Organic Analysis

4 A scientist used mass spectrometry to analyse a sample of the air near a fertiliser factory. The sample of air included traces of a gas which was shown by its molecular ion to have a precise M_r = 44.00105

4 (a) State the meaning of the term *molecular ion*.

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(1 mark)

4 (b) (i) Use the following data to show that the trace gas was dinitrogen oxide (N_2O). Show your working.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{14}N	14.00307
^{16}O	15.99491

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(1 mark)

4 (b) (ii) Propane is used as a fuel in the fertiliser factory. State why both propane and its combustion product, carbon dioxide, might have been identified as the trace gas if the scientist had used relative molecular masses calculated to one decimal place.

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(1 mark)

4 (b) (iii) State why the precise relative atomic mass for the ^{12}C isotope is exactly 12.00000

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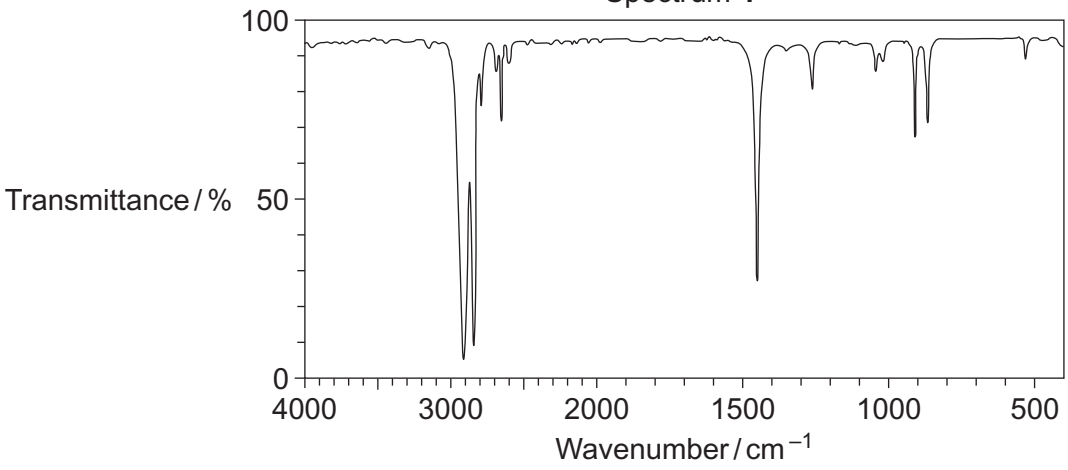
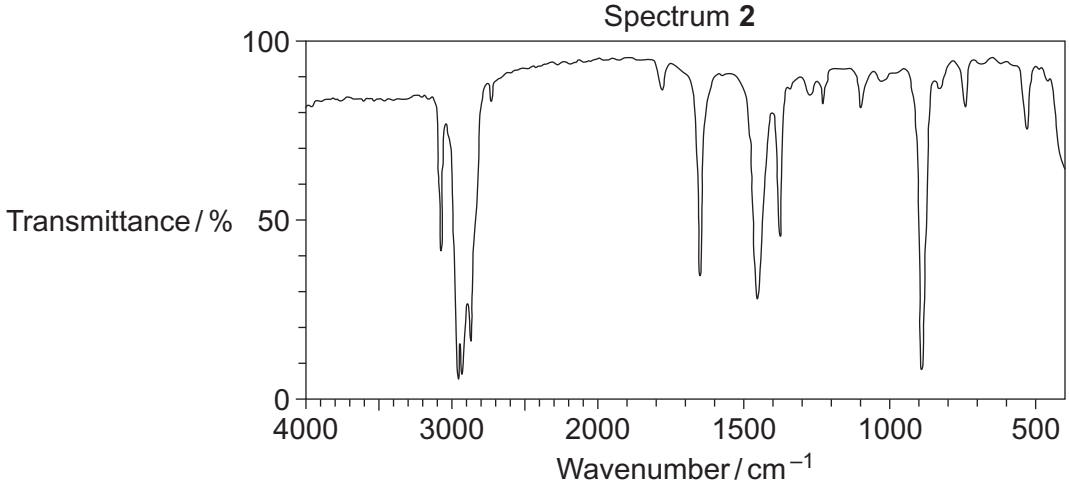
(1 mark)

6 (b) The infrared spectra of two compounds **R** and **S** are shown below. **R** and **S** have the molecular formula C_6H_{12} and are structural isomers of 3-methylpent-2-ene. **R** is an unsaturated hydrocarbon and **S** is a saturated hydrocarbon.

Spectrum **1**



Spectrum **2**



6 (b) (i) Identify the infrared Spectrum **1** or **2** that represents compound **R**.
Use information from the infrared spectra to give **one** reason for your answer.
You may find it helpful to refer to **Table 1** on the Data Sheet.

R is represented by Spectrum .....

Reason .....

.....

(2 marks)

6 (b) (ii) State the type of structural isomerism shown by **R** and **S**.

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(1 mark)

6 (b) (iii) Name **one** possible compound which could be **S**.

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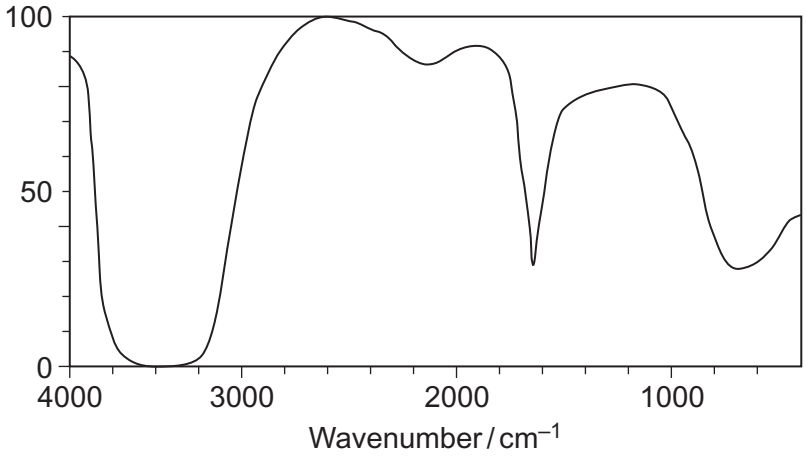
(1 mark)

9

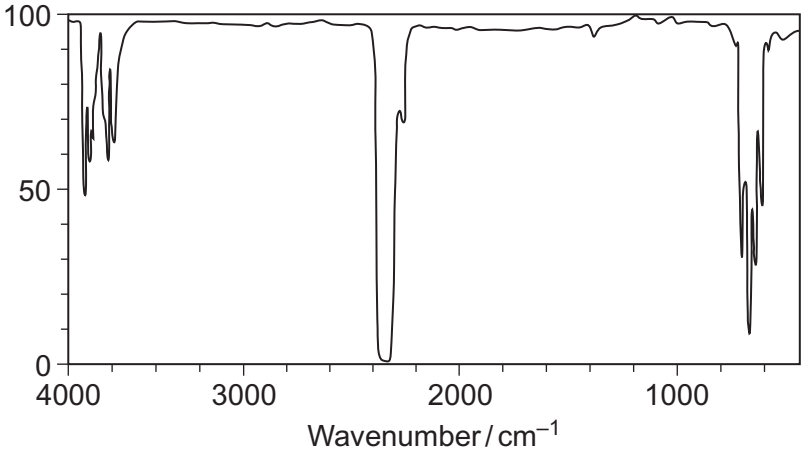
Turn over ▶

6 (a) A student used the infrared spectra of water vapour and of carbon dioxide to try to find a link between infrared radiation and global warming.

Infrared spectrum of water vapour



Infrared spectrum of carbon dioxide



6 (a) (i) Use information from the infrared spectra to deduce **one** reason why the student concluded that water vapour is a more effective greenhouse gas than carbon dioxide.

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(1 mark)

6 (a) (ii) Use your knowledge of the bonds in CO_2 to state why the infrared spectrum of carbon dioxide is **not** as might be predicted from the data provided in **Table 1** on the Data Sheet.

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(2 marks)

6 (b) The initiatives to decrease the carbon dioxide in the atmosphere include the use of carbon-neutral fuels and the development of carbon capture.
The mineral serpentine, $Mg_3Si_2O_5(OH)_4$, has been proposed as a solid for the capture of carbon dioxide gas.

6 (b) (i) Give the meaning of the term *carbon-neutral*, as applied to a fuel.

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(1 mark)

(Extra space) .....

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6 (b) (ii) Balance the following equation for the reaction of serpentine with carbon dioxide.

$Mg_3Si_2O_5(OH)_4$ + ...CO_2 ⟶ .....$MgCO_3$ + ...SiO_2 + ...H_2O

(1 mark)

5

Turn over for the next question

6 (b) An organic product, **X**, with M_r = 154.0 is obtained when chlorine reacts with trichloromethane.

6 (b) (i) Write an equation for the overall reaction of chlorine with trichloromethane to form **X**, by the same mechanism as that outlined in part **(a) (i)**.

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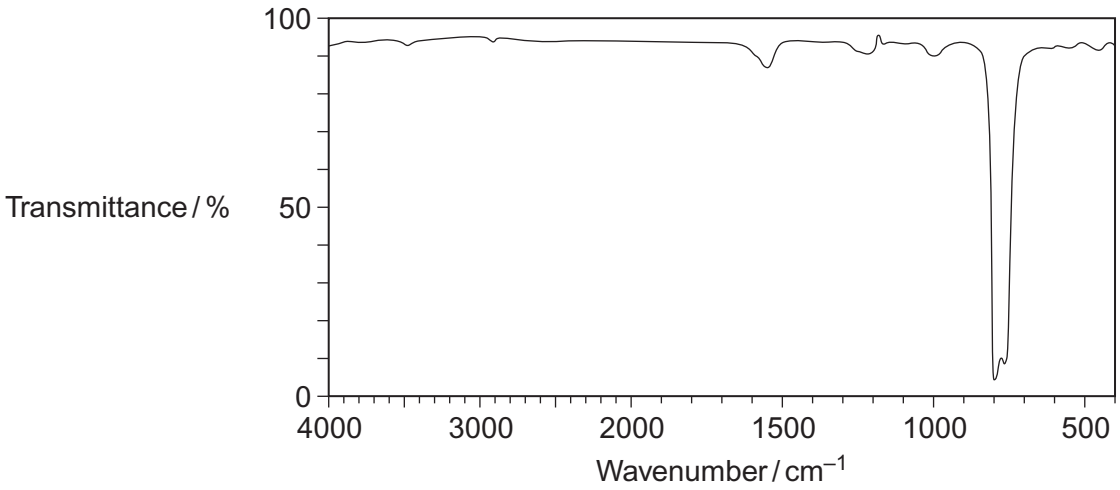
(1 mark)

6 (b) (ii) The following infrared spectrum was obtained for a sample of **X** produced in this reaction.



Use this infrared spectrum to explain why it is possible to deduce that this sample of **X** contains no trichloromethane.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(2 marks)

(Extra space) .....

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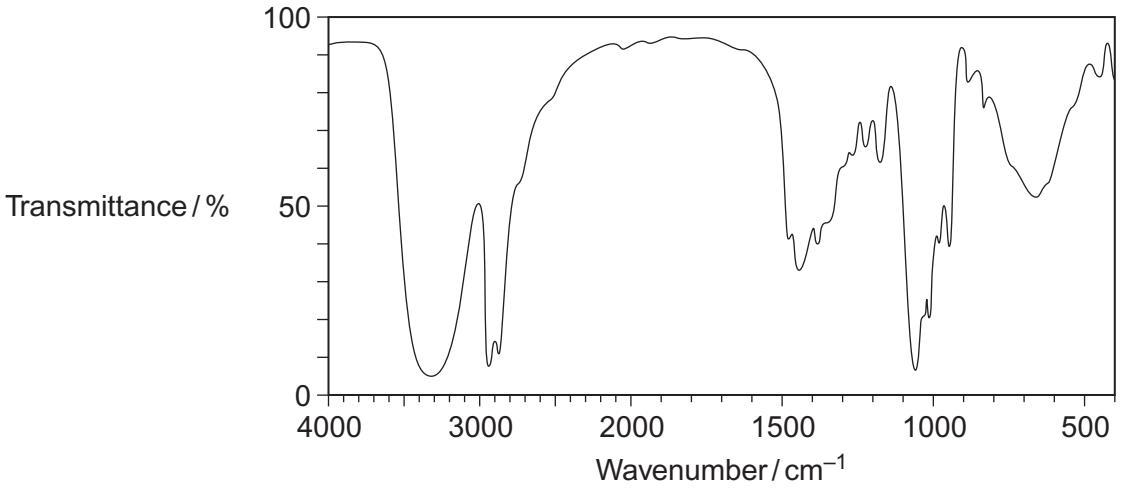
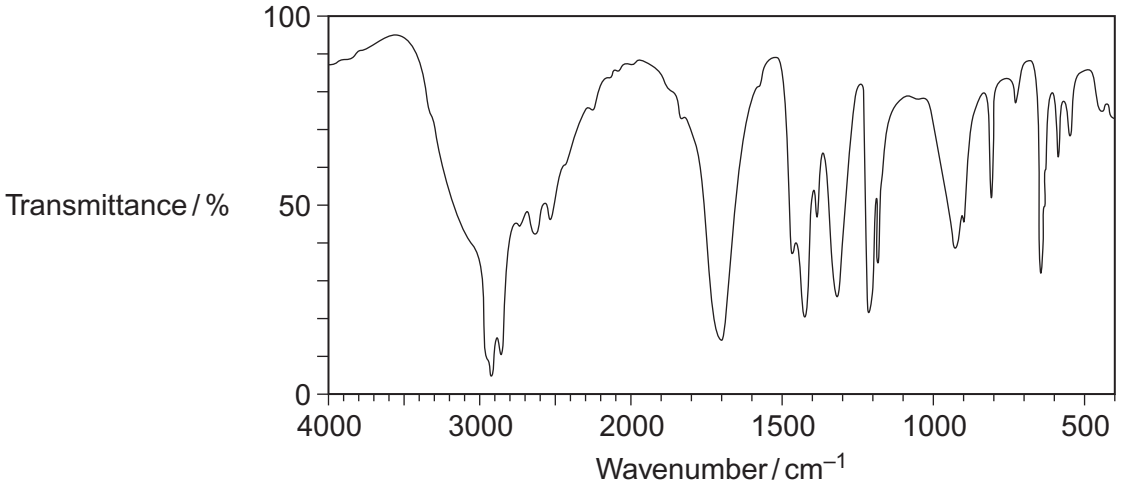
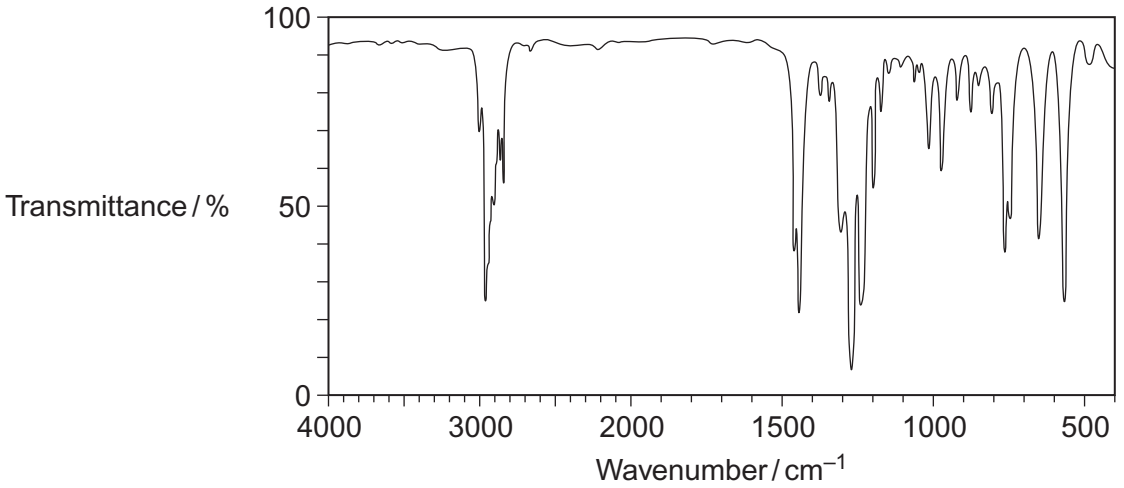
8 (b) (ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutane
Compound **B** butane-1,4-diol
Compound **C** butanedioic acid

Identify the compound responsible for each spectrum by writing the correct letter, **A**, **B** or **C**, in the box next to each spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.







(3 marks)

6 The table shows the structures and names of three compounds with M_r = 72.0

Compound	Formula	Name
1	$CH_3CH_2CH_2CHO$	butanal
2	$CH_3CH_2CH_2CH_2CH_3$	pentane
3	$CH_3CH_2COCH_3$	butanone

6 (a) Explain why M_r values, measured to five decimal places, cannot distinguish between compounds **1** and **3** but can distinguish between compounds **1** and **2**.

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(2 marks)

6 (b) A simple chemical test, using either Fehling's solution or Tollens' reagent, can be used to distinguish between compound **1** and compound **3**.
Choose one of these two reagents and state what you would observe with each of compound **1** and compound **3**.

Chosen reagent .....

Observation with compound **1**.....

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Observation with compound **3**.....

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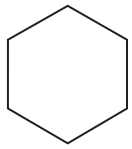
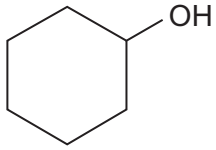
(2 marks)

4

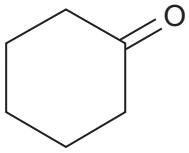
10 Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.



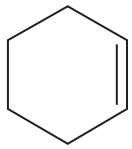
cyclohexane
A



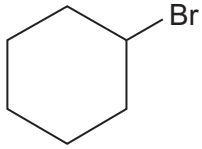
cyclohexanol
B



cyclohexanone
C



cyclohexene
D

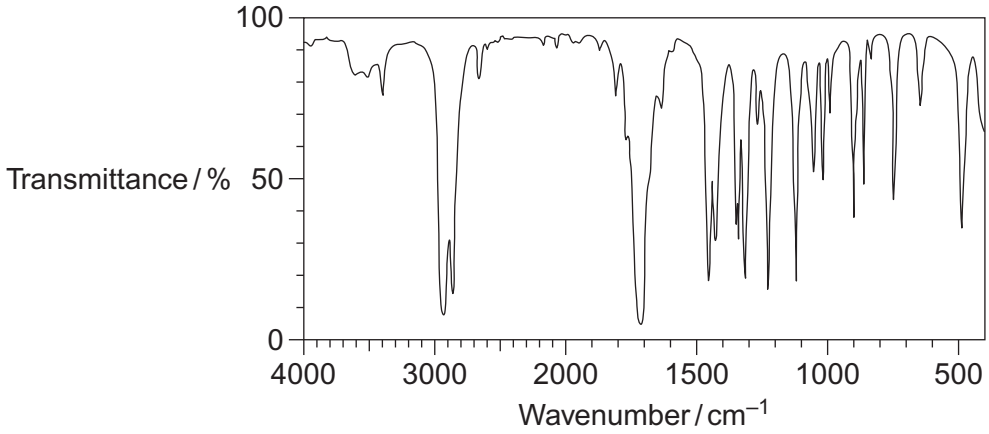


bromocyclohexane
E

10 (a) The infrared spectra of compounds **A**, **B**, **C** and **D** are shown opposite.

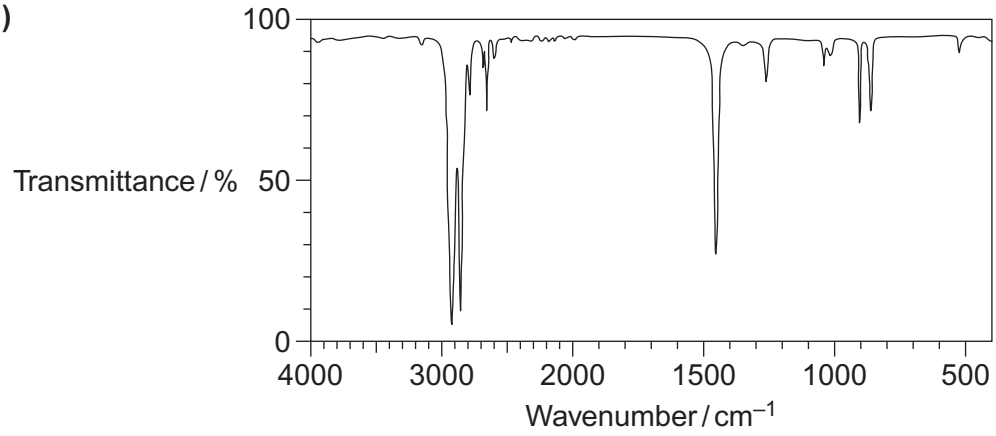
Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

10 (a) (i)



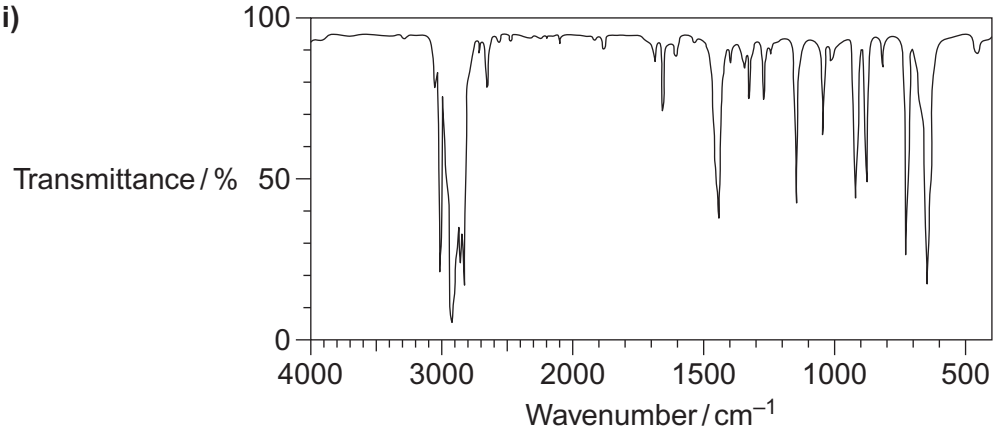
(1 mark)

10 (a) (ii)



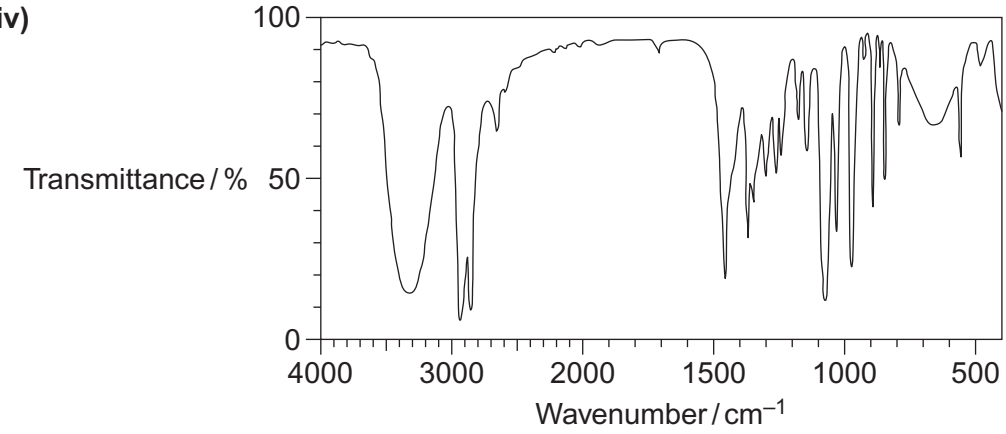
(1 mark)

10 (a) (iii)



(1 mark)

10 (a) (iv)



(1 mark)

Question 10 continues on the next page

Turn over ▶

10 (b) A simple chemical test can be used to distinguish between cyclohexane (**A**) and cyclohexene (**D**).
Give a reagent for this test and state what you would observe with each compound.

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(3 marks)

(Extra space) .....

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10 (c) Cyclohexanol (**B**) can be converted into cyclohexanone (**C**).

Give a reagent or combination of reagents that can be used for this reaction and state the type of reaction.

State the class of alcohols to which cyclohexanol belongs.

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(3 marks)

(Extra space) .....

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10 (d) Cyclohexane (**A**) can be converted into bromocyclohexane (**E**) by a reaction that is similar to the reaction of methane either with chlorine or with bromine.

Name and outline a mechanism for the reaction of methane (CH_4) with bromine to form bromomethane (CH_3Br). Give **one** condition for this reaction to occur.
Write an equation for each step in your mechanism.

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(5 marks)

(Extra space) .....

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15

END OF QUESTIONS

6 Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

6 (a) A mass spectrometer can be used to distinguish between samples of butane and propanal.

Table 1 shows some precise relative atomic mass values.

Table 1

Atom	Precise relative atomic mass
^{1}H	1.00794
^{12}C	12.00000

6 (a) (i) Use data from **Table 1** to show that, to 3 significant figures, a more accurate value for the M_r of butane is 58.1

[1 mark]

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6 (a) (ii) State why the precise relative atomic mass quoted in **Table 1** for the ^{12}C isotope is exactly 12.00000

[1 mark]

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Question 6 continues on the next page

6 (c) (iii) There are two functional groups in prop-2-en-1-ol. Each of these functional groups contains a bond with a characteristic absorption range in the infrared spectrum.

Use **Table A** on the Data Sheet to suggest a bond and its absorption range for each of the two functional groups.

[2 marks]

Bond 1 ..... Absorption range .....

Bond 2 ..... Absorption range .....

6 (d) Compound **X** is another isomer of propanal. The infrared spectrum of **X** shows an absorption in the range 1680–1750 cm^{-1}.

6 (d) (i) Draw the structure of **X**.

[1 mark]

6 (d) (ii) Which of the following, **A**, **B**, **C** or **D**, represents the type of isomerism shown by **X** and propanal?

Write the correct letter, **A**, **B**, **C** or **D**, in the box.

[1 mark]

A chain isomerism
B E–Z isomerism
C functional group isomerism
D position isomerism

9