Q1. Pure hydrogen peroxide is a colourless liquid with a boiling point of 150 °C. Hydrogen peroxide was originally produced commercially in a two-stage process. In the first stage barium was heated in air to form barium peroxide. In the second stage barium peroxide was added to aqueous nitric acid. The equations for the reactions are shown below.

Stage **1** $Ba(s) + O_2(g) \longrightarrow BaO_2(s)$

Stage **2** $BaO_2(s) + 2HNO_3(aq) \longrightarrow H_2O_2(aq) + Ba(NO_3)_2(aq)12$

(a) Suggest **one** method of separating hydrogen peroxide from the reaction mixture in Stage **2**.

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(1)

(b) Apart from cost, suggest **one** reason why nitric acid was eventually replaced by sulfuric acid in Stage **2**.

.....

.....

(1)

(c) Suggest **one** reason why infrared spectroscopy could **not** be used to indicate the presence of a small amount of water in hydrogen peroxide.

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.....

(1)

(Total 3 marks)

Q2. This question concerns four isomers, **W**, **X**, **Y** and **Z**, with the molecular formula $C_5H_{10}O_2$

(a) The proton n.m.r. spectrum of **W** shows 4 peaks.
The table below gives the chemical shifts, δ values, for each of these peaks, together with their splitting patterns and integration values.

δ/ppm	2.18	2.59	3.33	3.64
Splitting pattern	singlet	triplet	singlet	triplet
Integration value	3	2	3	2

State what can be deduced about the structure of **W** from the presence of the following in its n.m.r. spectrum.

(i) The singlet peak at δ = 2.18

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(ii) The singlet peak at δ = 3.33

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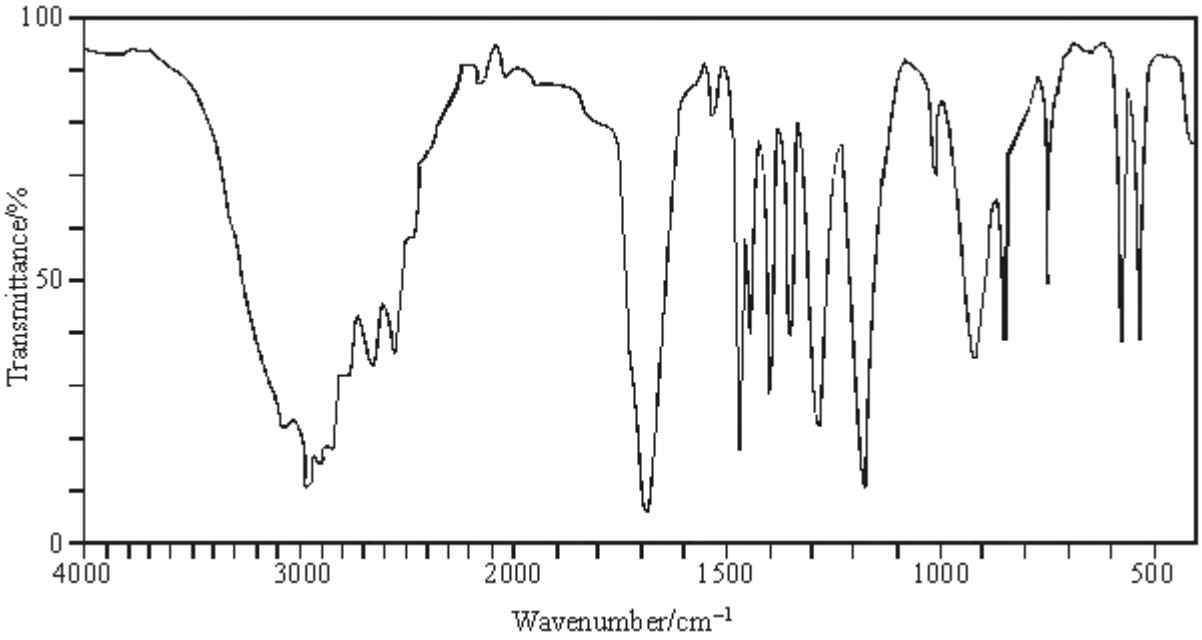
(iii) Two triplet peaks.

.....

(iv) Hence, deduce the structure of **W**.

(4)

(b) The infra-red spectrum of **X** is shown below.



(i) What can be deduced from the broad absorption centred on 3000 cm^{-1} in the infra-red spectrum of **X**?

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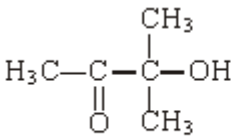
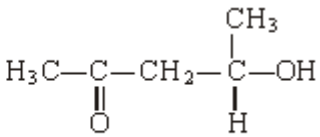
(ii) Given that the proton n.m.r. spectrum of **X** contains only two peaks with the integration ratio 9:1, deduce the structure of **X**.

(2)

(c) Isomers **Y** and **Z** have the structures shown below.



Y



Z

Identify the two reagents you could use in a simple chemical test to distinguish between **Y** and **Z**. State what you would observe when each of **Y** and **Z** is tested with a mixture of these two reagents.

Reagents .....

*Observation with **Y*** .....

*Observation with **Z*** .....

(3)
(Total 9 marks)

Q3. (a) Alcohols can be classed as primary, secondary or tertiary. Draw possible structures for a primary, a secondary and a tertiary alcohol which have the molecular formula C_4H_8O.
Which of the structures you have drawn cannot be oxidised by potassium dichromate in acid solution?

(4)

(b) Explain what is meant by the fingerprint region of an infra-red spectrum. State how it is used to confirm the identity of organic molecules such as the primary, secondary and tertiary alcohols of molecular formula C_4H_8O.

(2)

(c) Each of the parts below concerns a different pair of isomers. Deduce one possible structural formula for each of the species **A** to **F**. Use, where appropriate, the table of infra-red absorption data given on the data sheet.

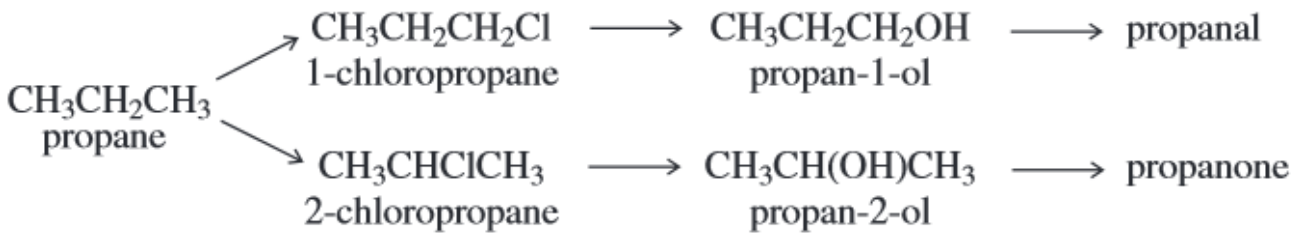
(i) **A** and **B** have the molecular formula C_3H_8O. **A** has a broad absorption band at 3300 cm^{-1} in its infra-red spectrum, but **B** does not.

(ii) **C** and **D** have the molecular formula C_5H_{10}. **C** has a weak absorption band at 1650 cm^{-1} in its infra-red spectrum, but **D** does not.

(iii) **E** and **F** have the molecular formula C_3H_6O and both have strong absorption bands at about 1700 cm^{-1} in their infra-red spectra. **E** reacts with Tollens' reagent but **F** does not.

(6)
(Total 12 marks)

Q4. Consider the following scheme of reactions.



(a) State the type of structural isomerism shown by propanal and propanone.

.....

(1)

(b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent.....

Observation with propanal.....

Observation with propanone.....

(3)

(c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 cm^{-1}.

.....

(1)

(d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

(i) Name the type of mechanism in the reaction of chlorine with methane.

.....

(1)

(ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula C_3H_7

.....

(4)

(e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise M_r values can be used to prove that thesample contains both of these gases.

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

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.....

(2)

(Total 12 marks)

Q5. Butan-2-ol can be oxidised by acidified potassium dichromate(VI) to form butanone as shown by the following equation.

$$CH_3CH_2CH(OH)CH_3 + [O] \rightarrow CH_3CH_2COCH_3 + H_2O$$

(a) State the class of alcohol to which butan-2-ol belongs.

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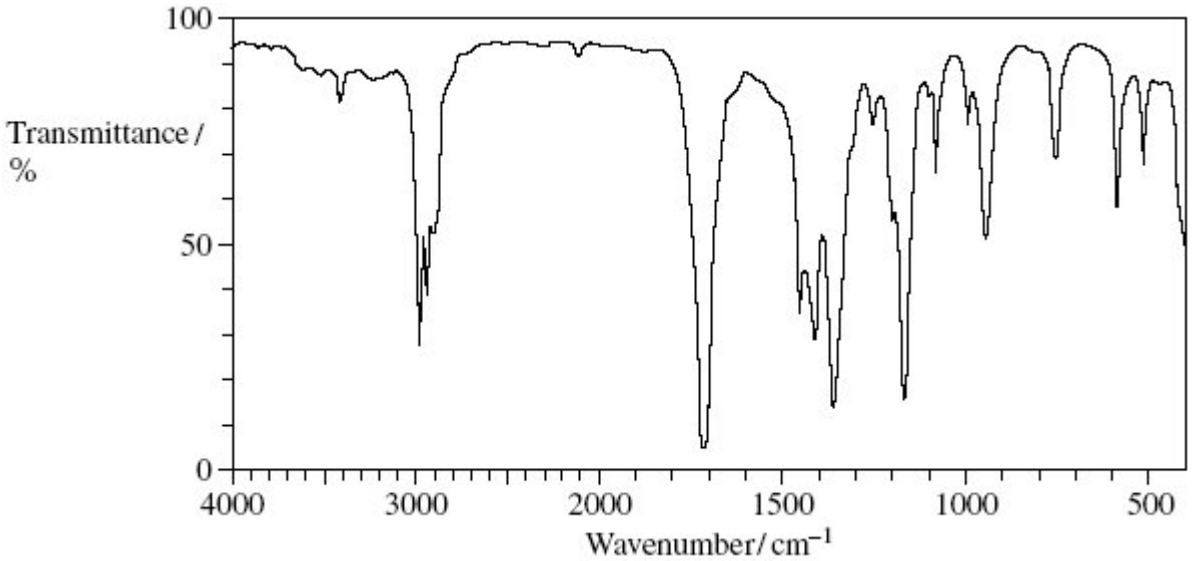
(1)

(b) The infrared spectrum shown below is either that of butan-2-ol or that of butanone.



Identify the compound to which this infrared spectrum refers.

Explain your answer.

You may find it helpful to refer to the table of infrared absorption data on the back of the Periodic Table (**Table 1**).

Identity of the compound .....

Explanation .....

.....

.....

(3)

(c) Draw the displayed formula of the alcohol C_4H_9OH which is resistant to oxidation by acidified potassium dichromate(VI).

.....

(1)
(Total 5 marks)

Q6. There are **four** isomeric alcohols with the molecular formula $C_4H_{10}O$

(a) Two of these are butan-l-ol ($CH_3CH_2CH_2CH_2OH$) and butan-2-ol.
The other two isomers are alcohol **X** and alcohol **Y**.

Draw the displayed formula for butan-2-ol.

Alcohol **X** does not react with acidified potassium dichromate(VI) solution.
Give the structure of alcohol **X**.

Name the fourth isomer, alcohol **Y**.

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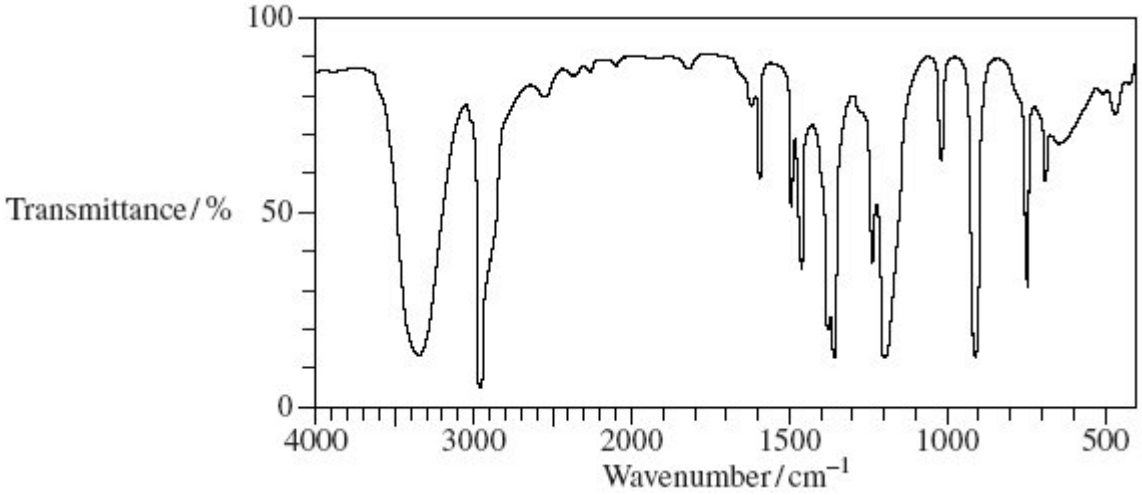
(3)

(b) The infrared spectrum of one of these isomeric alcohols is given below.



Identify **one** feature of the infrared spectrum which supports the fact that this is an alcohol. You may find it helpful to refer to **Table 1** on the Data Sheet.

Explain how infrared spectroscopy can be used to identify this isomeric alcohol.

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(3)

(c) British scientists have used bacteria to ferment glucose and produce the biofuel butan-1-ol.

Write an equation for the fermentation of glucose ($C_6H_{12}O_6$) to form butan-1-ol, carbon dioxide and water only.

State **one** condition necessary to ensure the complete combustion of a fuel in air.

Write an equation for the complete combustion of butan-1-ol and state why it can be described as a *biofuel*.

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(4)

(d) Butan-1-ol reacts with acidified potassium dichromate(VI) solution to produce two organic compounds.

State the class of alcohols to which butan-1-ol belongs.

Draw the displayed formula for **both** of the organic products.

State the type of reaction that occurs and the change in colour of the potassium dichromate(VI) solution.

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(5)
(Total 15 marks)