



A-Level Chemistry

Infrared Spectroscopy

Question Paper

Time available: 64 minutes

Marks available: 61 marks

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1.

A student was given unlabelled samples of pentan-1-ol, pent-1-ene, pentanoic acid and pentanal.

- (a) Name the reagent(s) that the student could use to identify the sample that was pent-1-ene. Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

Observation(s) _____

(2)

- (b) Name the reagent(s) that the student could use to identify the sample that was pentanoic acid.

Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

Observation(s) _____

(2)

- (c) Name the reagent(s) that the student could use to identify the sample that was pentanal.

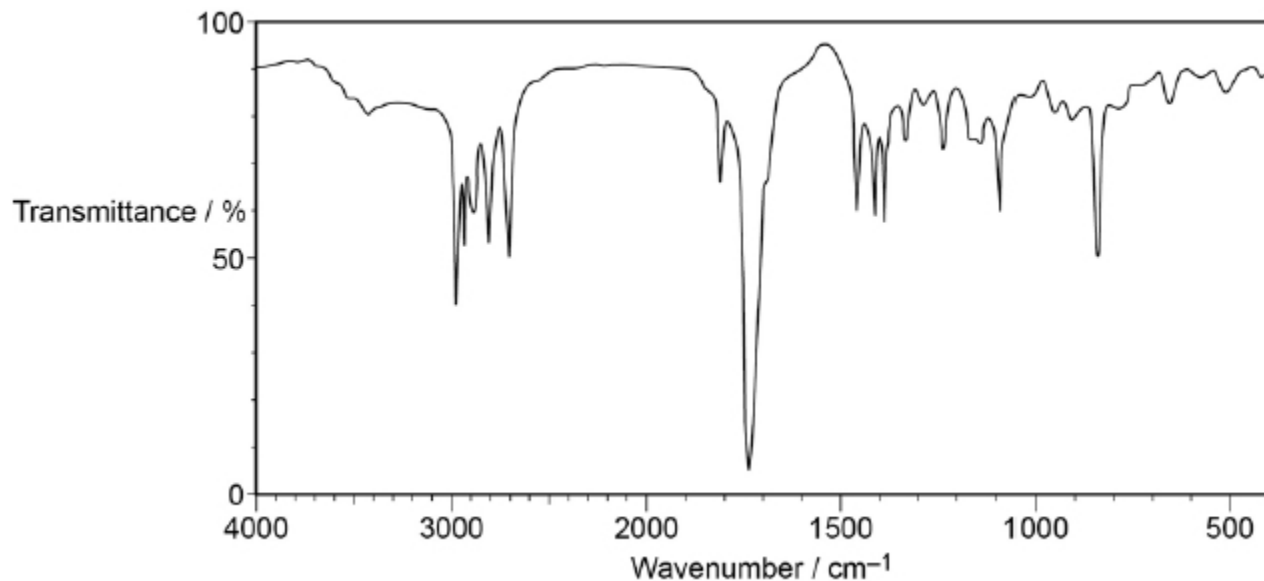
Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

Observation(s) _____

(2)

(d) The student deduced that the spectrum in the image below was that of pentanal.



Justify this deduction and suggest why this spectrum **cannot** be that of pentan-1-ol, pentanoic acid or pent-1-ene.

(4)
(Total 10 marks)

2.

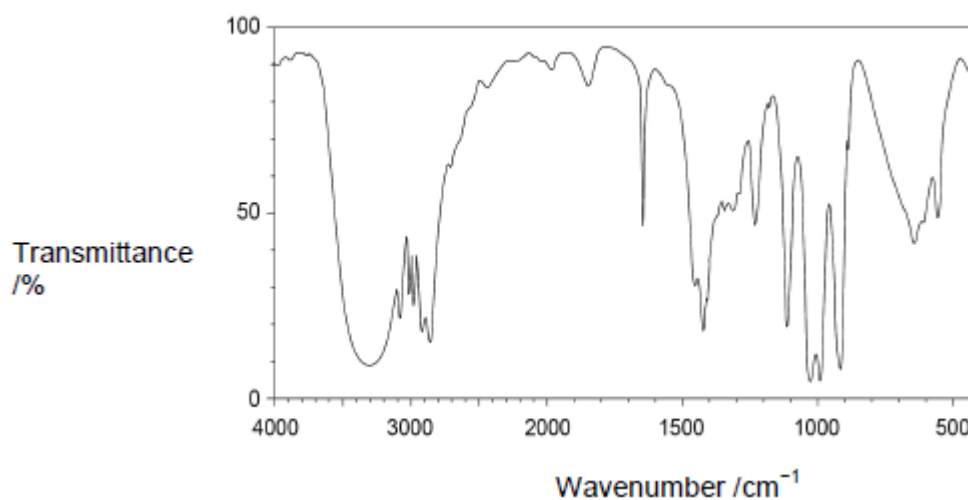
The compounds in the table all have a relative molecular mass of 58.0

Name	Propanal	Prop-2-en-1-ol	Butane
Structure	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{C}=\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $

- (a) Explain why determining the precise relative molecular mass of propanal and prop-2-en-1-ol by mass spectrometry could not be used to distinguish between samples of these two compounds.

(2)

- (b) The infrared spectrum of one of these three compounds is shown below.



Use the spectrum to identify the compound.

State the bond that you used to identify the compound and give its wavenumber range.

You should only consider absorptions with wavenumbers greater than 1500 cm⁻¹.

Compound _____

Bond used to identify compound _____

Wavenumber range of bond used to identify compound _____ cm⁻¹

(2)

- (b) Compounds **A** and **B** are both straight-chain compounds.
A can be oxidised to form **P**.
B can be oxidised to form **Q**.
P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in the table are obtained.

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**.
Explain your answer with reference to the functional groups in **P** and **Q**.

Identity of **A** _____

Identity of **B** _____

Explanation _____

(3)

- (c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1} .

State the bond that causes the absorption in the range 1620–1680 cm^{-1} .

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

Bond _____

Displayed formula of **C**

Reagent _____

Condition _____

(4)

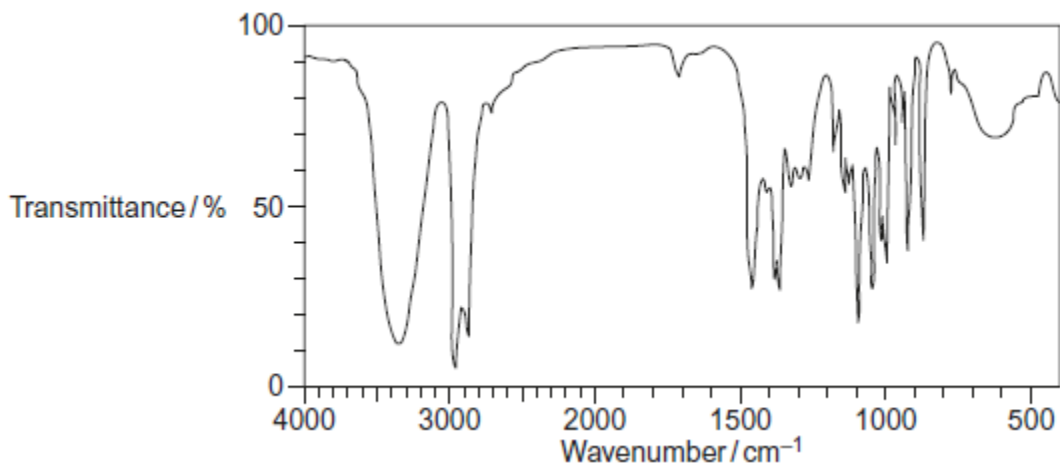
- (d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.
- (i) Compound **S** is obtained by distilling it off as it forms during the oxidation. Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

(3)

- (ii) A student claims to have oxidised compound **D**. The infrared spectrum of the product obtained by the student is shown.



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

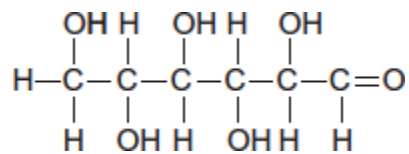
(2)

(Total 13 marks)

4.

Glucose is an organic molecule. Glucose can exist in different forms in aqueous solution.

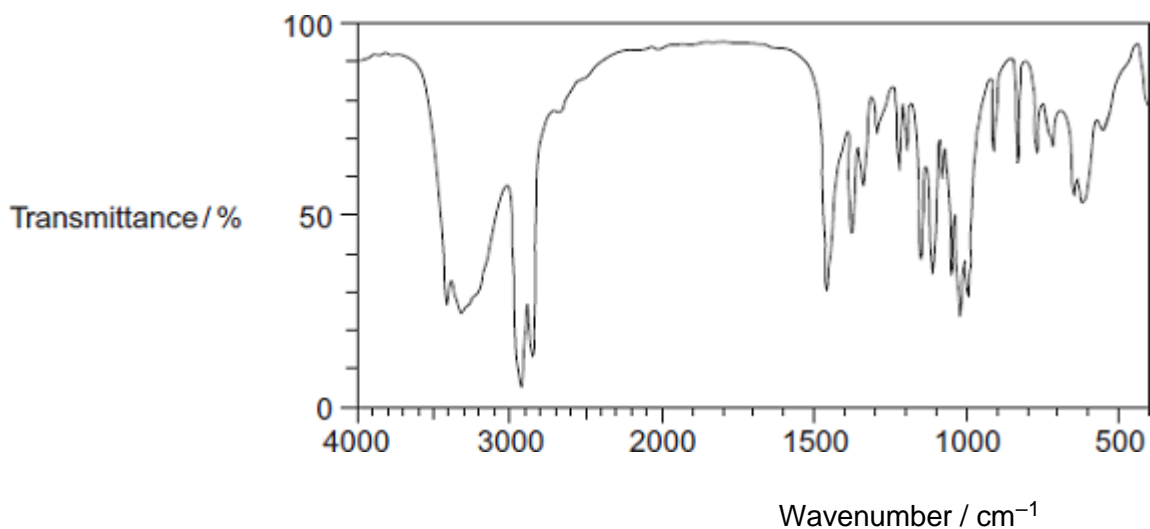
(a) In aqueous solution, some glucose molecules have the following structure.



(i) Deduce the empirical formula of glucose.

(1)

(ii) Consider the infrared spectrum of solid glucose.



State why it is possible to suggest that in the solid state very few molecules have the structure shown.

You may find it helpful to refer to **Table 1** on the Data Sheet.

(1)

- (b) In the absence of oxygen, an aqueous solution of glucose can be fermented to produce ethanol for use in alcoholic drinks.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for the production of ethanol in this fermentation.

Equation

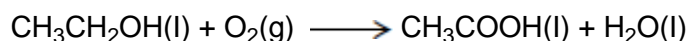
Condition 1 _____

Condition 2 _____

(3)

- (c) Any ethanol present in the breath of a drinker can be detected by using a breathalyser. The ethanol is converted into ethanoic acid. The breathalyser has negative and positive electrodes. A current is measured and displayed in terms of alcohol content.

The overall redox equation is as follows



- (i) Draw the displayed formula for ethanoic acid.

(1)

- (ii) Deduce a half-equation for the reduction of atmospheric oxygen to water in acidic solution at one electrode of the breathalyser.

(1)

- (iii) Deduce a half-equation for the oxidation of ethanol in water to ethanoic acid at the other electrode of the breathalyser.

(1)

- (iv) The earliest breathalysers used laboratory chemicals to oxidise the ethanol to ethanoic acid. Detection was by a colour change.

Identify a reagent or combination of reagents that you would use in the laboratory to oxidise ethanol to ethanoic acid.

State the colour **change** that you would expect to see.

Reagent or combination of reagents _____

Colour change _____

(2)

- (d) The fermentation of glucose from crops is the main method for the production of ethanol. The product is called bioethanol. The European Union has declared that bioethanol is carbon-neutral.

- (i) State the meaning of the term *carbon-neutral*.

(1)

- (ii) Other than carbon-neutrality, state the **main** advantage of the use of glucose from crops as the raw material for the production of ethanol.

(1)

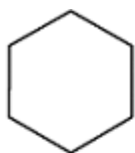
- (iii) Give *one* disadvantage of the use of crops for the production of ethanol.

(1)

(Total 13 marks)

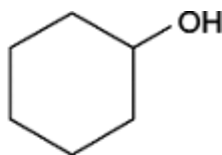
5.

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



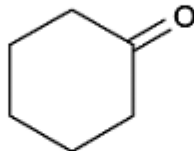
cyclohexane

A



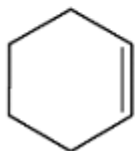
cyclohexanol

B



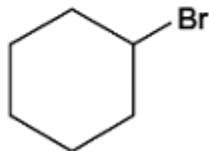
cyclohexanone

C



cyclohexene

D



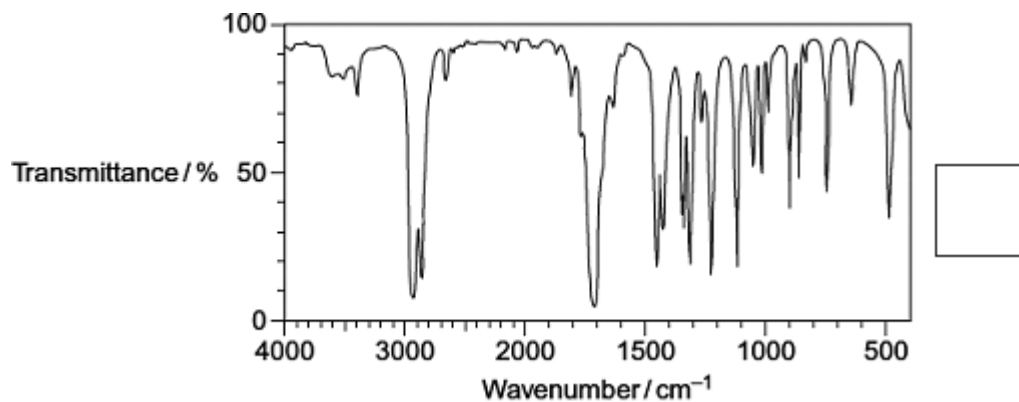
bromocyclohexane

E

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

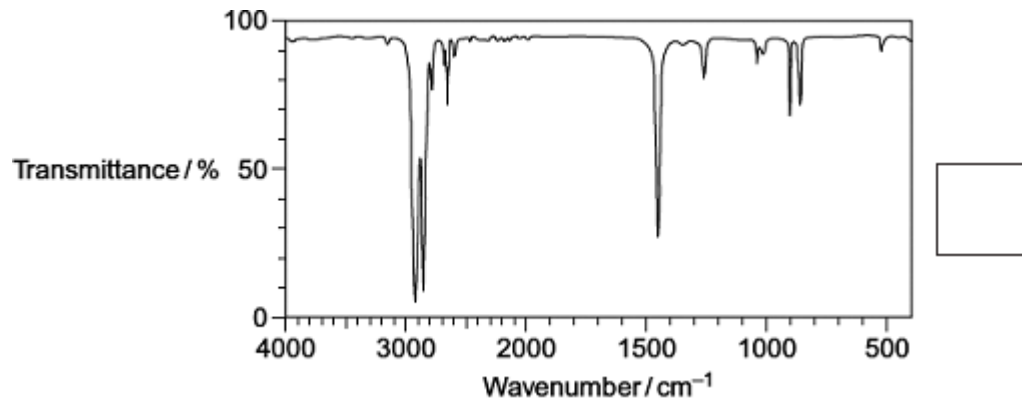
Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

(i)



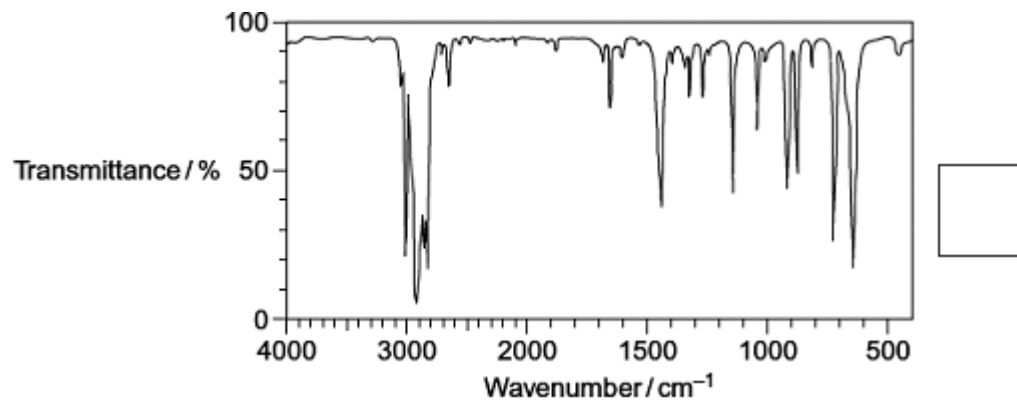
(1)

(ii)



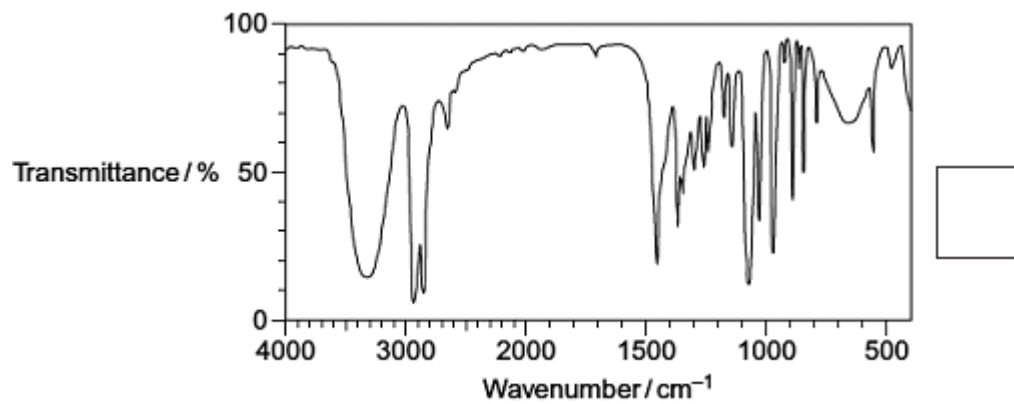
(1)

(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.

(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.

(3)

