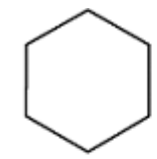
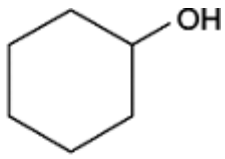
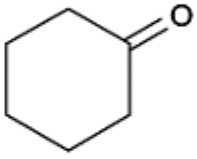
Q1. Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.



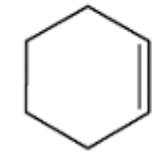
cyclohexane
A



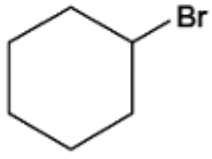
cyclohexanol
B



cyclohexanone
C



cyclohexene
D

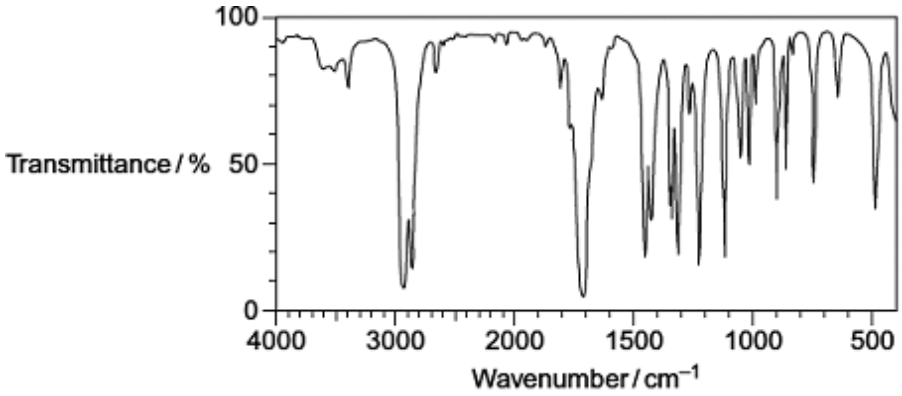


bromocyclohexane
E

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

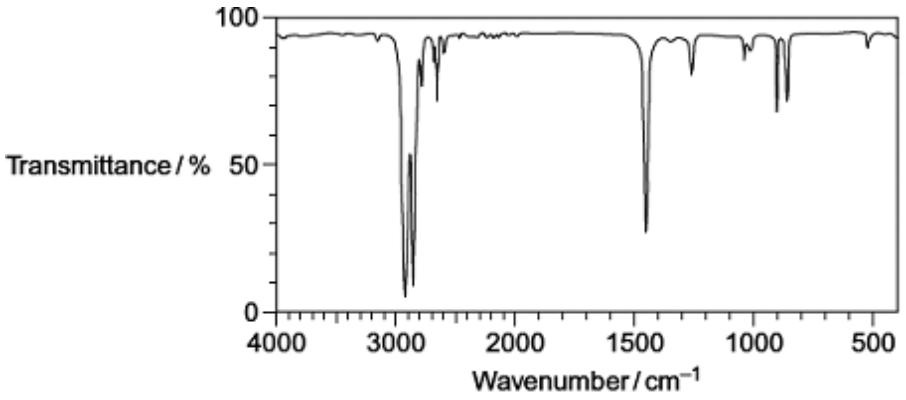
Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

(i)



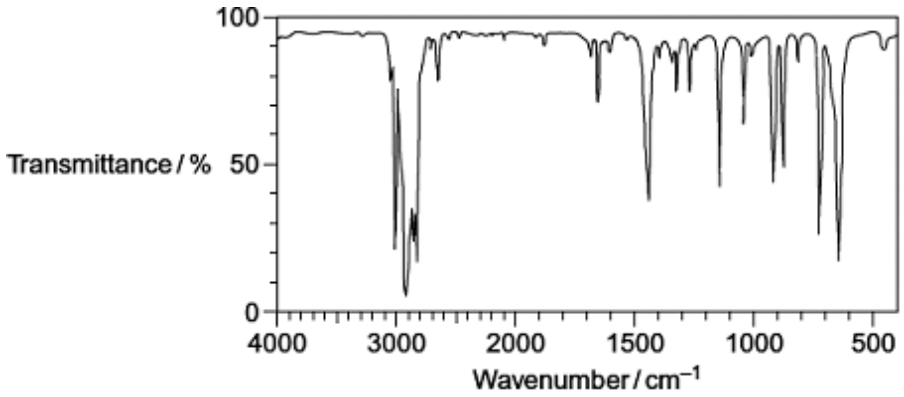
(1)

(ii)



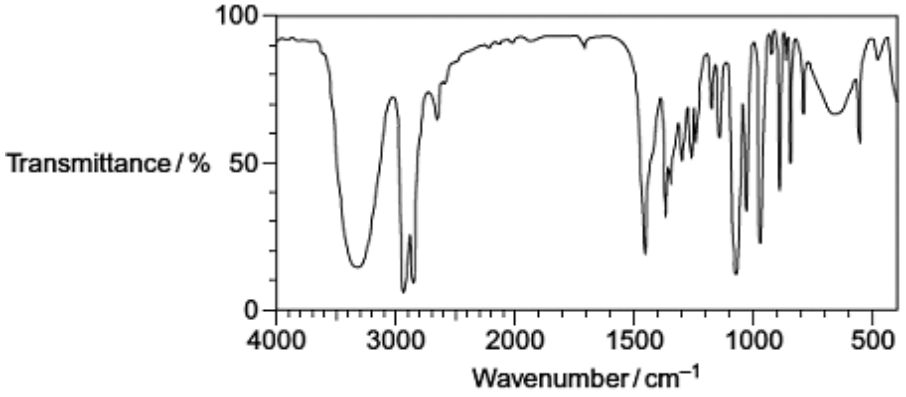
(1)

(iii)



(1)

(iv)



(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) .....

.....

.....

(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)

Q2. Infrared spectroscopy can be used to distinguish between esters, alcohols and carboxylic acids.

Use the table below, where appropriate, to answer the following questions.

Infrared absorption data

Bond	**Wavenumber / cm^{-1}**
N – H (amines)	3300 – 3500

O – H (alcohols)	3230 – 3550
C – H	2850 – 3300
O – H (acids)	2500 – 3000
C ≡ N	2220 – 2260
C = O	1680 – 1750
C = C	1620 – 1680
C – O	1000 – 1300
C – C	750 – 1100

(a) Identify an absorption that would enable you to distinguish between methyl ethanoate and ethanoic acid.

.....

(1)

(b) Identify an absorption that would enable you to distinguish between methanol and ethanoic acid.

.....

(1)

(c) State how infrared spectroscopy can be used to show that an unknown ester is definitely methyl ethanoate.

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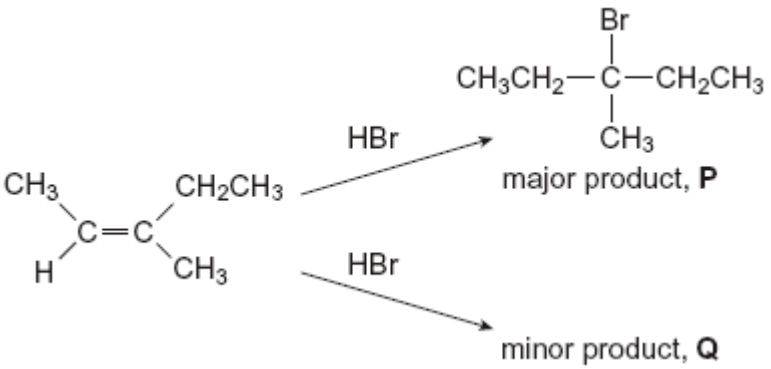
(2)
(Total 4 marks)

Q3. The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



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

.....

(1)

(ii) Name the mechanism for these reactions.

.....

(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 .....

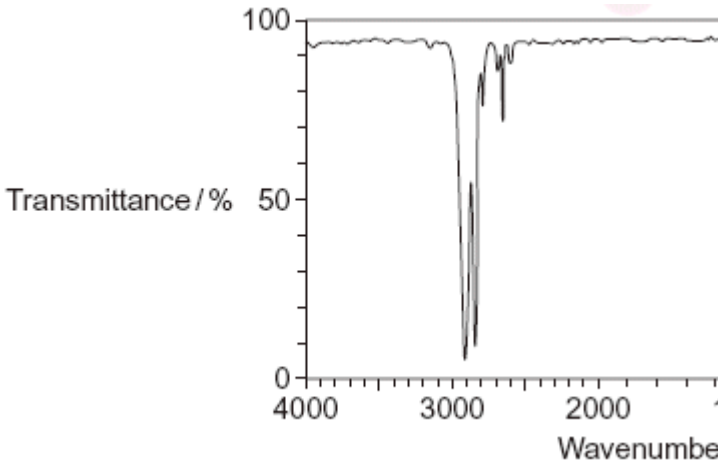
(2)

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

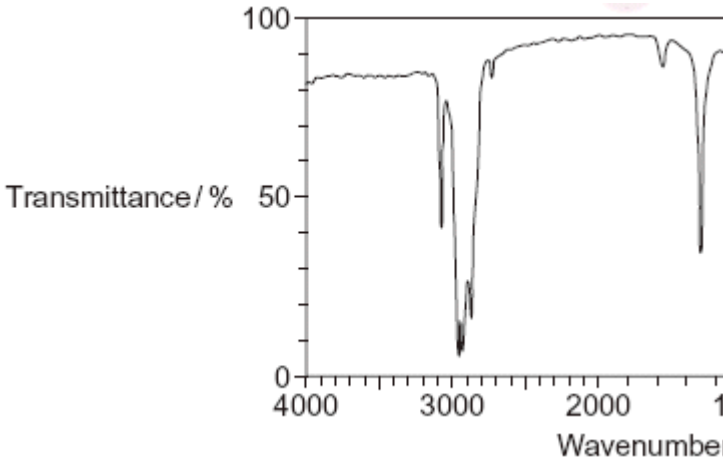
(1)

(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 .....

.....

(2)

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

.....

(1)

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

.....

(1)
(Total 9 marks)

Q4. 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

.....

.....

.....

(1)

(iii) *hydrolysis*

.....

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.....

(1)

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

.....

.....

.....

(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.

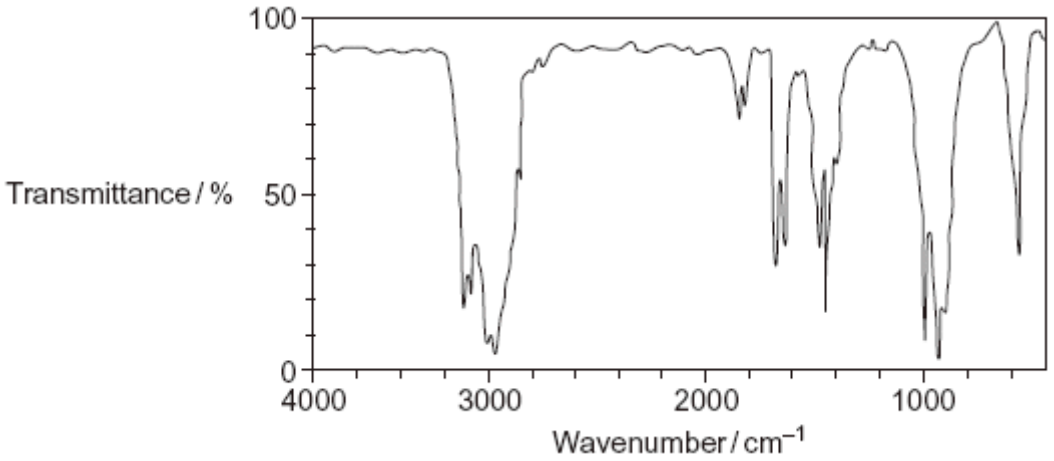
(2)

(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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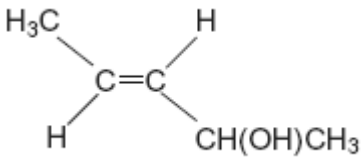
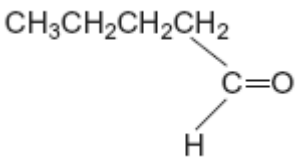
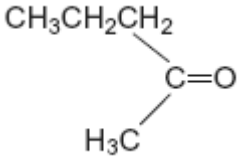
(2)
(Total 11 marks)

Q5. 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.

.....

(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.

.....

(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**.....

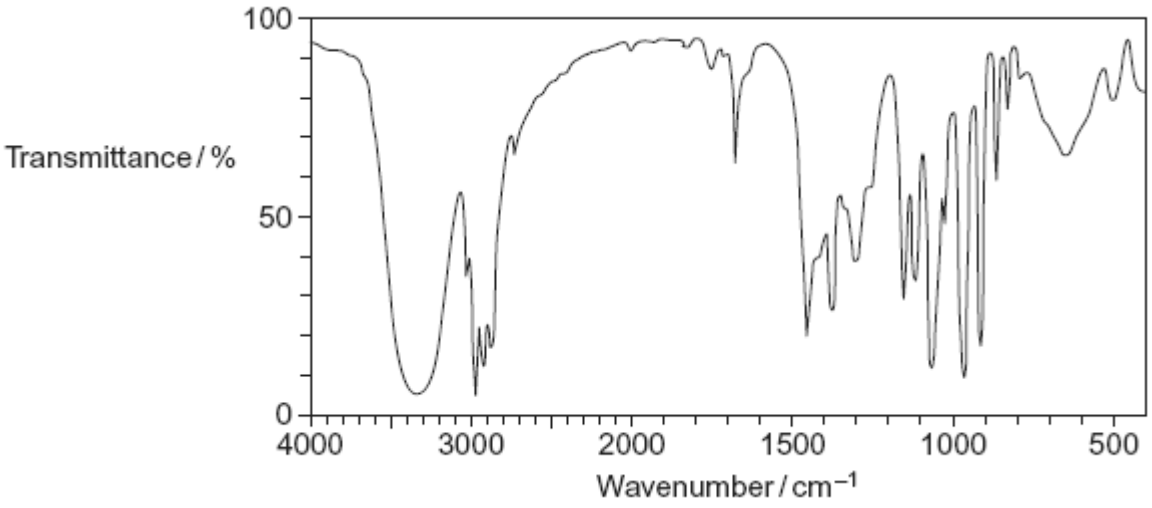
.....

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

.....

(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.

.....

(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 .....

.....

.....

.....

Feature 2 and functional group .....

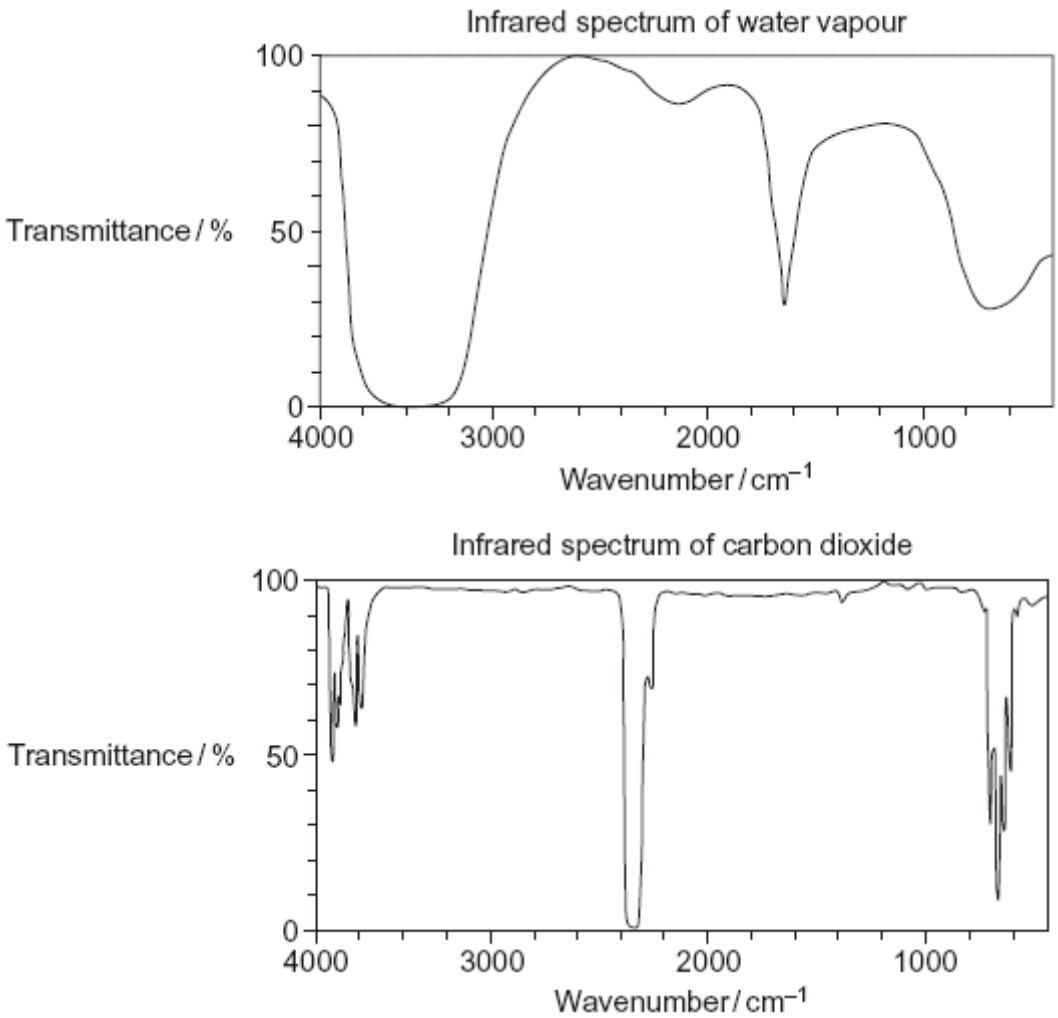
.....

.....

.....

(2)
(Total 10 marks)

Q6. 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.

.....

.....

(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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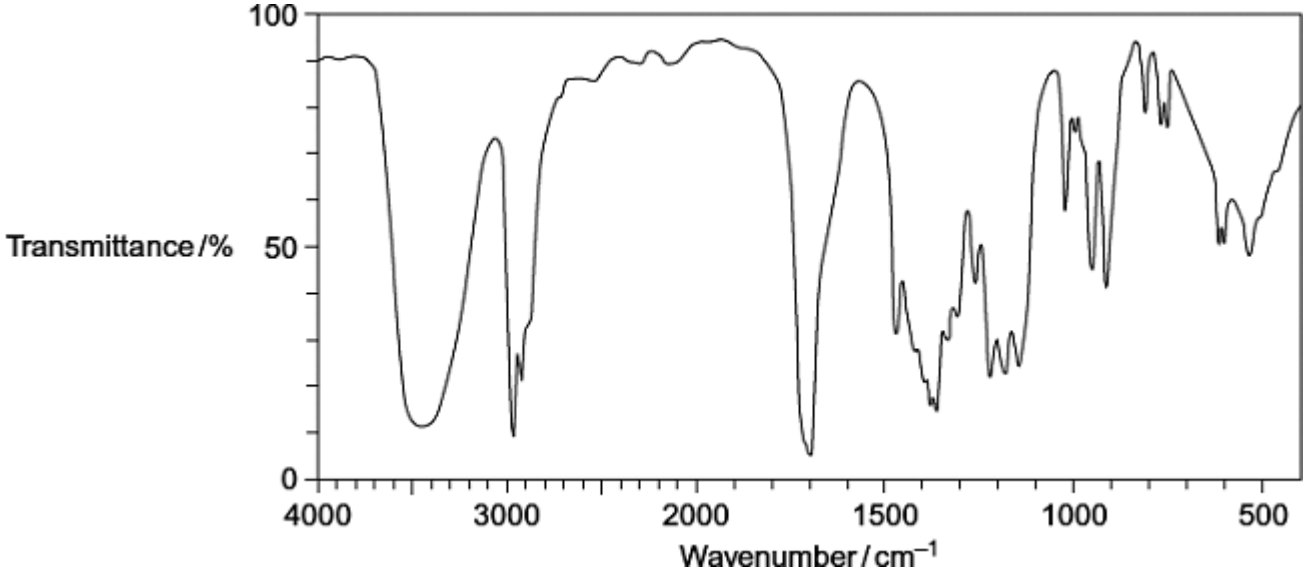
.....

.....

(2)
(Total 3 marks)

Q7. Compound **X** ($C_6H_{12}O_2$) was analysed by infrared spectroscopy and by proton nuclear magnetic resonance spectroscopy.

(a) The infrared spectrum of **X** is shown below.
Use **Table 1** on the Data Sheet to help you answer the question.



Identify the functional group that causes the absorption at 3450cm^{-1} in the spectrum.

.....

(1)

(b) The proton n.m.r. spectrum of **X** consists of 4 singlet peaks.

The table below gives the chemical shift for each of these peaks, together with their integration values.

δ /ppm	1.2	2.2	2.6	3.8
Integration value	6	3	2	1

Use **Table 2** on the Data Sheet to help you answer the following questions.

Use the chemical shift and the integration data to show what can be deduced about the structure of **X** from the presence of the following in its proton n.m.r. spectrum.

(i) The peak at δ = 2.6

.....

(1)

(ii) The peak at δ = 2.2

.....

(1)

(iii) The peak at δ = 1.2

.....

(1)

(iv) Deduce the structure of **X** ($C_6H_{12}O_2$)

(1)
(Total 5 marks)