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

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** | |



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

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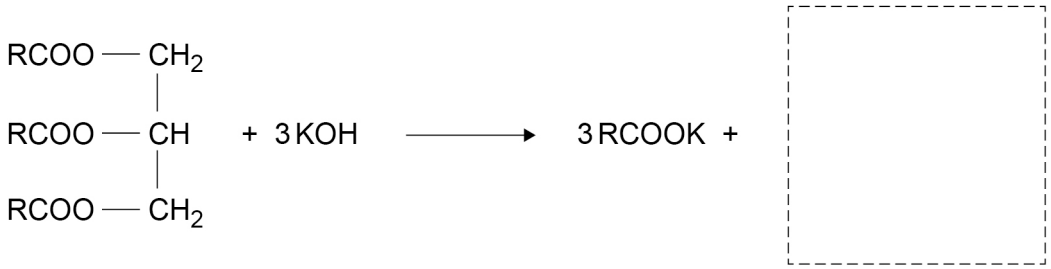
**0 1** Coconut oil contains a triester with three identical R groups.
This triester reacts with potassium hydroxide.




**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 $CH_3(CH_2)_n$

Deduce the value of n in $CH_3(CH_2)_n$
Show your working.

**[3 marks]**

n _____

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**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 _____

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**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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**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 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]**

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

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]**

**Question 2 continues on the next page**

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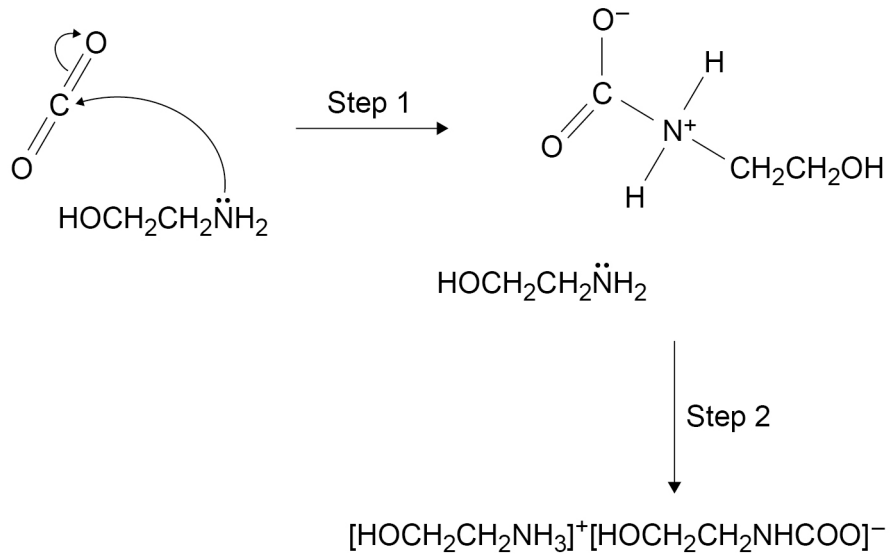
**0 2 . 4** Compound **Z** ($HOCH_2CH_2NH_2$) can be used to remove carbon dioxide from the mixture of waste gases produced in some power stations.

**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 _____

_____

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**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 _____

_____

**Question 2 continues on the next page**

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**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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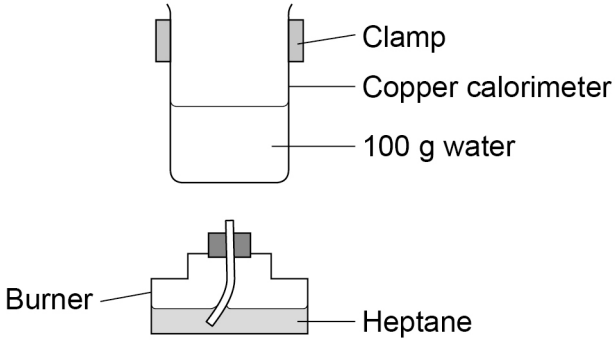
**0 3** A student does an experiment to determine a value for the enthalpy of combustion of heptane.

**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 _____

_____

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**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**

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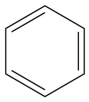
**0 4** Kekulé suggested this structure for benzene. 

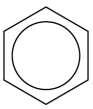
Benzene is now represented by this structure. 

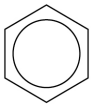
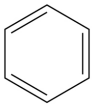
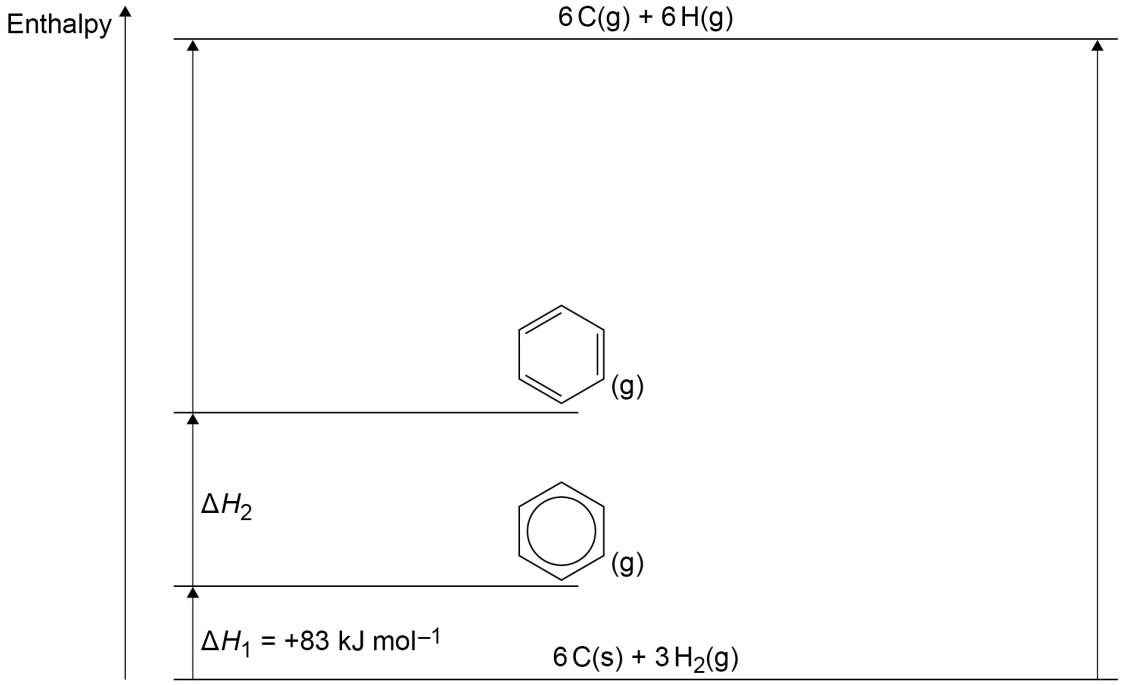
**Figure 3** shows the relative stability of  compared to  .

**Figure 3**

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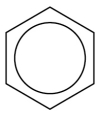
**0 4 . 1** Use **Figure 3** and the data shown in **Table 1** to calculate $\Delta H_2$

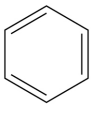
**[3 marks]**

**Table 1**

| | $\Delta H$ / 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 |

$\Delta H_2$ _____ 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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**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.

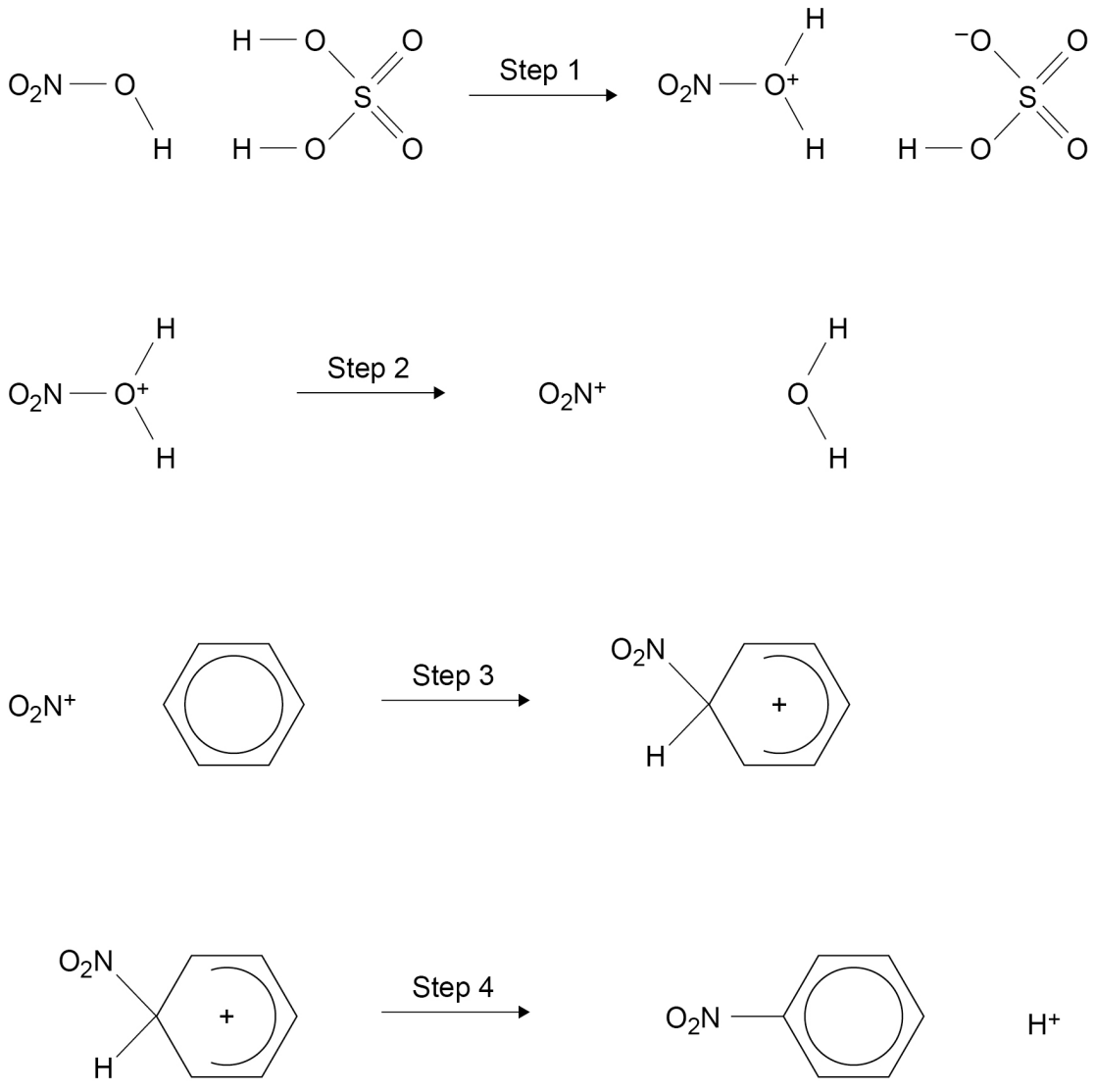
Name the mechanism.

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**

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**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** 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**



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**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

7

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**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 |
|---|---|
| | |

**Question 6 continues on the next page**



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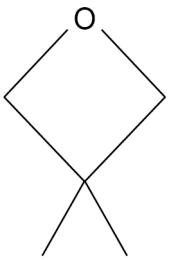
**0 6 . 4** Isomer J is cyclic and has an ether functional group (C–O–C)
Isomer J has only three peaks in its $^{13}C$ NMR spectrum.

**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]**

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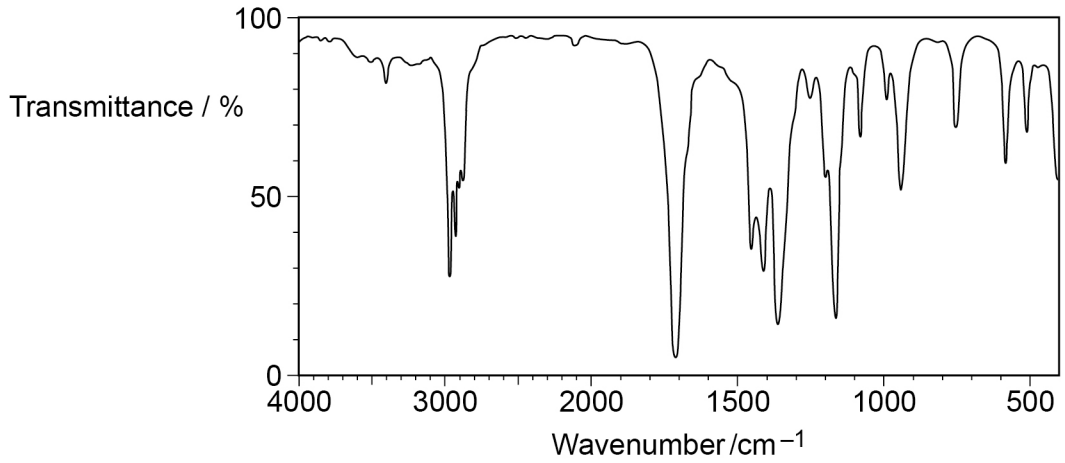
**0 7** This question is about spectroscopy.

**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**

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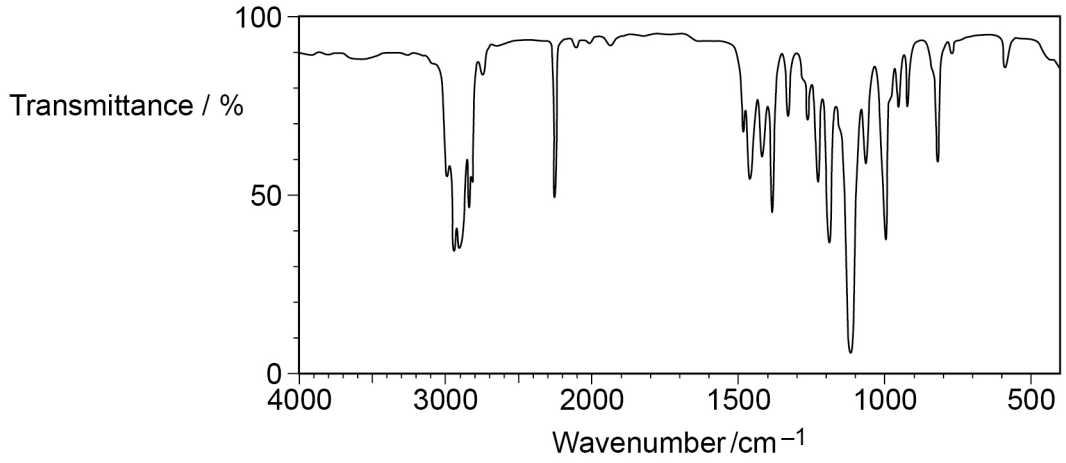
**0 7 . 2** Compound **L** has molecular formula $C_4H_7NO$
**Figure 6** shows the infrared spectrum of **L**.

**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 _____

_____

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**0 7 . 3** **Figure 7** shows the $^1$H NMR spectrum of **Q**, $C_3H_7ClO$

**Figure 7**

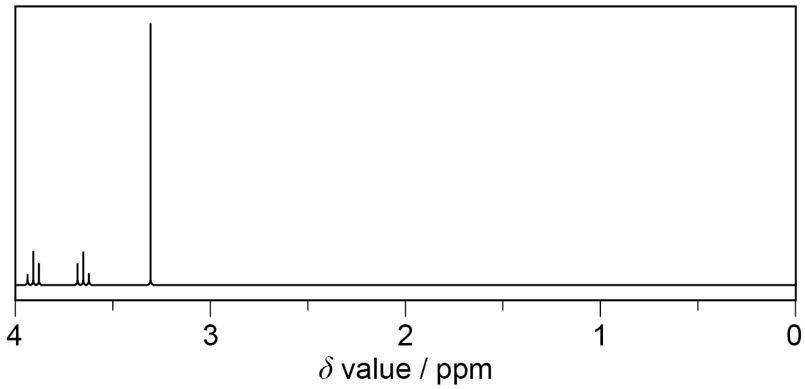


**Table 4** shows the chemical shifts (δ values) and integration values for each peak.

**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**

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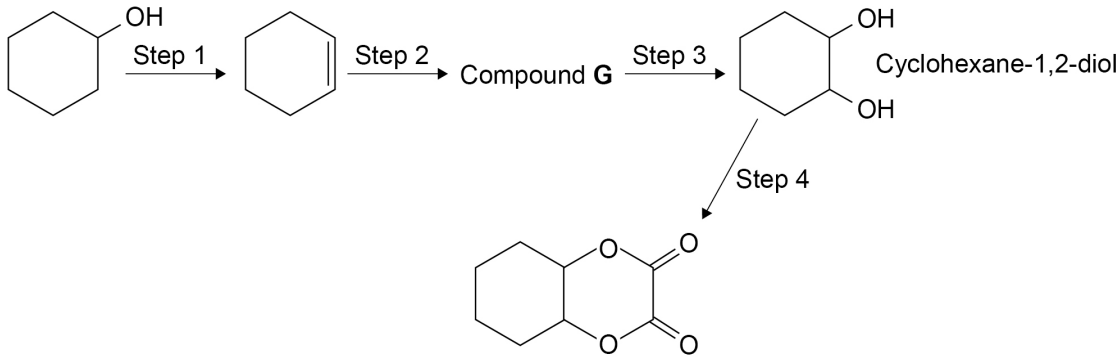
**0 8** This question is about making a diester from cyclohexanol.




**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

_____

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**0 8 . 3** Cyclohexane-1,2-diol reacts with ethanedioyl dichloride.

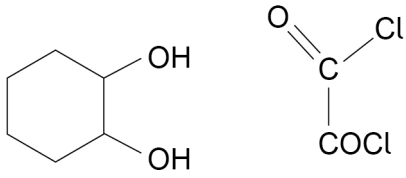
Give the name of the mechanism for this reaction.

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

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**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]**

_____ → $\bullet CHF_2$ + HCl

$\bullet CHF_2$ + $Cl_2$ → _____

Type of step _____

7

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**1 0** This question is about rates of reaction.
Iodine and propanone react together in an acid-catalysed reaction

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

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 $5.0 \times 10^{-3}$ 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]**

**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**



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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.

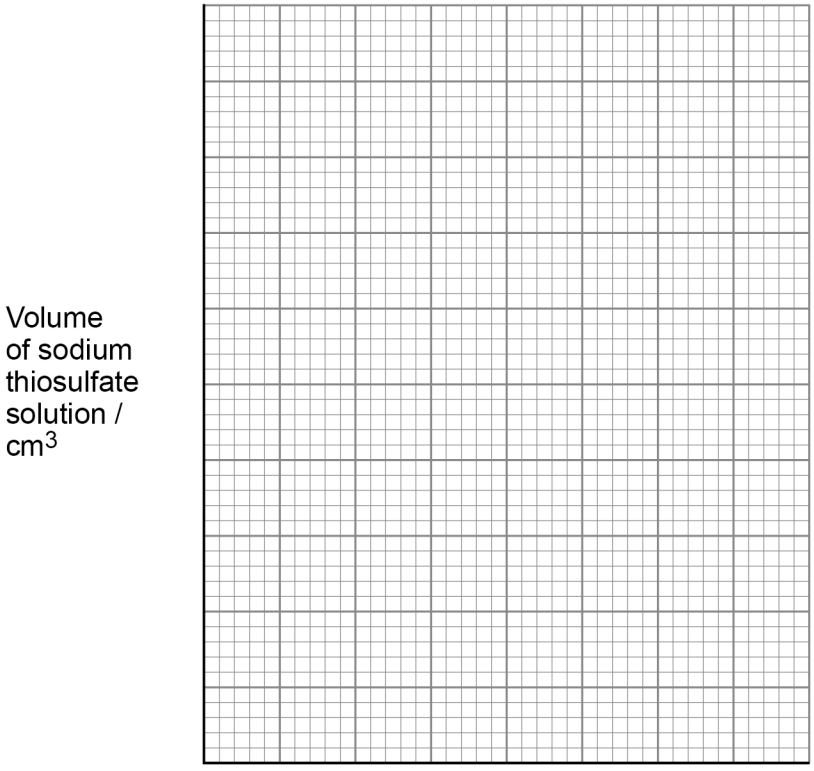
**Table 5**

| 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]**

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**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**

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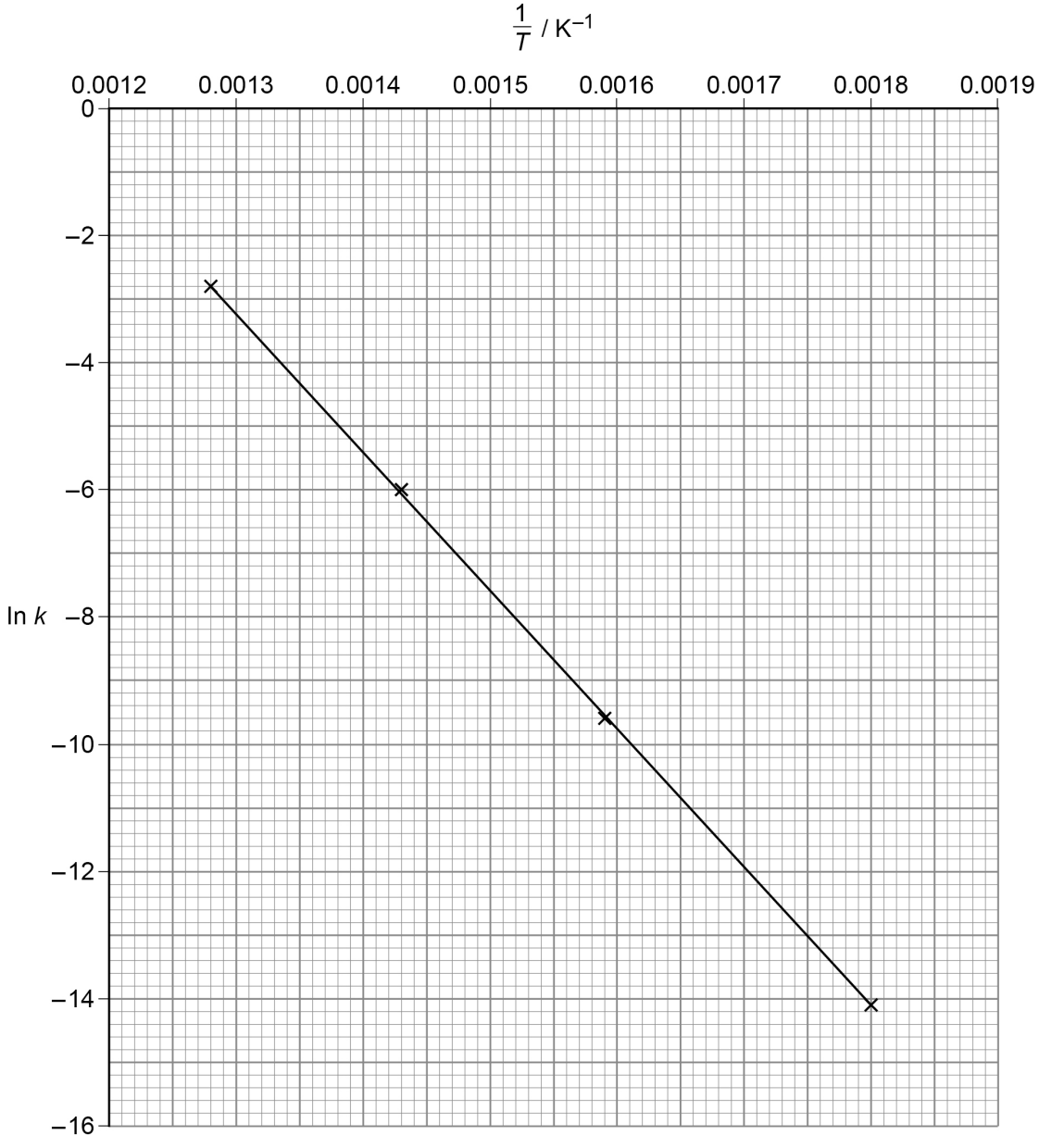
**1 0 . 5** The Arrhenius equation can be written as

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

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

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

**Figure 8**

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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$^{-1}$

12

**END OF QUESTIONS**

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