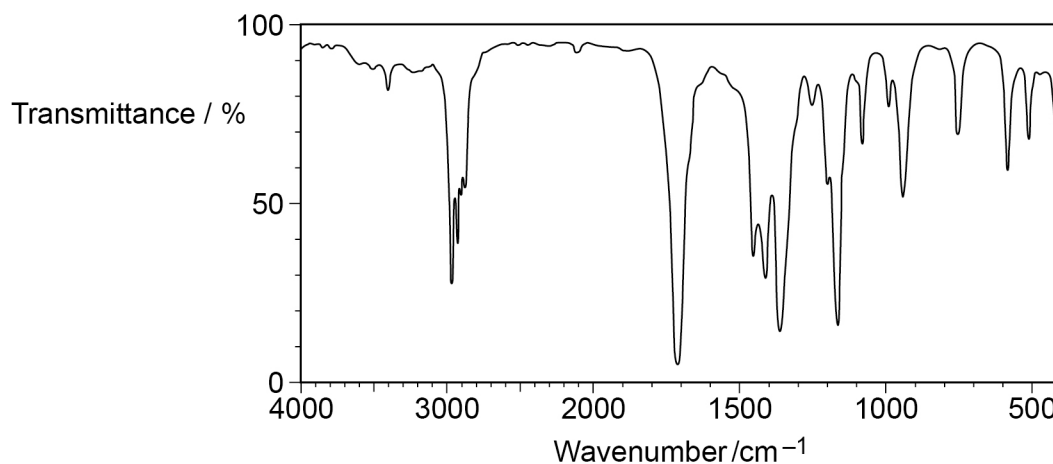
**[2 marks]**

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

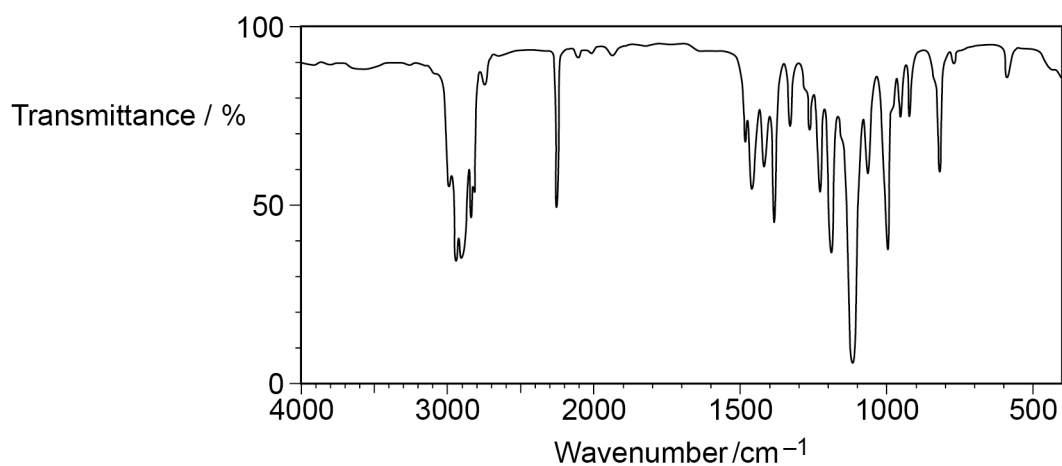
Question 7 continues on the next page

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 \_\_\_\_\_

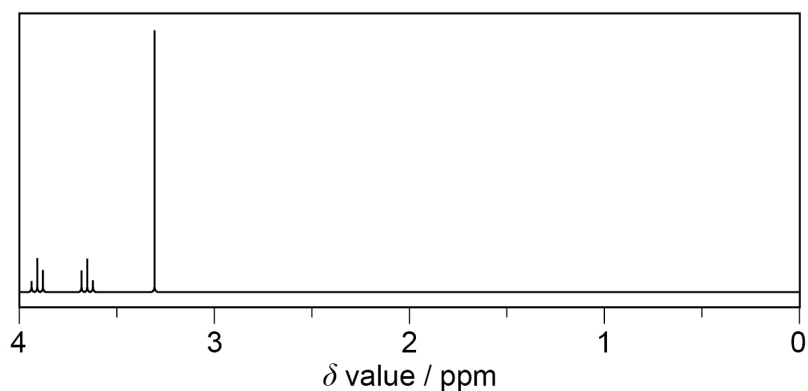
2 \_\_\_\_\_

3 \_\_\_\_\_



**0 7 . 3** Figure 7 shows the  $^1\text{H}$  NMR spectrum of **Q**,  $\text{C}_3\text{H}_7\text{ClO}$

**Figure 7**



**Table 4** shows the chemical shifts ( $\delta$  values) and integration values for each peak.

**Table 4**

$\delta$ 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]**

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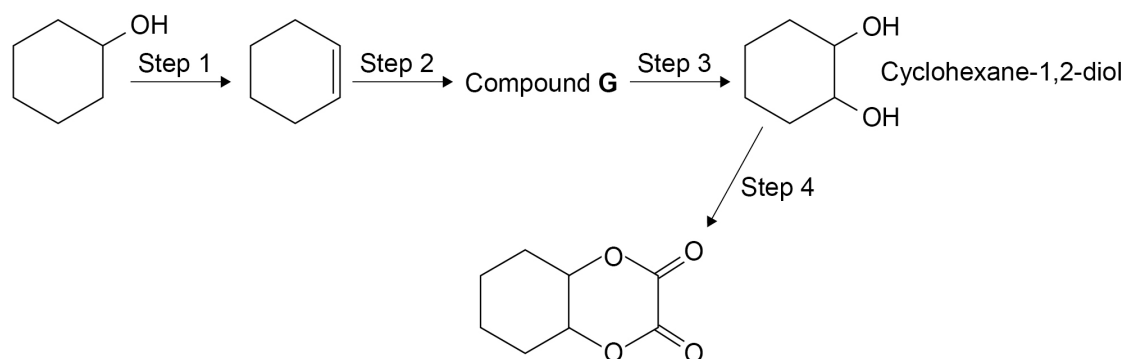
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0 8

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.

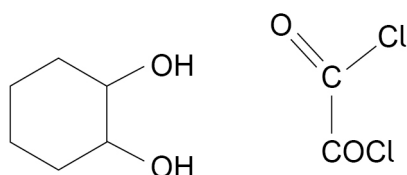
Give the name of the mechanism for this reaction.

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 \_\_\_\_\_

\_\_\_\_\_



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]

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0 9 . 2

State how chlorofluorocarbons (CFCs) form chlorine atoms in the upper atmosphere.

[1 mark]

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0 9 . 3

Give equations to show how chlorine atoms catalyse the decomposition of ozone.

[2 marks]

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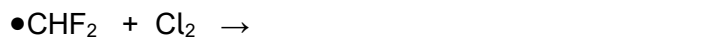
0 9 . 4

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 \_\_\_\_\_

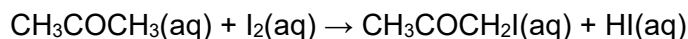
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**1 0**

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 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> propanone solution into a conical flask.
- Add 10 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> HCl(aq)
- Add 25 cm<sup>3</sup> of 5.0 × 10<sup>-3</sup> mol dm<sup>-3</sup> I<sub>2</sub>(aq) and start a timer.
- At intervals of 1 minute, remove a 1.0 cm<sup>3</sup> sample of the mixture and add each sample to a separate beaker containing an excess of NaHCO<sub>3</sub>(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<sup>3</sup> portions of the reaction mixture are added to an excess of NaHCO<sub>3</sub> solution.

**[2 marks]**

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**1 0 . 2**

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

**[2 marks]**

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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 <sup>3</sup>
1	41
2	35
3	24
4	22
5	16
6	10

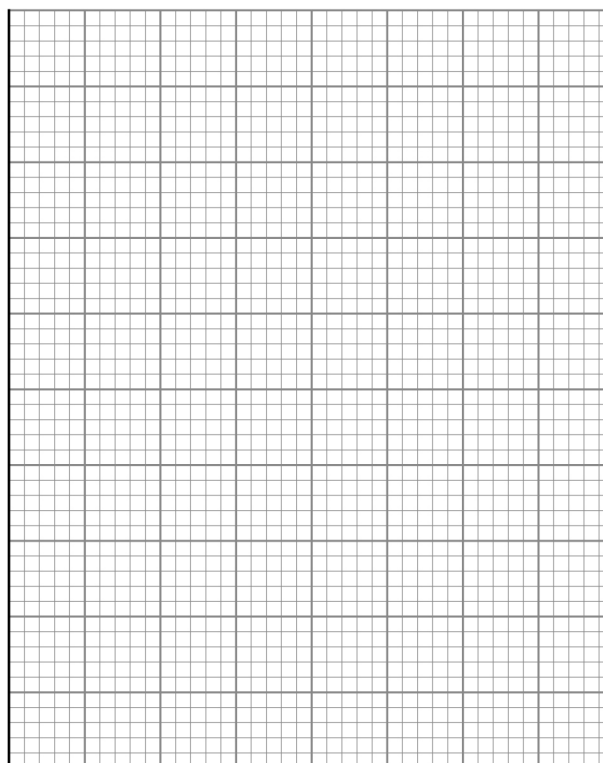
1 0 . 3

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<sup>3</sup>



Time / minutes



10.4

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

**[2 marks]**

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**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

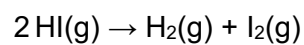
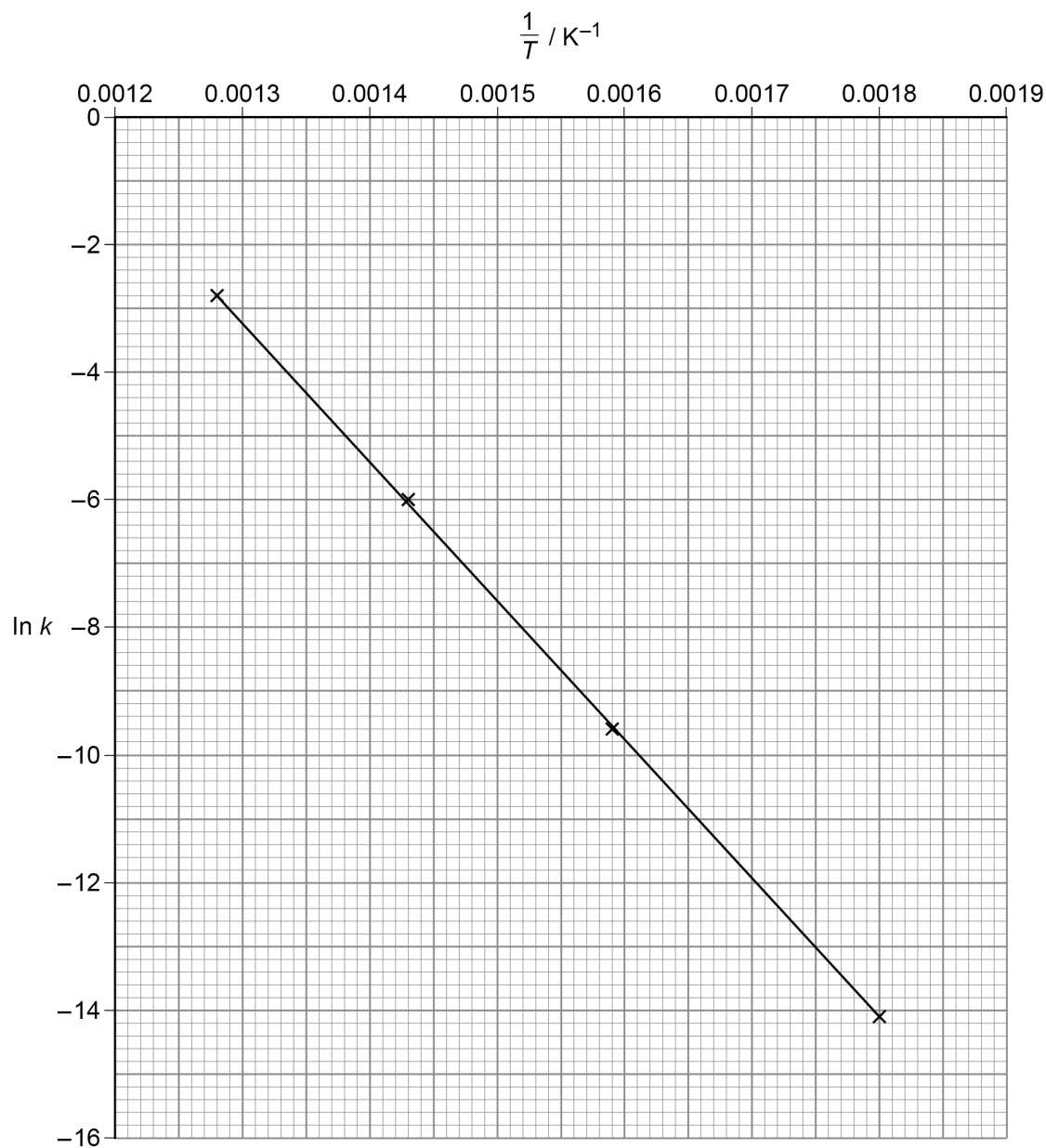


Figure 8



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

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

**[3 marks]**

$E_a$  \_\_\_\_\_  $\text{kJ mol}^{-1}$

12

**END OF QUESTIONS**



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