Q1. Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

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

The table shows some precise relative atomic mass values.

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

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

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(1)

(ii) State why the precise relative atomic mass quoted in the table for the ^{12}C isotope is exactly 12.00000

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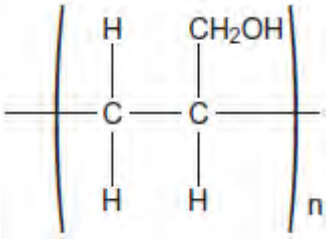
(1)

(b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

(1)

(c) Prop−2−en−1−ol is an isomer of propanal and can be polymerised to form a polymer represented by the following structure.



(i) Draw the structure of prop−2−en−1−ol.

(1)

(ii) Deduce the type of polymerisation that results in the formation of this polymer from prop−2−en−1−ol.

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(1)

(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.

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

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

(2)

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

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

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

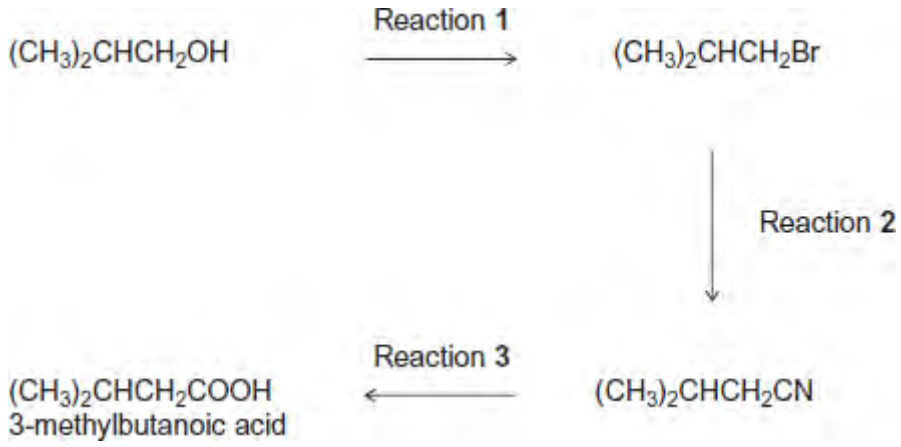
Write the correct letter, **A**, **B**, **C** or **D**, in the box.

A chain isomerism
B E−Z isomerism
C functional group isomerism

D position isomerism

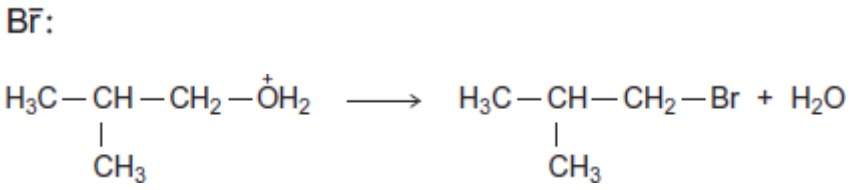
(1)
(Total 9 marks)

Q2. The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes.
The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



(a) One of the steps in the mechanism for Reaction **1** involves the replacement of the functional group by bromine.

(i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.



(2)

(ii) Deduce the name of the mechanism in part (i).

Give the IUPAC name of $(CH_3)_2CHCH_2Br$

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(2)

(b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(CH_3)_2CHCH_2CN$ and a **different** bond in $(CH_3)_2CHCH_2COOH$ that can be used with infrared spectroscopy to distinguish between each compound. For each of these bonds, give the range of wavenumbers at which the bond absorbs.
Use **Table A** on the Data Sheet when answering this question.

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(3)

(c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.

$$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons \underset{\text{an ester}}{(CH_3)_2CHCH_2COOCH_2CH_3} + H_2O$$

The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

(i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

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(Extra space) .....

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(3)

(ii) Explain how a catalyst increases the rate of a reaction.

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(Extra space) .....

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(2)

(Total 12 marks)

Q3. Glucose can decompose in the presence of microorganisms to form a range of products. One of these is a carboxylic acid (M_r = 88.0) containing 40.9% carbon and 4.5% hydrogen by mass.

(a) Deduce the empirical and molecular formulas of the carboxylic acid formed.

Empirical formula = ... Molecular formula = ...

(4)

(b) Ethanol is formed by the fermentation of glucose.

A student carried out this fermentation reaction in a beaker using an aqueous solution of glucose at a temperature of 25 °C in the presence of yeast.

Write an equation for the reaction occurring during fermentation.

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(1)

(c) In industry, this fermentation reaction is carried out at 35 °C rather than 25 °C.

Suggest **one** advantage and **one** disadvantage for industry of carrying out the fermentation at this higher temperature.

Advantage .....

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Disadvantage .....

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(2)

(d) The method used by the student in part (b) would result in the ethanol being contaminated by ethanoic acid.

How does this contamination occur?

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(1)

(e) Give **two** differences between the infrared spectrum of a carboxylic acid and that of an alcohol other than in their fingerprint regions.
Use **Table A** on the Data Sheet.

Difference 1 .....

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Difference 2 .....

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(2)
(Total 10 marks)

Q4. The following table gives the names and structures of some structural isomers with the molecular formula C_5H_{10}.

	Name of isomer	Structure
Isomer **1**	pent-2-ene	$CH_3CH = CHCH_2CH_3$
Isomer **2**	cyclopentane	
Isomer **3**	3-methylbut-1-ene	$(CH_3)_2CHCH = CH_2$
Isomer **4**	2-methylbut-2-ene	$(CH_3)_2C = CHCH_3$
Isomer **5**	2-methylbut-1-ene	$H_2C = C(CH_3)CH_2CH_3$

(a) Isomer **1** exists as E and Z stereoisomers.

(i) State the meaning of the term **stereoisomers**.

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(2)

(ii) Draw the structure of the E stereoisomer of Isomer **1**.

(1)

(b) A chemical test can be used to distinguish between separate samples of Isomer **1** and Isomer **2**.

Identify a suitable reagent for the test.
State what you would observe with Isomer **1** and with Isomer **2**.

Reagent.....

Observation with Isomer **1**.....

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

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(3)

(c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

(i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

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(1)

(ii) State **one** way that the infrared spectrum of Isomer 3 is different from the infrared spectrum of Isomer **4**.

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(1)

(d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

(1)

(e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

(i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

$$(CH_3)_2C = CHCH_3 + HBr \longrightarrow (CH_3)_2CBrCH_2CH_3$$

Name of mechanism.....

Mechanism

(5)

(ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

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(2)

(f) Name and outline a mechanism for the following reaction to form Isomer **5**. State the role of the hydroxide ion in this reaction.

$$(CH_3)_2CBrCH_2CH_3 + KOH \longrightarrow H_2C = C(CH_3)CH_2CH_3 + KBr + H_2O$$

Name of mechanism .....

Mechanism

Role of hydroxide ion .....

(5)

(Total 21 marks)

Q5. The infrared spectrum (**Figure 1**) and the ^{1}H NMR spectrum (**Figure 2**) of compound **R** with molecular formula $C_6H_{14}O$ are shown.

Figure 1

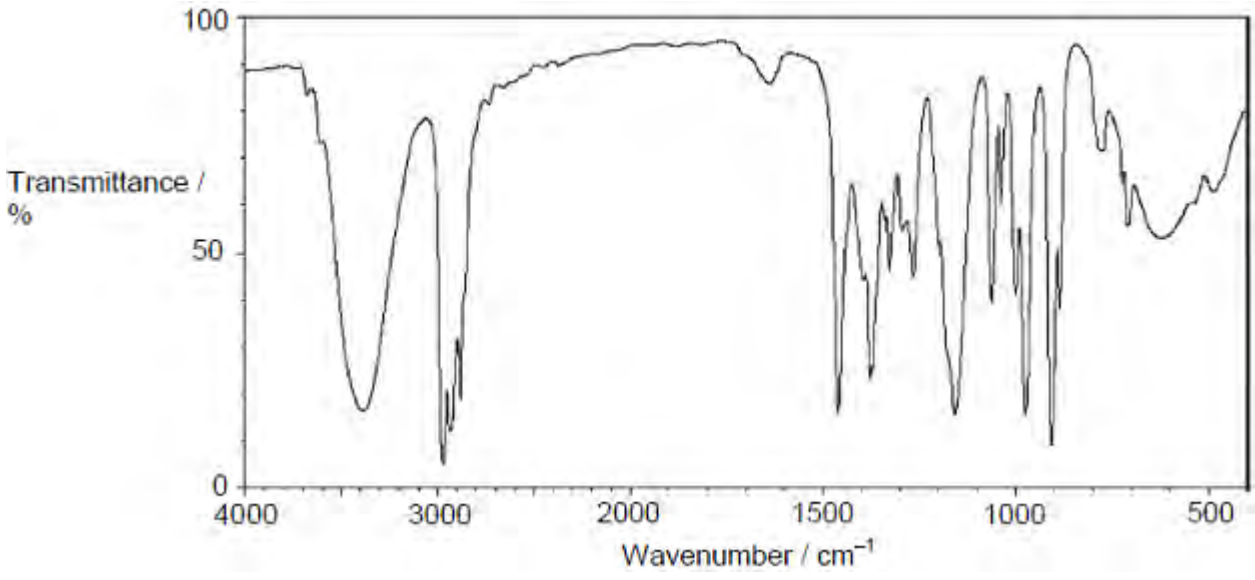
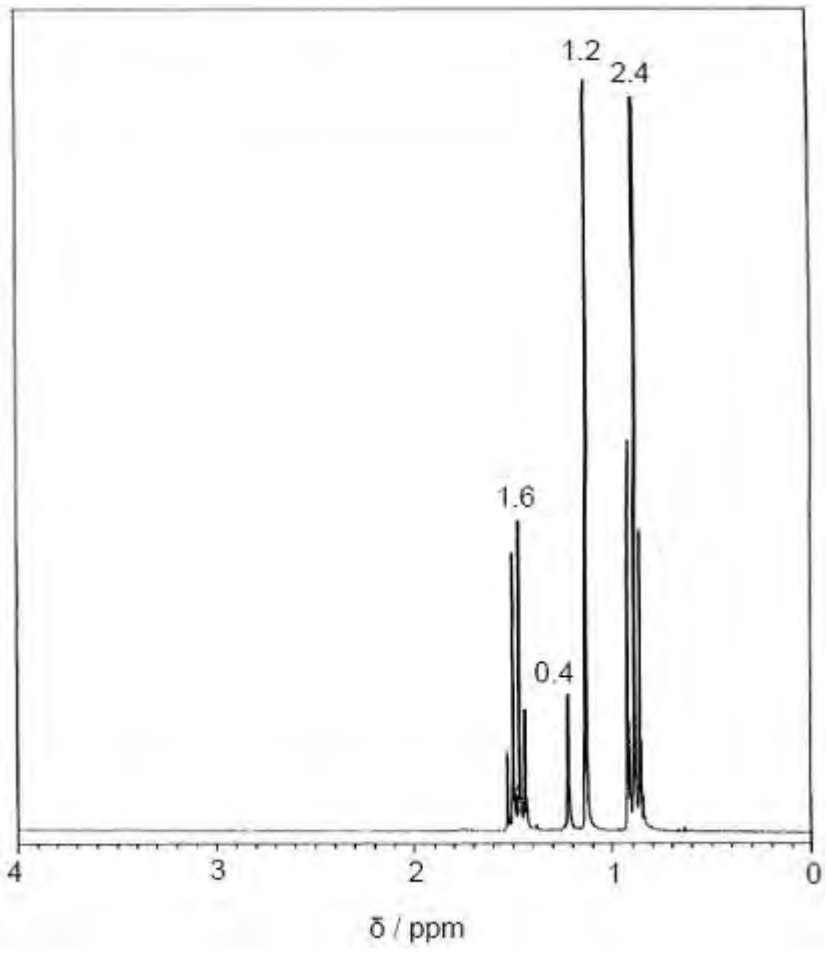


Figure 2



The relative integration values for the NMR peaks are shown on **Figure 2**.

Deduce the structure of compound **R** by analysing **Figure 1** and **Figure 2**.
Explain each stage in your deductions.

Use **Table A** and **Table B** on the Data Sheet.

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(Total 8 marks)