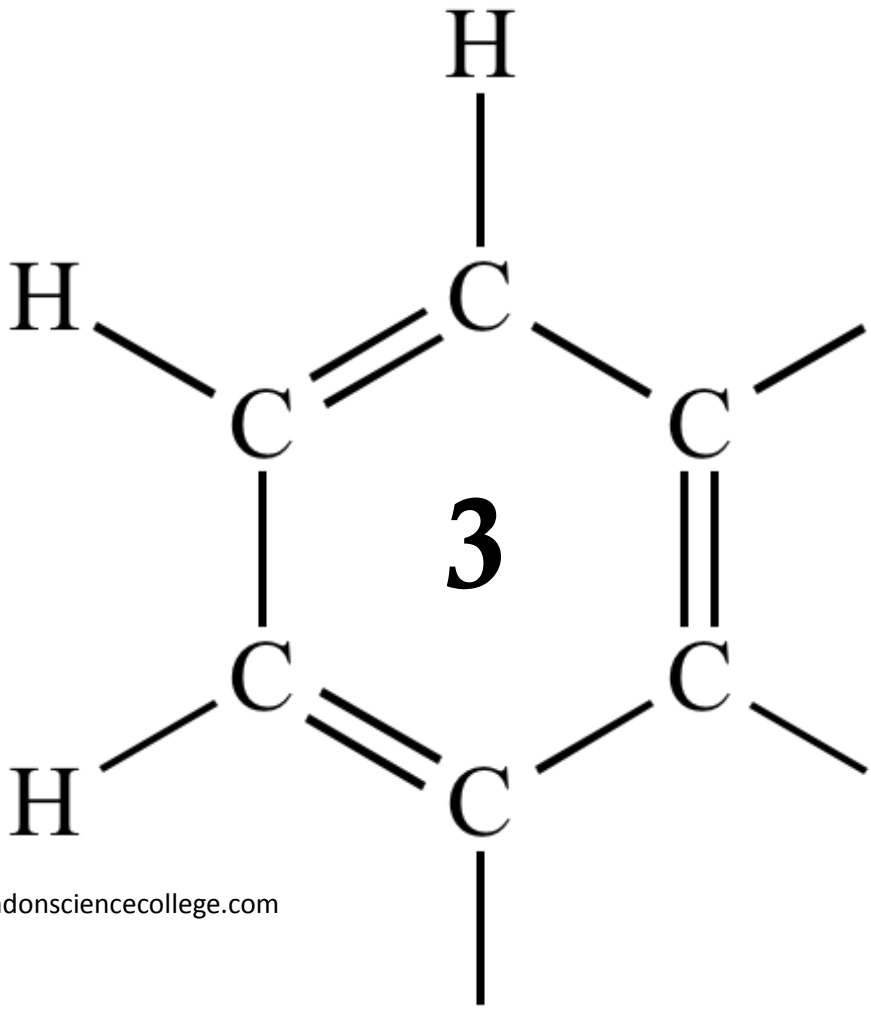
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

ORGANIC ANAYLSIS



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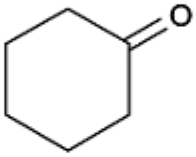
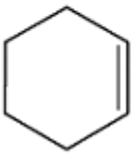
1 Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.

cyclohexane
A

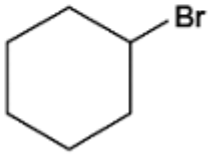
cyclohexanol
B



cyclohexanone
C



cyclohexene
D

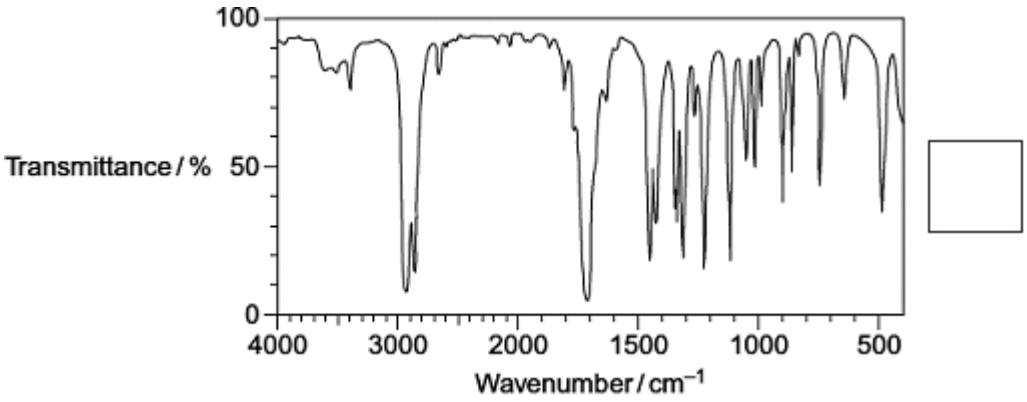


bromocyclohexane
E

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

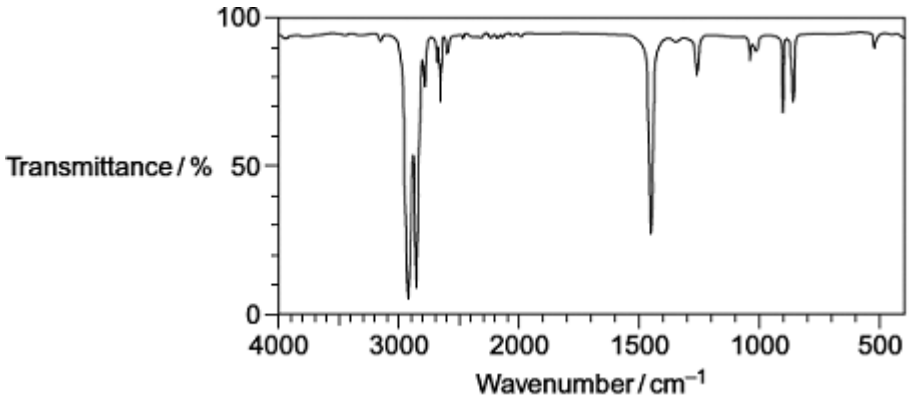
Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

(i)



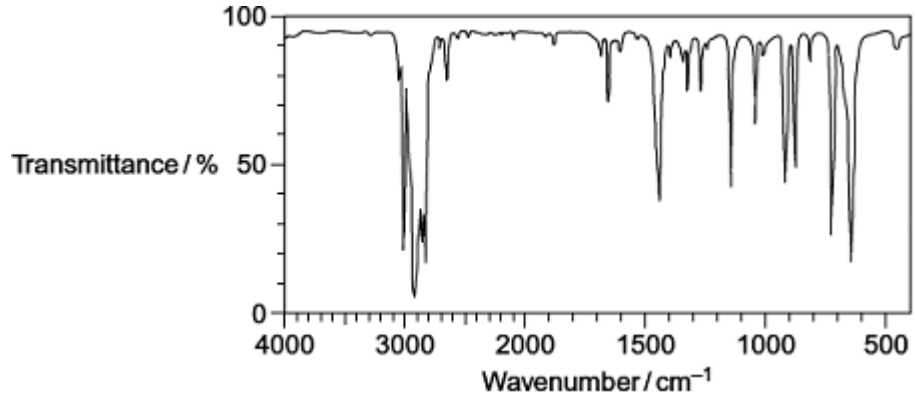
(1)

(ii)


100
Transmittance / %
50
0
4000
3000
2000
1500
1000
500
Wavenumber / cm⁻¹

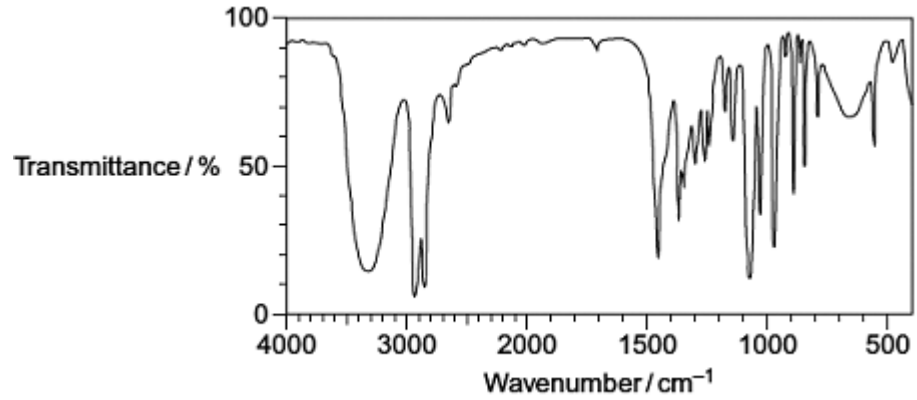
(1)

(iii)


100
Transmittance / %
50
0
4000
3000
2000
1500
1000
500
Wavenumber / cm⁻¹

(1)

(iv)


100
Transmittance / %
50
0
4000
3000
2000
1500
1000
500
Wavenumber / cm⁻¹

(1)

(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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(Extra space) .....

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(3)

(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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(Extra space) .....

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(3)

(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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(Extra space) .....

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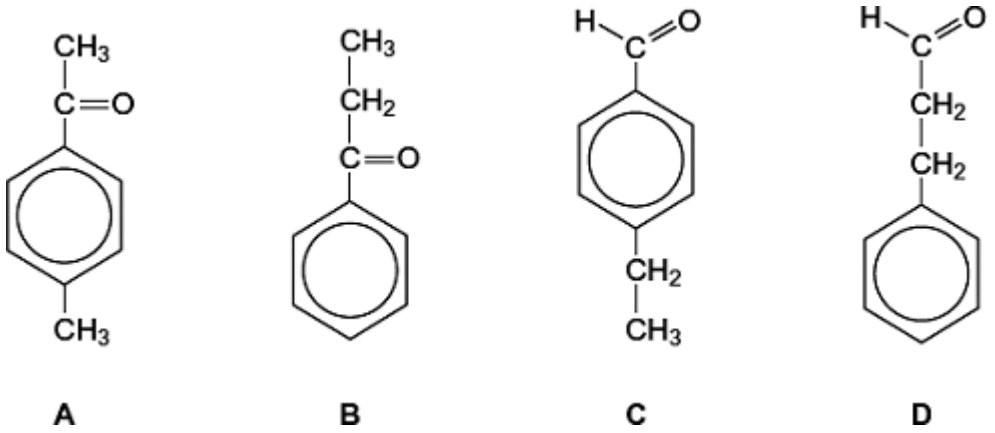
(5)
(Total 15 marks)

2 Mass spectrometry is used by organic chemists to help distinguish between different compounds.

Four isomers of $C_9H_{10}O$, shown below, were analysed by mass spectrometry.



A **B** **C** **D**

The mass spectra obtained from these four isomers were labelled in random order as I, II, III and IV.

Each spectrum contained a molecular ion peak at *m/z* = 134

The data in the table below show the *m/z* values greater than 100 for the major peaks in each spectrum due to fragmentation of the molecular ion. The table also shows where no major peaks occurred.

Spectrum	***m/z* values for major peaks**	**No major peak at *m/z***
I	119	133, 105
II	133, 119 and 105	
III	133, 105	119
IV	105	133, 119

(a) Two of the molecular ions fragmented to form an ion with *m/z* = 133 by losing a radical. Identify the radical that was lost.

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(1)

(b) Two of the molecular ions fragmented to form an ion with *m/z* = 119 by losing a radical. Identify the radical that was lost.

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(1)

(c) Three of the molecular ions fragmented to form ions with m/z = 105 by losing a radical with M_r = 29

Identify **two** different radicals with M_r = 29 that could have been lost.

Radical 1 .....

Radical 2 .....

(2)

(d) Consider the structures of the four isomers and the fragmentations indicated in parts (a) to (c).
Write the letter **A**, **B**, **C** or **D**, in the appropriate box below, to identify the compound that produces each spectrum.

Spectrum I ☐

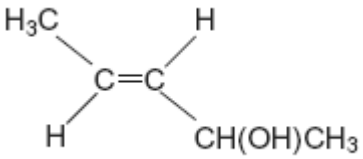
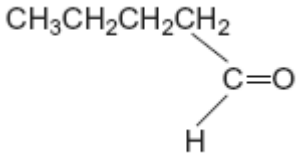
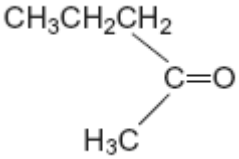
Spectrum II ☐

Spectrum III ☐

Spectrum IV ☐

(4)
(Total 8 marks)

3 The table below shows the structures of three isomers with the molecular formula $C_5H_{10}O$

Isomer **1** 	(*E*)-pent-3-en-2-ol
Isomer **2** 	pentanal
Isomer **3** 	

(a) Complete the table by naming Isomer **3**.

(1)

(b) State the type of structural isomerism shown by these three isomers.

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(1)

(c) The compound (*Z*)-pent-3-en-2-ol is a stereoisomer of (*E*)-pent-3-en-2-ol.

(i) Draw the structure of (*Z*)-pent-3-en-2-ol.

(1)

(ii) Identify the feature of the double bond in (*E*)-pent-3-en-2-ol and that in (*Z*)-pent-3-en-2-ol that causes these two compounds to be stereoisomers.

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(1)

(d) A chemical test can be used to distinguish between separate samples of Isomer **2** and Isomer **3**.
Identify a suitable reagent for the test.
State what you would observe with Isomer **2** and with Isomer **3**.

Test reagent .....

Observation with Isomer **2**.....

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Observation with Isomer **3**.....

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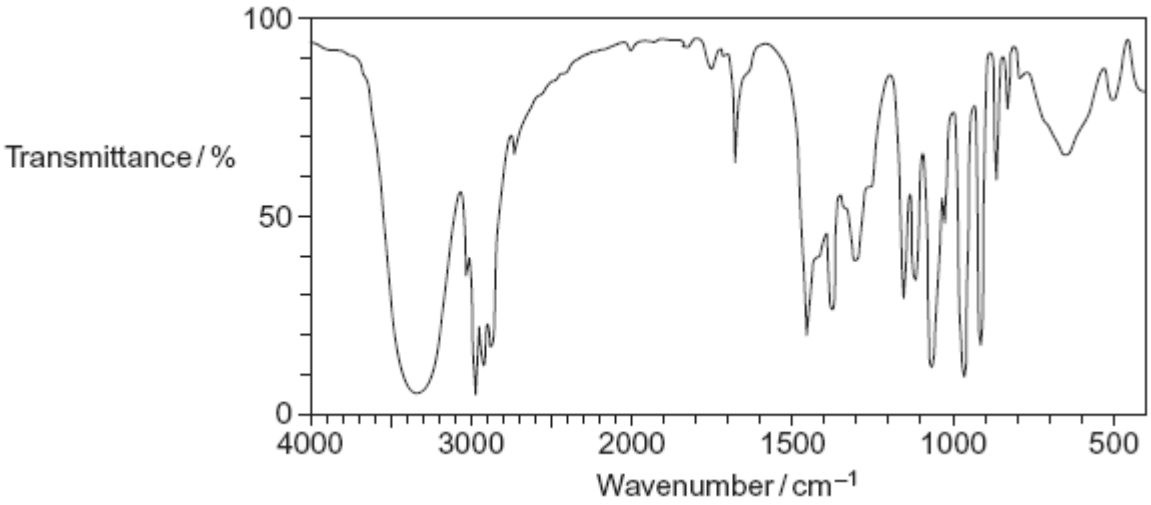
(3)

(e) The following is the infrared spectrum of one of the isomers **1**, **2** or **3**.



(i) Deduce which of the isomers (**1**, **2** or **3**) would give this infrared spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

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(1)

(ii) Identify two features of the infrared spectrum that support your deduction.
In each case, identify the functional group responsible.

Feature 1 and functional group .....

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Feature 2 and functional group .....

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(2)
(Total 10 marks)

4 (a) Some scientists thought that the waste water from a waste disposal factory contained **two** sodium halides.

They tested a sample of the waste water.

They added three reagents, one after the other, to the same test tube containing the waste water.

The table below shows their results.

Reagent added	Observations
1. Silver nitrate solution (acidified with dilute nitric acid)	A cream precipitate formed
2. Dilute ammonia solution	A yellow precipitate remained
3. Concentrated ammonia solution	The yellow precipitate did not dissolve

(i) Identify the yellow precipitate that did **not** dissolve in concentrated ammonia solution.
Write the **simplest** ionic equation for the formation of this precipitate from silver ions and the correct halide ion.
Identify the other sodium halide that must be present in this mixture of two sodium halides.

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(3)

(ii) Give **one** reason why the silver nitrate solution was acidified before it was used in this test.

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(1)

(iii) The method that the scientists used could **not** detect one type of halide ion. Identify this halide ion.
Give **one** reason for your answer.

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(2)

(b) The scientists thought that the waste water also contained dissolved barium ions. An aqueous solution of sodium sulfate can be used to test for the presence of dissolved barium ions.

Write the **simplest** ionic equation for the reaction between barium ions and sulfate ions to form barium sulfate.

State what is observed in this reaction.

Give a use for barium sulfate in medicine and explain why this use is possible, given that solutions containing barium ions are poisonous.

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(4)

(c) The scientists also analysed the exhaust gases from an incinerator used to destroy waste poly(ethene).
Mass spectrometry showed that there was a trace gas with a precise $M_r = 28.03176$ in the exhaust gases from the incinerator.

The table below contains some precise relative atomic mass data.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

Use the data to show that the trace gas is ethene. Show your working.

Suggest why both ethene and carbon monoxide might have been identified as the trace gas if the scientists had used relative atomic masses to a precision of only one decimal place.

Write an equation for the incomplete combustion of ethene to form carbon monoxide and water only.

Ethene is used to make poly(ethene).
Draw the displayed formula for the repeating unit of poly(ethene).
Name this type of polymer.

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(5)
(Total 15 marks)

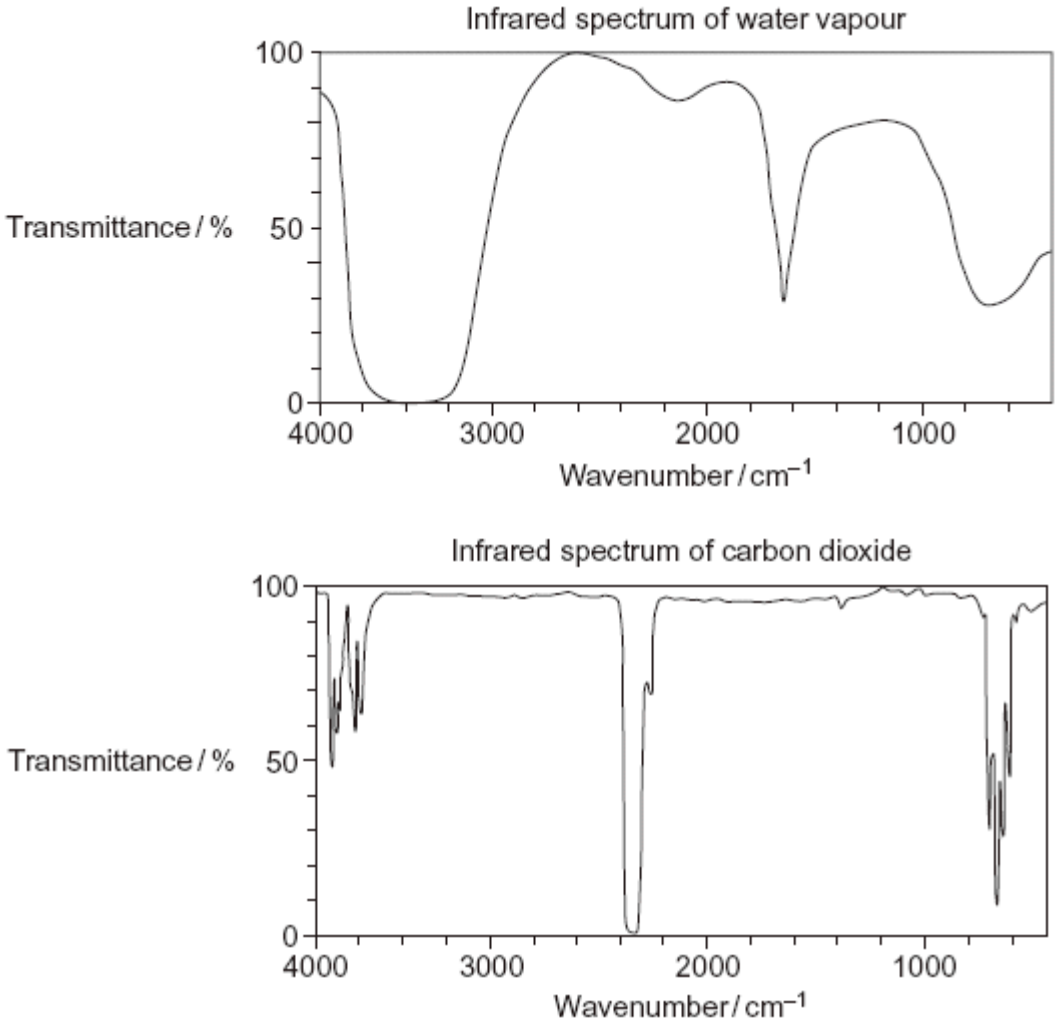
5 A sample of an alcohol was thought to be contaminated with an alkene. Give a reagent that could be used to confirm the presence of an alkene. State what you would observe.

Reagent .....

Observation .....

(Total 2 marks)

6 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.



(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)

(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)
(Total 3 marks)

7 A student read the following passage on the Internet.

> Haloalkanes contain a polar covalent bond. The carbon atom of the polar covalent bond can be attacked by nucleophiles. Nucleophilic attack enables haloalkanes to undergo substitution reactions.
> A nucleophilic substitution reaction occurs when a haloalkane undergoes hydrolysis; the rate of hydrolysis of the haloalkane is influenced by the carbon–halogen bond enthalpy.

(a) Explain the meaning of each of the following terms in the information given above.

(i) *nucleophile*

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(1)

(ii) *substitution,* as applied to nucleophilic substitution in a haloalkane

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(1)

(iii) *hydrolysis*

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(1)

(iv) *bond enthalpy,* as applied to a carbon–halogen bond.

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(1)

(b) Outline a mechanism for the nucleophilic substitution reaction in which 2-bromopropane ($CH_3CHBrCH_3$) reacts with potassium hydroxide to form propan-2-ol.

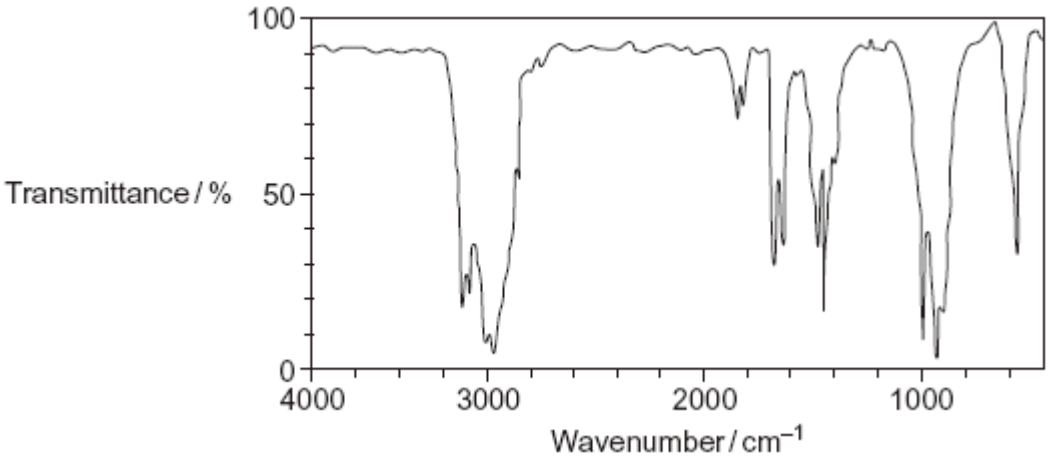
(2)

(c) Haloalkanes also undergo elimination reactions to produce alkenes.

(i) Outline a mechanism for the elimination reaction in which 2-bromopropane reacts with potassium hydroxide to form propene.

(3)

(ii) A student obtained the following infrared spectrum for the product from this elimination reaction.



Use information from the infrared spectrum to state and explain how the student deduced that the product was an alkene.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(2)
(Total 11 marks)

8 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

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

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.....

(1)

(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)

(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)

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

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(1)

(c) Dinitrogen oxide is formed when ammonia is oxidised according to the following equation.

$$2NH_3(g) + 2O_2(g) \rightarrow N_2O(g) + 3H_2O(l)$$

(i) Use the standard enthalpies of formation in the table below to calculate a value for the standard enthalpy change of this reaction.

	$NH_3(g)$	$O_2(g)$	$N_2O(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$/ kJ mol^{-1}	–46	0	+82	–286

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(3)

(ii) State **one** condition necessary for enthalpies of formation to be quoted as standard values at a specified temperature of 298 K.

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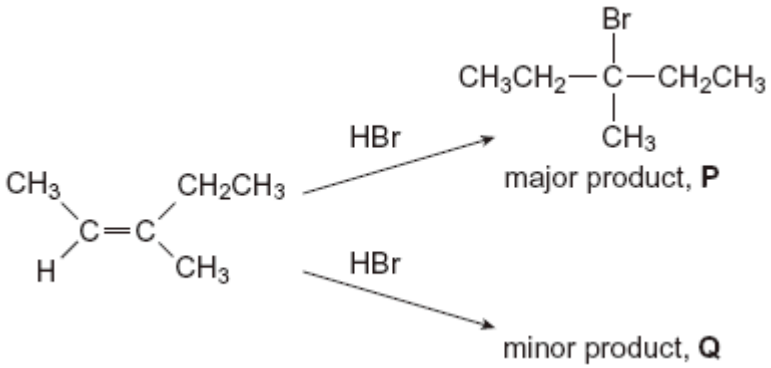
(1)

(Total 8 marks)

9 The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



(a) (i) Name the major product **P**.

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(1)

(ii) Name the mechanism for these reactions.

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(1)

(iii) Draw the displayed formula for the minor product **Q** and state the type of structural isomerism shown by **P** and **Q**.

Displayed formula for **Q**

Type of structural isomerism .....

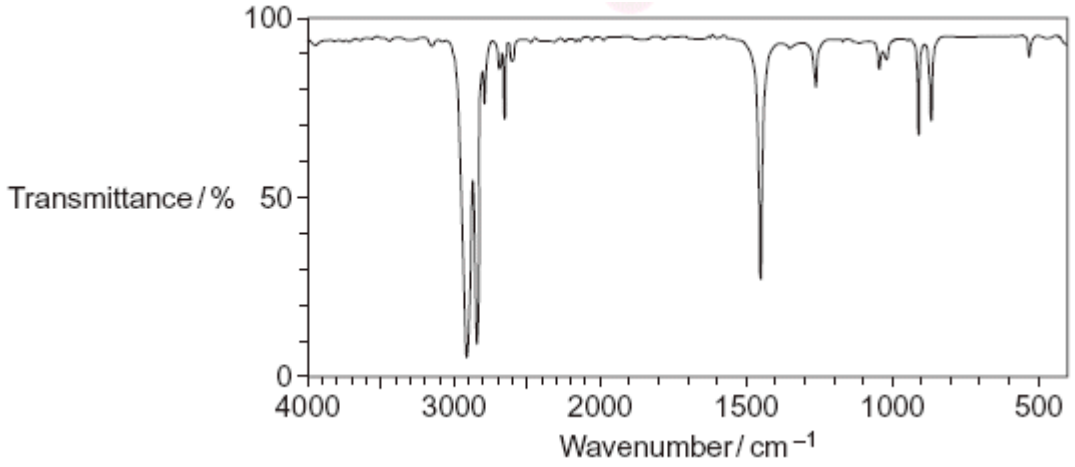
(2)

(iv) Draw the structure of the (E)-stereoisomer of 3-methylpent-2-ene.

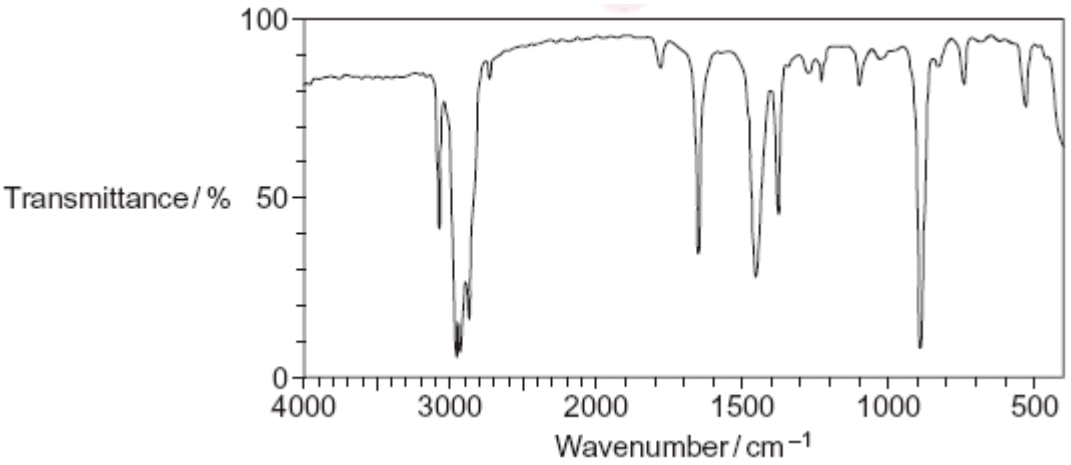
(1)

(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**



(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 .....

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(2)

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

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(1)

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

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(1)

(Total 9 marks)