AQA

SPECIMEN MATERIAL v1.0

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level
CHEMISTRY

Paper 2: Organic and Physical Chemistry

Specimen materials (set 2)

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 the 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.
- 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	
TOTAL	

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

0 1 The mechanisms of some reactions can be deduced from kinetic data.

Table 1 shows the results of five experiments involving the reaction between benzaldehyde (C_6H_5CHO) and potassium hydroxide solution.

Table 1

Experiment	**Initial rate / mol dm^{-3} s^{-1}**	**[C_6H_5CHO] / mol dm^{-3}**	**[C_6H_5CHO]^2**	**[KOH] / mol dm^{-3}**
1	0	0		0
2	2.90×10^{-6}	0.25		0.25
3	1.16×10^{-5}	0.50		0.25
4	2.61×10^{-5}	0.75		0.25
5	4.65×10^{-5}	1.00		0.25

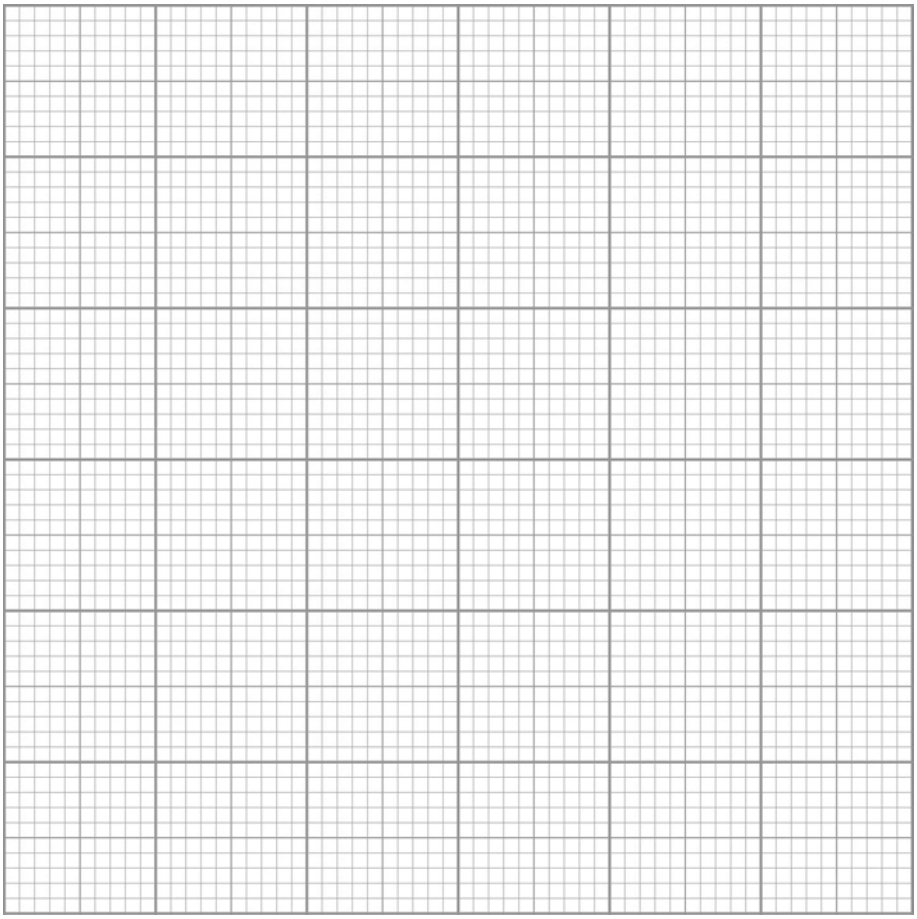
0 1 . 1 Calculate the value of [C_6H_5CHO]^2 for each experiment.

Write your answers in **Table 1**.

Plot a graph of initial rate against [C_6H_5CHO]^2 on the grid opposite.

Label the axes with units.

[4 marks]



0 1 . 2 Deduce the order of the reaction with respect to C_6H_5CHO from the graph.

Explain your answer.

[2 marks]

Order _____

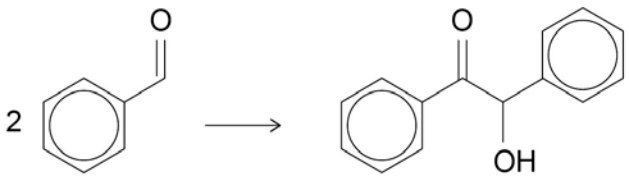
Explanation _____

_____

_____

Question 1 continues on the next page

0 1 . 3 Benzaldehyde (C_6H_5CHO) undergoes a dimerisation reaction as shown:



The rate equation for the reaction is

$$rate = k\,[C_6H_5CHO]\,[CN^-]$$

Suggest the role of the cyanide ion in the reaction.

Explain your answer.

[2 marks]

Role of CN^- _____

Explanation _____

_____

_____

8

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

0 2 This question is about halogenoalkanes.

0 2 . 1 Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

[2 marks]

1 _____

_____

2 _____

_____

0 2 . 2 Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

[2 marks]

Role of potassium hydroxide _____

Role of propan-1-ol _____

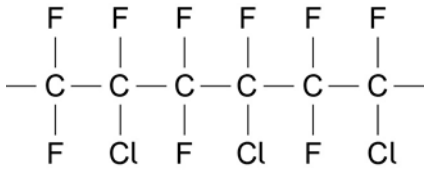
0 2 . 3 Name and outline a mechanism for the reaction in Question **02.2** between chloroethane and potassium hydroxide to produce ethene.

[4 marks]

Name of mechanism _____

Mechanism

0 2 . 4 The structure of polymer **A** is shown.



Draw the structure of the monomer used to form polymer **A**.

[1 mark]

Question 2 continues on the next page

0 2 . 5 Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes, ^{35}Cl and ^{37}Cl, in the ratio 3:1
Fluorine only exists as one isotope, ^{19}F

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at *m/z* = 220, 222 and 224

Determine the formula of each of the three molecular ions of **B**.

Predict and explain the ratio of the relative abundancies of each of the three molecular ion peaks at *m/z* = 220, 222 and 224

To gain full marks you must show all your working.

[6 marks]

Turn over for the next question

15

0 3 This question is about isomerism.

0 3 . 1 How many isomers are represented by the formula C_5H_{12}?

Tick (✓) **one** box.

[1 mark]

2 ☐ 3 ☐ 4 ☐ 5 ☐

0 3 . 2 Name the type of structural isomerism shown by the isomers of C_5H_{12}

[1 mark]

0 3 . 3 2-Hydroxypropanenitrile displays optical isomerism.

Draw three-dimensional representations of the two enantiomers of 2-hydroxypropanenitrile, showing how the two structures are related to each other.

[2 marks]

0 3 . 4 Describe how separate samples of each of these enantiomers could be distinguished.

[2 marks]

0 3 . 5 Butan-2-ol reacts with concentrated sulfuric acid to produce three isomeric alkenes.

Name and outline a mechanism to show how any **one** of the alkenes is formed.

Explain how this reaction can lead to the formation of each of these **three** alkenes.

[8 marks]

Name of mechanism _____

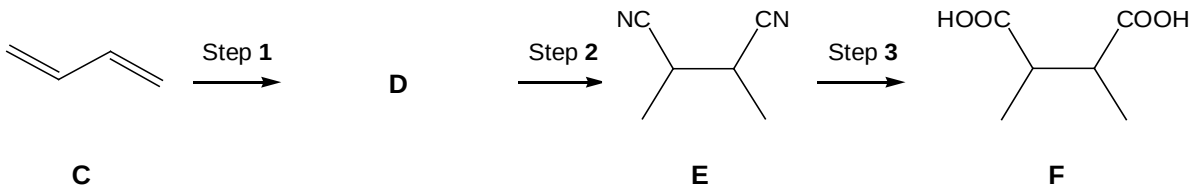
Mechanism

Explanation _____

0 4 Chemists design synthetic routes to convert one organic compound into another.

Buta-1,3-diene, **C**, is converted into compound **F** as shown in **Figure 1**.

Figure 1



0 4 . 1 State the IUPAC name of compound **F**.

[1 mark]

0 4 . 2 Deduce the structure of compound **D**.

For each of the conversions in steps **1** and **2**, suggest a reagent for the conversion and name the mechanism.

Suggest the type of reaction occurring in step **3**.

[6 marks]

Structure of **D**

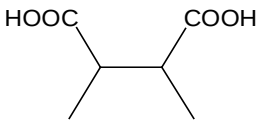
Step **1**

Step **2**

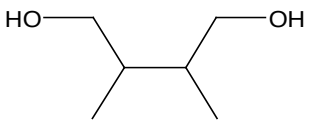
Type of reaction in Step **3**

Question 4 continues on the next page

0 4 . 3 Compound **F** can also be made from compound **G**.



F



G

State a reagent (or combination of reagents) that can be used in a test-tube reaction to distinguish between **F** and **G**.

Describe what you would observe when the reagent is added to each compound and the test tube is shaken.

[3 marks]

Reagent(s) _____

_____

Observation with **F** _____

_____

_____

Observation with **G** _____

_____

_____

0 4 . 4 Compounds **F** and **G** react to form a polymer.

Draw the repeating unit of the polymer.

[2 marks]

0 4 . 5 In an experiment, 0.930 kg of purified **F** were obtained from 1.11 dm^3 of **G** (density 1.04 g cm^{-3}).

Calculate the percentage yield.

Give your answer to the appropriate number of significant figures.

[4 marks]

Percentage yield _____ %

Question 4 continues on the next page

0 4 . 6 One reason for a yield of less than 100% in Question **04.5** is that **G** reacts to form a number of other compounds.

The other compounds are all liquids at room temperature.

Name the technique that should be used to separate and collect each of these other compounds from the reaction mixture.

Include in your answer a description of the apparatus.

Your description of the apparatus can be either a description in words or a labelled sketch.

[4 marks]

Name of technique _____

Apparatus

20

Turn over for the next question

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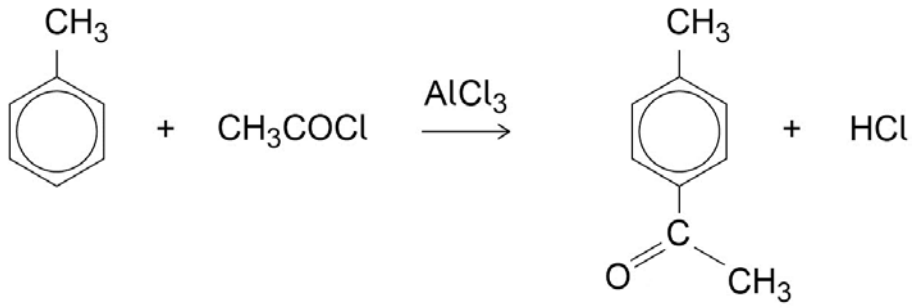
ANSWER IN THE SPACES PROVIDED

0 5 When methylbenzene reacts with ethanoyl chloride in the presence of aluminium chloride, the product, **H**, is formed.



H

0 5 . 1 Deduce the molecular formula of **H**.

[1 mark]

0 5 . 2 Two other isomers are also produced in the reaction.

Draw the structure of **one** of the other isomers.

Name the type of structural isomerism shown by these three products.

[2 marks]

Structure

Type of isomerism _____

0 5 . 3 Name and outline the mechanism for the reaction of ethanoyl chloride with methylbenzene to produce **H**.

Include an equation for the formation of the reactive intermediate that is involved in the reaction.

[5 marks]

Name _____

Equation _____

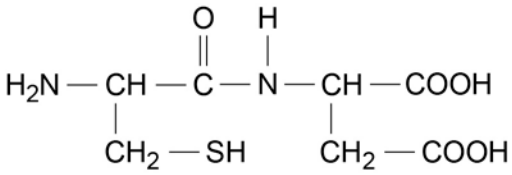
Mechanism

Turn over for the next question

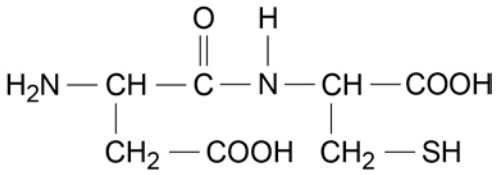
8

0 6 Chromatography is used to identify amino acid sequences in compounds.

The dipeptide cysteine-aspartic acid (cys-asp), **J**, and the dipeptide aspartic acid-cysteine (asp-cys), **K**, are shown.



J (cys – asp)



K (asp – cys)

0 6 . 1 A mixture of the two dipeptides **J** and **K** is analysed by gas chromatography followed by mass spectrometry (GC-MS).

Explain why **J** and **K** can be separated by gas chromatography and why mass spectrometry using electrospray ionisation does **not** enable you to identify them.

[4 marks]

Gas chromatography explanation

Mass spectrometry explanation

0 6 . 2 A tripeptide, **L**, is partially hydrolysed with concentrated hydrochloric acid to produce two dipeptides and the amino acids alanine (ala), lysine (lys) and serine (ser).

The two dipeptides are separated by chromatography. **Figure 2** shows the chromatogram.

Figure 2

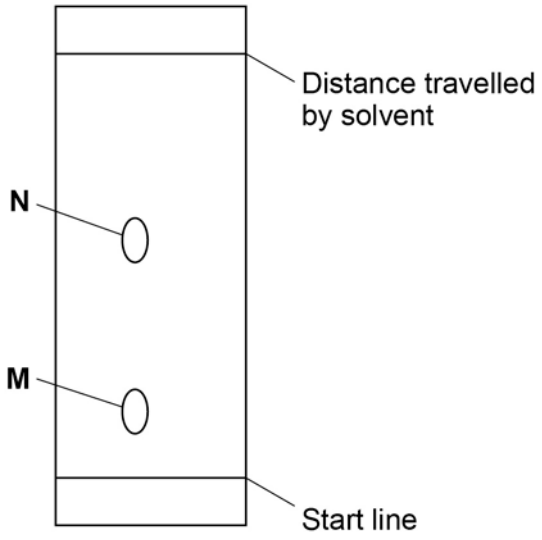


Table 2 contains the R_f values of some dipeptides.

Table 2

Dipeptide	ala-lys	ala-ser	lys-ser	lys-ala	ser-ala	ser-lys
R_f value	0.55	0.85	0.10	0.20	0.15	0.45

Use the chromatogram in **Figure 2** and the R_f values in **Table 2** to identify the two dipeptides present in spots **M** and **N**.

Use your answers to deduce the order of the amino acids in the tripeptide **L**.

[3 marks]

Dipeptide responsible for spot **M** _____

_____

Dipeptide responsible for spot **N** _____

_____

Order of amino acids in tripeptide **L** _____

_____

0 7 Use the information in the Data Booklet to help you answer these questions.

A single strand of DNA is made from many nucleotides linked together.

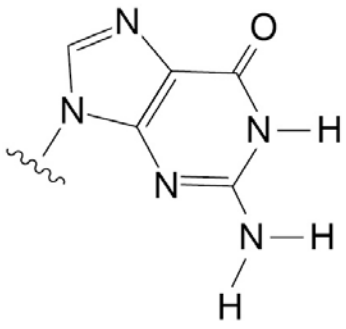
0 7 . 1 Draw the structure of the nucleotide that contains guanine, showing clearly the bonding between the components.

[3 marks]

0 7 . 2 Two complementary strands of DNA form a double helix in which one strand is attracted to another by interactions between pairs of bases.

Complete the base pair diagram showing the interactions.

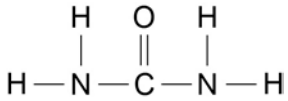
[2 marks]



0 7 . 3 State how the interactions in the adenine-thymine base pair differ from those you identified in Question **07.2**.

[1 mark]

0 7 . 4 Urea has the displayed formula



Suggest why urea is effective at separating the complementary strands in DNA.

[2 marks]

8

Turn over for the next question

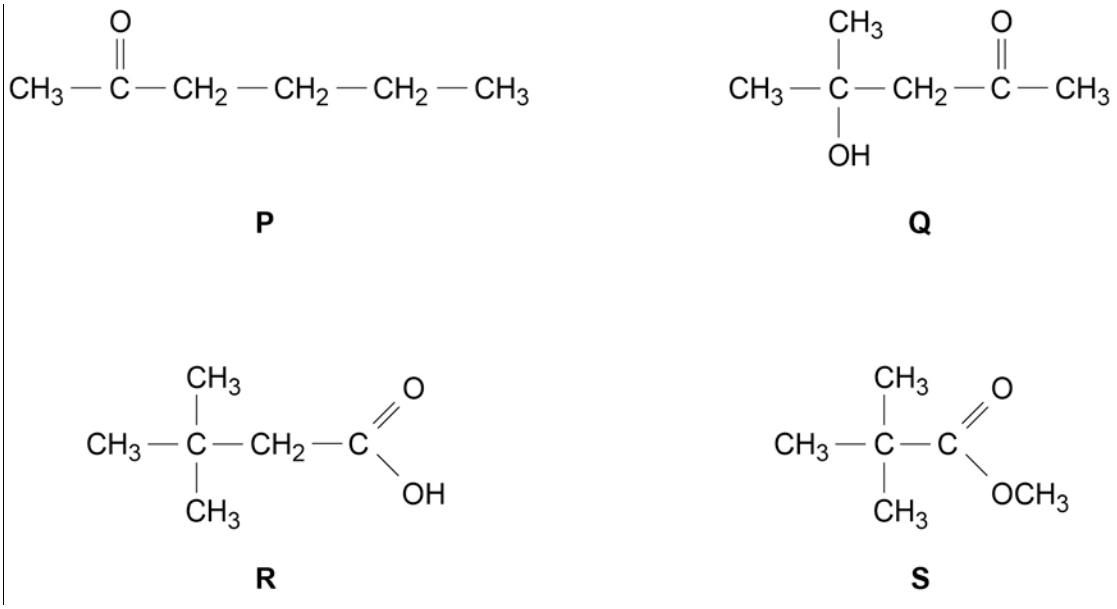
0 8 ^{1}H NMR, ^{13}C NMR and infrared spectroscopy are used in organic chemistry to distinguish between compounds and to identify them.

0 8 . 1 Give the skeletal formula of the compound that is used as the standard when recording a ^{13}C NMR spectrum.

[1 mark]

0 8 . 2 Four isomers of $C_6H_{12}O_2$, **P**, **Q**, **R** and **S**, shown in **Figure 3**, were analysed by ^{13}C NMR spectrometry.

Figure 3



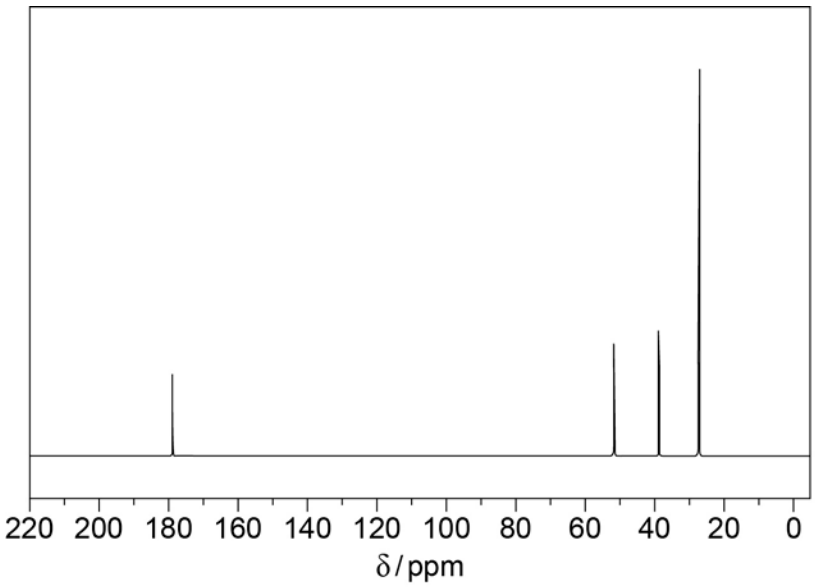
The ^{13}C NMR spectra of three of these isomers are shown in **Figure 4**.

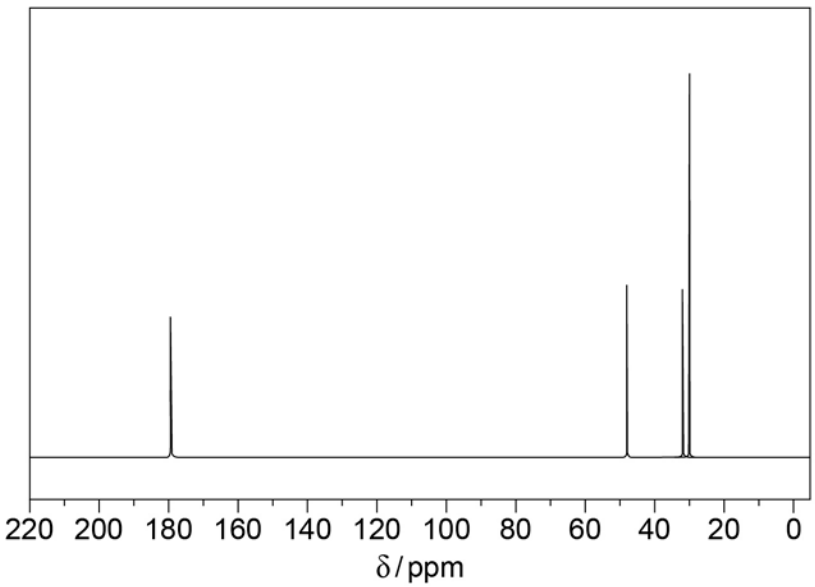
Use **Table C** in the Data Booklet to help you to identify which isomer produces each spectrum.

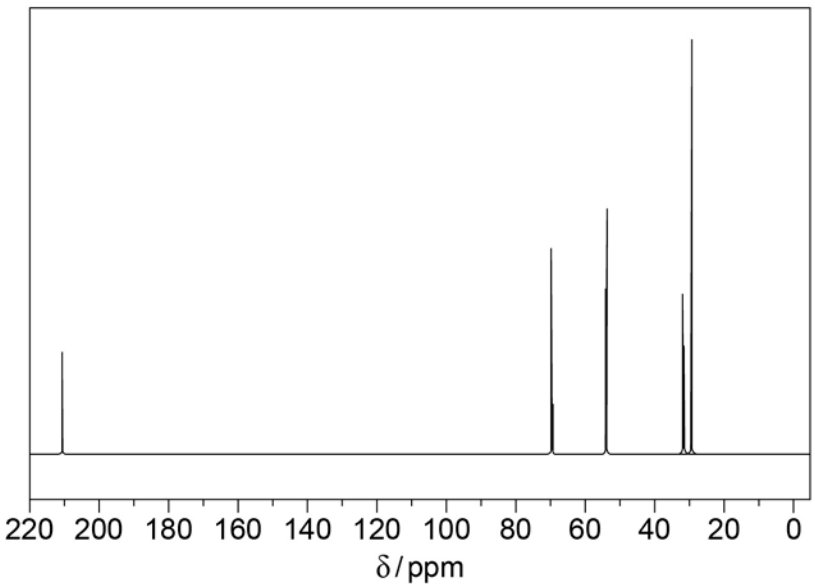
Write the letter of each isomer opposite its spectrum in **Figure 4**.

[3 marks]

Figure 4



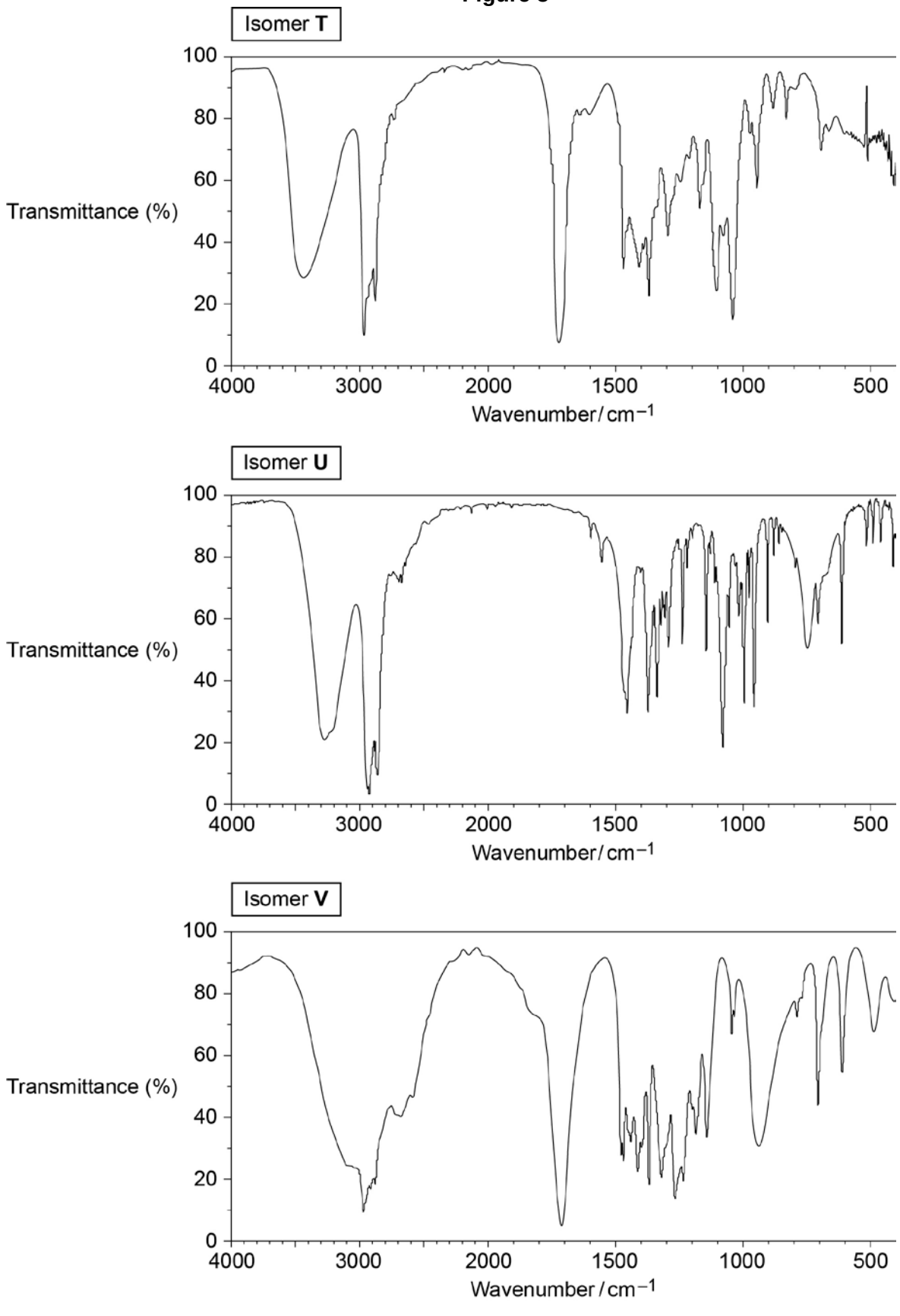




Question 8 continues on the next page

0 8 . 3 The infrared spectra shown in **Figure 5** are those of three different isomers of $C_6H_{12}O_2$, isomers **T**, **U** and **V**.

Figure 5



Identify the functional group(s) present in each isomer **T**, **U** and **V** of $C_6H_{12}O_2$ using **Table A** in the Data Booklet.

Explain your answer.

[6 marks]

Question 8 continues on the next page

0 8 . 4 The integration values for the peaks in the ^{1}H NMR spectrum of **X**, a different isomer of $C_6H_{12}O_2$, are given in **Table 3**.

Table 3

Chemical shift, δ / ppm	3.7	3.5	2.6	2.2	1.1
Integration value	0.6	0.6	0.6	0.9	0.9
Splitting pattern	triplet	quartet	triplet	singlet	triplet

Deduce the simplest ratio of the relative numbers of protons in each environment in compound **X**.

[1 mark]

0 8 . 5 Use the data in **Table 3** and **Table B** in the Data Booklet to help you answer this question.

Deduce the part of the structure of **X** that causes the signal at δ= 3.5 and the part of the structure at **X** that causes the signal at δ=2.2

Explain the splitting patterns of these peaks.

[4 marks]

Signal at δ= 3.5

Signal at δ= 2.2

0 8 . 6 Deduce the structure of compound **X**, $C_6H_{12}O_2$

Use your answer from Question **08.5** to help you.

You are **not** required to explain how you deduced the structure.

[2 marks]

17

Turn over for the next question

0 9 . 1 The Arrhenius equation can be written as:

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

Table 4 shows the value of the rate constant at different temperatures for a reaction.

Table 4

Rate constant k / s^{-1}	**ln k**	**Temperature / K**	**$\frac{1}{T}$**
6.13×10^{-5}		700	
2.75×10^{-4}		727	
8.25×10^{-4}		746	
8.23×10^{-3}		793	

Complete **Table 4** by calculating the values of ln k and $\frac{1}{T}$ at each temperature.

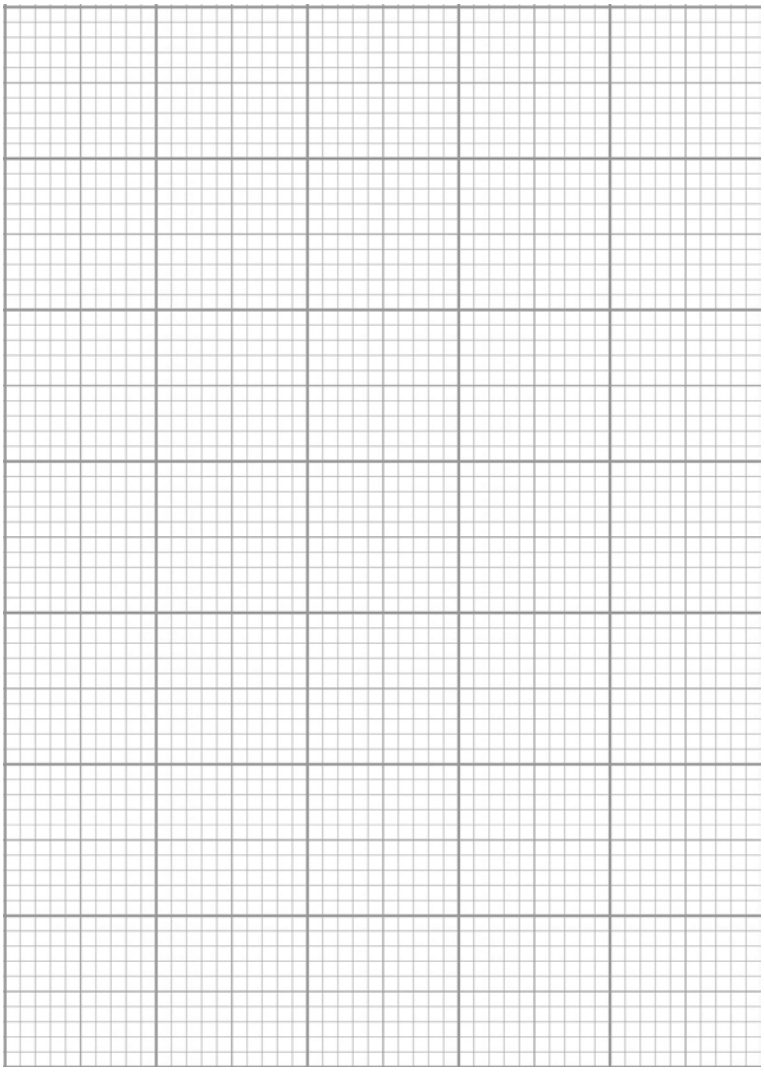
Plot a graph of ln k against $\frac{1}{T}$ on the grid opposite.

Use your graph to calculate a value for the activation energy, in kJ mol^{-1}, for this reaction.

To gain full marks you must show all your working.

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

[8 marks]



E_a _____ kJ mol^{-1}

END OF QUESTIONS

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