1 Alcohol **A** $(CH_3)_2CHCH(OH)CH_3$ undergoes reactions separately with acidified potassium dichromate(VI) and with concentrated sulfuric acid.

(a) Deduce the IUPAC name for alcohol **A**.

.....

(1)

(b) Draw the structure of the organic product, **B**, formed when **A** is oxidised in the reaction with acidified potassium dichromate(VI).

(1)

(c) Two isomeric alkenes, **C** and **D**, are formed when **A** is dehydrated in the reaction with concentrated sulfuric acid.

Name the mechanism for this dehydration reaction.

.....

(1)

(d) Draw the structure of each isomer.

Isomer **C** Isomer **D**

(2)

(e) Name the type of structural isomerism shown by **C** and **D**.

.....

(1)

(f) List alcohol **A**, product **B** and isomer **C** in order of increasing boiling point.

.....

(1)

(g) Draw the structure of the isomer of **A** that is **not** oxidised by acidified potassium dichromate(VI).

(1)

(h) Draw the structure of the isomer of **A** that **cannot** be dehydrated to form an alkene by reaction with concentrated sulfuric acid.

(1)
(Total 9 marks)

2 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

ethanol ⟶ ethanal ⟶ ethanoic acid

(a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

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(3)

(b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

.....

(1)

(c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

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(5)

(d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

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(2)

(e) A student obtained a sample of a liquid using the apparatus in part **(c)**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

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(5)
(Total 16 marks)

3 The following pairs of compounds can be distinguished by simple test−tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them.
State what is observed in each case.

(a) Butan−2−ol and 2−methylpropan−2−ol

Reagent .....

Observation with butan−2−ol

.....

.....

Observation with 2−methylpropan−2−ol

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(3)

(b) Propane and propene

Reagent .....

Observation with propane

.....

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Observation with propene

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(3)

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent .....

Observation with aqueous silver nitrate

.....

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Observation with aqueous sodium nitrate

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.....

(3)

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent .....

Observation with aqueous magnesium chloride

.....

.....

Observation with aqueous barium chloride

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.....

(3)
(Total 12 marks)

4

(a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

(i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.

.....$C_6H_{12}O_6$ ⟶ .....CH_3COCH_3 + ...CO_2 + ...H_2O

(1)

(ii) Deduce the role of the bacteria in this reaction.

.....

(1)

(b) Propanone is also formed by the oxidation of propan−2−ol.

(i) Write an equation for this reaction using [O] to represent the oxidising agent.

.....

(1)

(ii) State the class of alcohols to which propan−2−ol belongs.

.....

(1)

(c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter.
The student found that the temperature of 150 g of water increased by 8.0 °C when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of propanone is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

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(3)

(d) Define the term **standard enthalpy of combustion**.

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(3)

(e) Use the mean bond enthalpy data in the table and the equation given below the table to calculate a value for the standard enthalpy change when gaseous propanone is burned.

	C−H	**C−C**	**C−O**	**O−H**	**C=O**	**O=O**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	463	805	496

$$CH_3COCH_3(g) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(g)$$

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(3)

(f) Suggest **two** reasons why the value obtained by the student in part (c) is different from the value calculated in part (e).

Reason 1 .....

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Reason 2 .....

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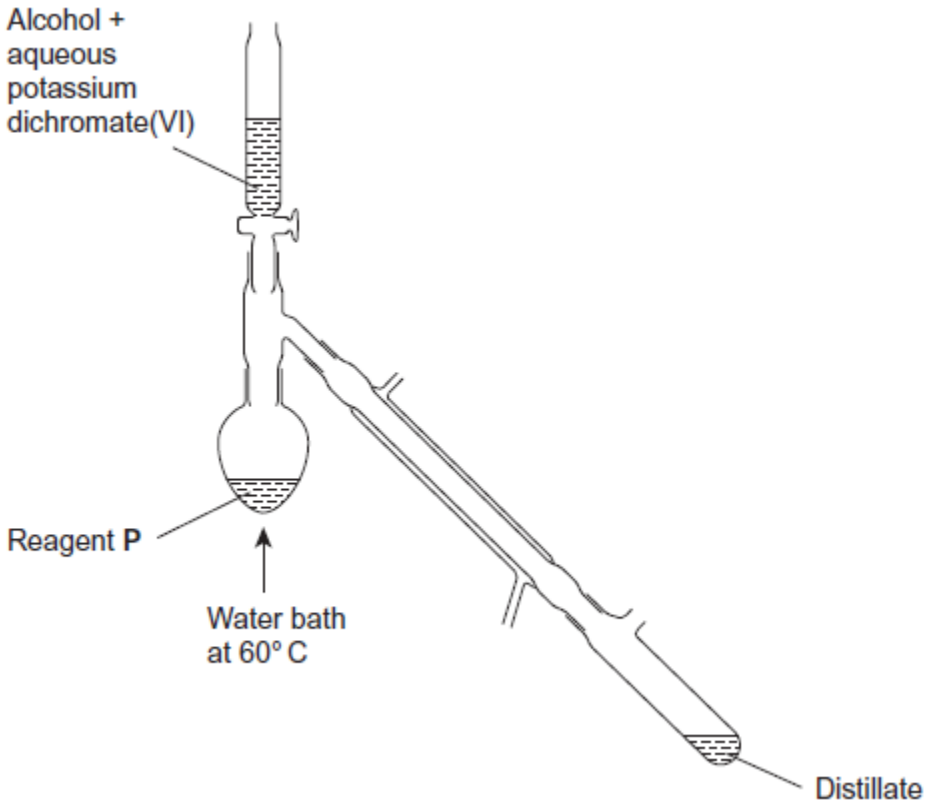
(2)
(Total 15 marks)

5 This question concerns the oxidation of a primary alcohol.

The experiment was carried out using the distillation apparatus shown in the diagram.
The oxidation product was distilled off as soon as it was formed.



(a) Suggest the identity of reagent **P**.

.....

(1)

(b) State the chemical change that causes the solution in the flask to appear green at the end of the reaction.

.....

(1)

(c) Give **one** reason why using a water bath is better than direct heating with a Bunsen burner.

.....

.....

(1)

(d) Suggest a reagent that could be used to confirm the presence of an aldehyde in the distillate.
State the observation you would expect to make if an aldehyde were present.

Reagent .....

Observation .....

(2)
(Total 5 marks)

6 A sample of 2-methylpropan-2-ol was contaminated with butan-2-ol. The student separated the two alcohols using chromatography.

Identify a reagent or combination of reagents that the student could use to distinguish between these alcohols. State what would be observed for each alcohol.

Reagent(s) .....

Observation with 2-methylpropan-2-ol .....

.....

.....

Observation with butan-2-ol .....

.....

.....

(Total 3 marks)

7 In each of the following questions, you should draw the structure of the compound in the space provided.

(a) Draw the structure of the alkene that would form 1,2-dibromo-3-methylbutane when reacted with bromine.

(1)

(b) Draw the structure of the alcohol with molecular formula $C_4H_{10}O$ that is resistant to oxidation by acidified potassium dichromate(VI).

(1)

(c) Draw the structure of the alkene that has a peak, due to its molecular ion, at $m/z = 42$ in its mass spectrum.

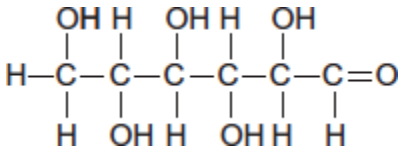
(1)

(d) Draw the structure of the organic product with $M_r = 73$, made from the reaction between 2-bromobutane and ammonia.

(1)
(Total 4 marks)

8 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.

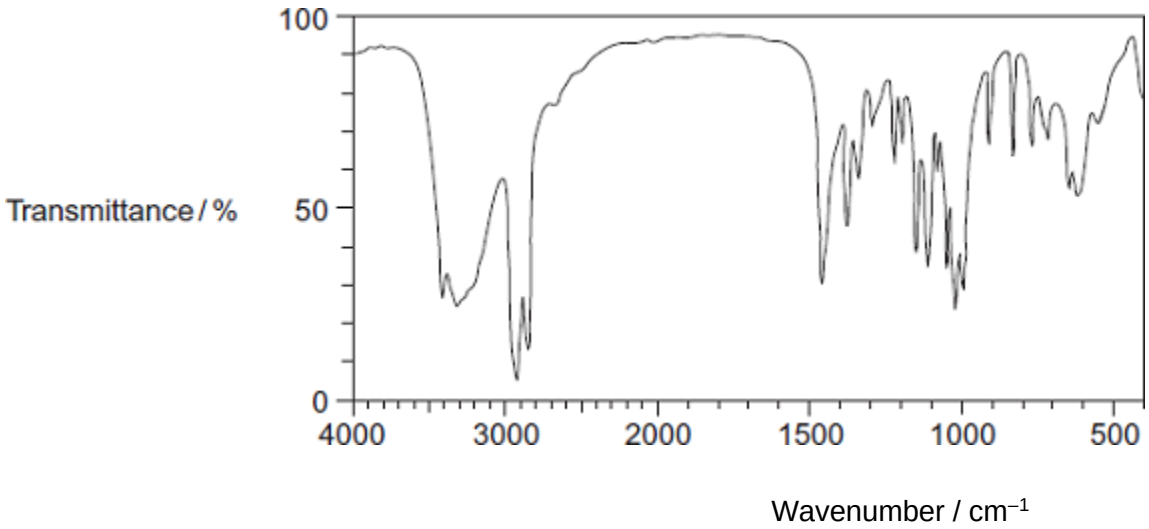


(i) Deduce the empirical formula of glucose.

.....

(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

$$CH_3CH_2OH(l) + O_2(g) \longrightarrow CH_3COOH(l) + H_2O(l)$$

(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*.

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(Extra space) .....

.....

(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.

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(1)

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

.....

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(1)

(Total 13 marks)

9 The reaction of butane-1,4-diol with butanedioic acid produces the polymer PBS used in biodegradable packaging and disposable cutlery.
Butanedioic acid is produced by two different processes.

Process 1

- Aqueous sodium hydroxide reacts with 1,4-dibromobutane to make butane-1,4-diol.
- Butane-1,4-diol is oxidised to butanedioic acid.

Process 2

- Glucose reacts with carbon dioxide in the presence of microorganisms to produce butanedioic acid directly.
- The carbon dioxide used in this process is obtained from a local factory that produces bioethanol.

(a) Deduce **one** safety reason and one environmental reason why **Process 2** is preferred to **Process 1**.

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(Extra space) .....

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(2)

(b) (i) Name and outline a mechanism for the following reaction that occurs in **Process 1**.

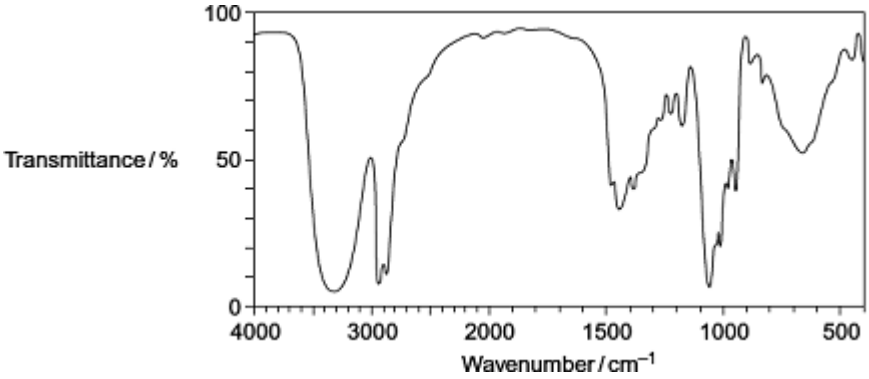
.....

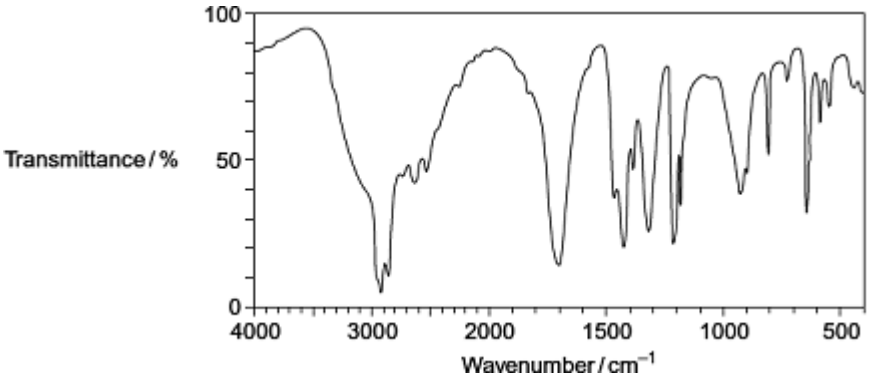
(3)

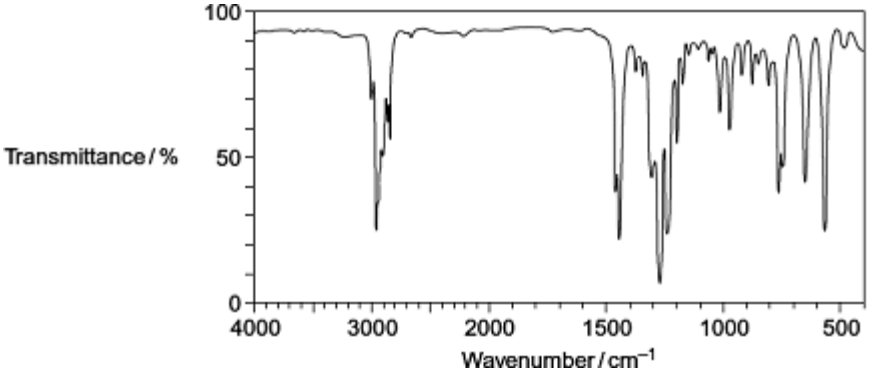
(ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutane
Compound **B** butane-1,4-diol
Compound **C** butanedioic acid

Identify the compound responsible for each spectrum by writing the correct letter, **A**, **B** or **C**, in the box next to each spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.







(3)

(c) In the production of bioethanol, glucose ($C_6H_{12}O_6$) is converted into a dilute aqueous solution of ethanol and carbon dioxide.

Give the name of this process and state **three** essential conditions necessary to produce a good yield of ethanol.

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(Extra space) .....

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(4)

(d) State the class of alcohols to which the diol butane-1,4-diol belongs.

Identify a suitable reagent or combination of reagents for the conversion of butane-1,4-diol into butanedioic acid ($HOOCCH_2CH_2COOH$).

Write an equation for this oxidation reaction using [O] to represent the oxidising agent.

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(Extra space) .....

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(3)
(Total 15 marks)

10 Some alcohols can be oxidised by an acidified solution of potassium dichromate(Vl).
Aldehydes can be oxidised by Tollens' reagent or by Fehling's solution.

An unknown pure liquid **A** contains only a single alcohol.
Outline a simple procedure to allow you to determine whether **A** is a primary, a secondary or a tertiary alcohol.

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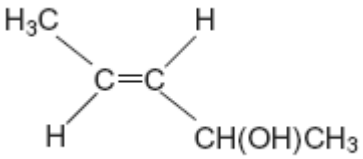
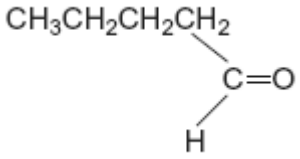
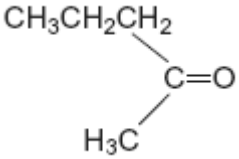
(Total 3 marks)

11 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**.....

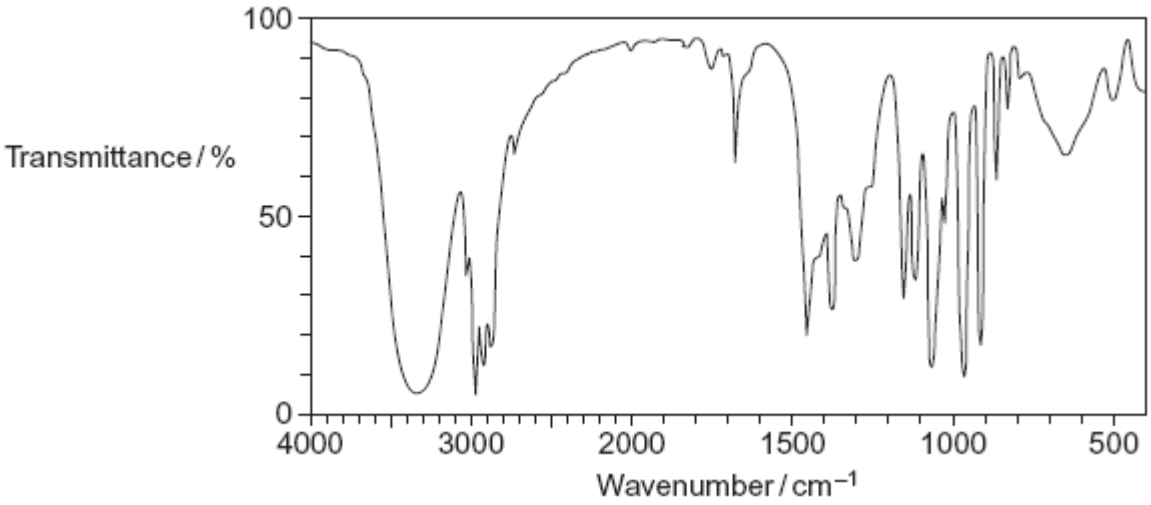
.....

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.

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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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.....

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(2)
(Total 10 marks)

12 (a) Propanoic acid can be made from propan-1-ol by oxidation using acidified potassium dichromate(VI). Propanal is formed as an intermediate during this oxidation.

(i) State the colour of the chromium species after the potassium dichromate(VI) has reacted.

.....

(1)

(ii) Describe the experimental conditions and the practical method used to ensure that the acid is obtained in a high yield. Draw a diagram of the assembled apparatus you would use.

Conditions .....

.....

Apparatus

(4)

(iii) Describe the different experimental conditions necessary to produce propanal in high yield rather than propanoic acid.

.....

.....

(2)

(b) Propan-1-ol is a volatile, flammable liquid.
Give **one** safety precaution that should be used during the reaction to minimise this hazard.

.....

(1)

(c) A student followed the progress of the oxidation of propan-1-ol to propanoic acid by extracting the organic compounds from one sample of reaction mixture.

(i) Give a chemical reagent which would enable the student to confirm the presence of propanal in the extracted compounds.
State what you would observe when propanal reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(ii) Give a chemical reagent that would enable the student to confirm the presence of propanoic acid in the extracted compounds.
State what you would observe when propanoic acid reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(d) Predict which **one** of the compounds, propan-1-ol, propanal and propanoic acid will have the highest boiling point. Explain your answer.

Prediction .....

Explanation .....

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.....

(3)
(Total 15 marks)

13 The following pairs of compounds can be distinguished by observing what happens in test-tube reactions.
For each pair, give a suitable aqueous reagent that could be added separately to each compound.
Describe what you would observe in each case.

(a) NaF(aq) and NaCl(aq)

Reagent .....

Observation with NaF(aq) .....

Observation with NaCl(aq) .....

(3)

(b) $BaCl_2(aq)$ and $MgCl_2(aq)$

Reagent .....

Observation with $BaCl_2(aq)$ .....

Observation with $MgCl_2(aq)$ .....

(3)

(c) AgCl(s) and AgI(s)

Reagent .....

Observation with AgCl(s) .....

Observation with AgI(s) .....

(3)

(d) Butan-2-ol(l) and 2-methylpropan-2-ol(l)

Reagent .....

Observation with butan-2-ol(l) .....

Observation with 2-methylpropan-2-ol(l) .....

(3)
(Total 12 marks)

14 A student devised an experiment to investigate the enthalpies of combustion of some alcohols. The student chose the following series of primary alcohols.

Name	Formula
Methanol	CH_3OH
Ethanol	CH_3CH_2OH
Propan-1-ol	$CH_3CH_2CH_2OH$
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$
Pentan-1-ol	$CH_3CH_2CH_2CH_2CH_2OH$
Alcohol **X**	$CH_3CH_2CH_2CH_2CH_2CH_2OH$
Heptan-1-ol	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$

(a) (i) Name alcohol **X**.

.....

(1)

(ii) State the general name of the type of series shown by these primary alcohols.

.....

(1)

(iii) Draw the displayed formula of the position isomer of butan-1-ol.

(1)

(iv) Using [O] to represent the oxidising agent, write an equation for the oxidation of butan-1-ol to form an aldehyde.

.....

(1)

(v) Draw the displayed formula of a functional group isomer of this aldehyde.

(1)

(b) The student carried out a laboratory experiment to determine the enthalpy change when a sample of butan-1-ol was burned.
The student found that the temperature of 175 g of water increased by 8.0 °C when 5.00×10^{-3} mol of pure butan-1-ol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of butan-1-ol is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

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(3)

(c) (i) Give the meaning of the term *standard enthalpy of combustion*.

.....

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(3)

(ii) Use the standard enthalpy of formation data from the table and the equation for the combustion of butan-1-ol to calculate a value for the standard enthalpy of combustion of butan-1-ol.

	$CH_3CH_2CH_2CH_2OH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–327	0	–394	–286

$$CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

.....

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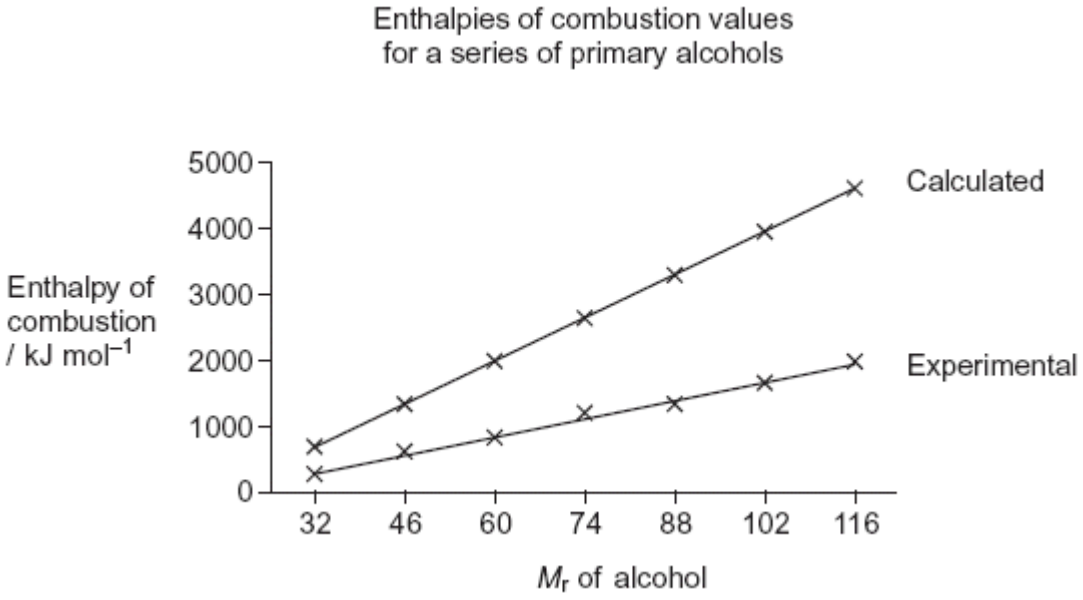
.....

(3)

(d) The student repeated the experiment described in part (b) and obtained an experimental value for the enthalpy of combustion for each alcohol in this series.
These experimental values were then compared with calculated values from standard enthalpies of formation, as shown in the graph below.



(i) In terms of bonds broken and bonds formed, explain why the calculated values of enthalpies of combustion of these alcohols, when plotted against M_r, follow a straight line.

.....

.....

.....

.....

(2)

(ii) Give **two** reasons why the experimental values obtained by the student are lower than the calculated values using the enthalpy of formation data.

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.....

(2)
(Total 18 marks)

15 Sulfuric acid is an important chemical in many industrial and laboratory reactions. Consider the following three reactions involving sulfuric acid.

Reaction **1** $Mg(OH)_2 + H_2SO_4 \rightarrow MgSO_4 + 2H_2O$

Reaction **2** The reaction of solid sodium bromide with concentrated sulfuric acid

Reaction **3** $H_2C{=}CH_2 + H_2O \xrightarrow{\text{conc. } H_2SO_4} CH_3CH_2OH$

(a) Give a use for magnesium hydroxide in medicine.

.....

(1)

(b) Sulfuric acid behaves as an oxidising agent in Reaction **2**.

(i) In terms of electrons, state the meaning of the term oxidising agent.

.....

(1)

(ii) Give the formula of the oxidation product that is formed from sodium bromide in Reaction **2**.

.....

(1)

(iii) Deduce the half-equation for the reduction of H_2SO_4 to SO_2 in Reaction **2**.

.....

(1)

(c) The formation of ethanol in Reaction **3** uses concentrated sulfuric acid and proceeds in two stages according to the following equations.

Stage **1** $H_2C{=}CH_2 + H_2SO_4 \longrightarrow CH_3CH_2OSO_2OH$

Stage **2** $CH_3CH_2OSO_2OH + H_2O \longrightarrow CH_3CH_2OH + H_2SO_4$

(i) State the overall role of sulfuric acid in Reaction **3**.

.....

(1)

(ii) Outline a mechanism for Stage **1** of this reaction.

(4)

(iii) State the class of alcohols to which ethanol belongs.

.....

(1)

(iv) Draw the displayed formula of the carboxylic acid formed when ethanol is oxidised by an excess of acidified potassium dichromate(VI) solution.

(1)
(Total 11 marks)

16 Ethanol can be oxidised slowly to ethanal. State how a sample of ethanol could be tested to confirm the presence of ethanal. State what you would observe.

Test .....

Observation .....

(Total 2 marks)

17 Ethanal is prepared by heating ethanol with potassium dichromate(VI) in the presence of sulfuric acid. **Figures 1** and **2** show two possible ways of heating this reaction mixture.

Figure 1

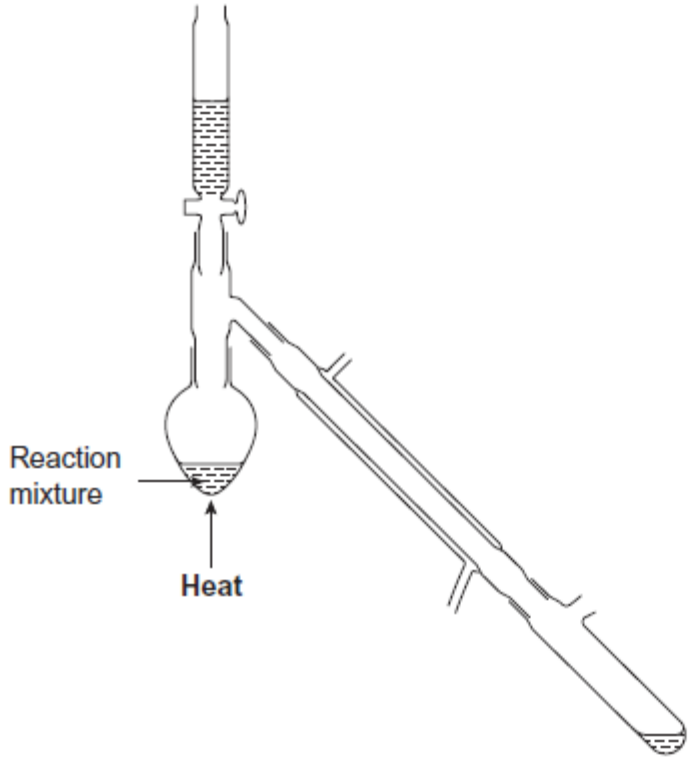
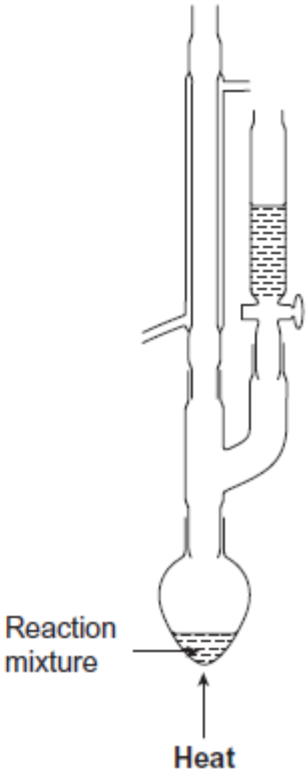


Figure 2



State which arrangement would **not** be suitable for the preparation of ethanal. Explain your answer.

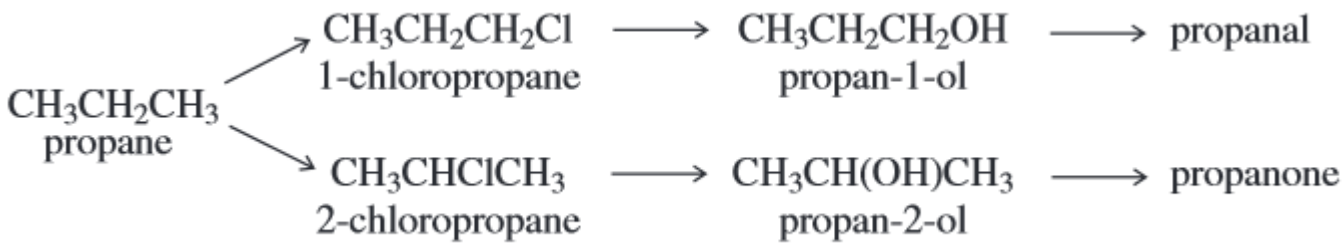
Arrangement .....

Explanation .....

.....

(Total 2 marks)

18 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

.....

.....

.....

(2)

(Total 12 marks)

19 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**.

.....

.....

.....

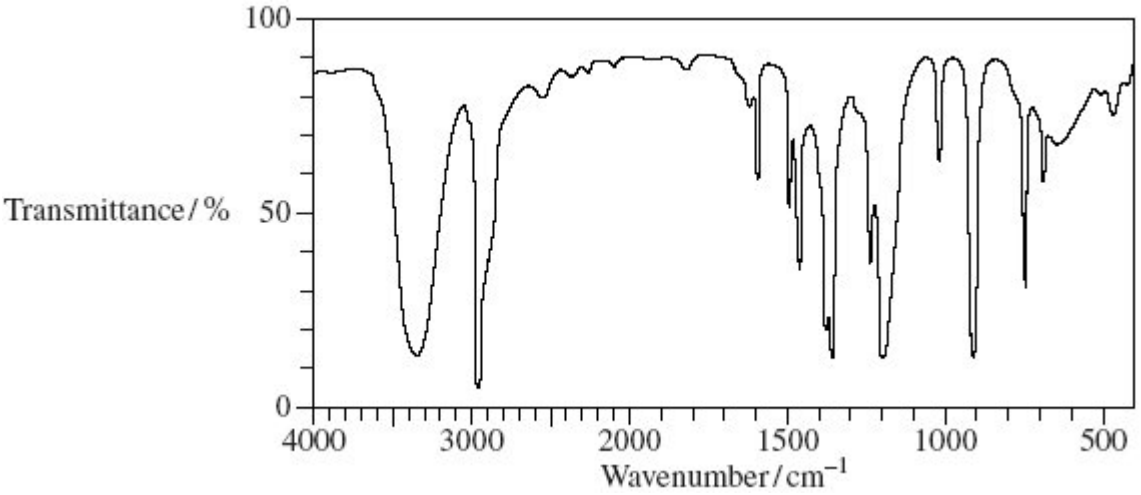
.....

.....

.....

(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.

.....

.....

.....

.....

.....

(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*.

.....

.....

.....

.....

.....

.....

.....

.....

(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.

.....

.....

.....

.....

.....

.....

.....

(5)
(Total 15 marks)

20 In an investigation of the chemical properties of alcohols, a mixture of ethanol and acidified potassium dichromate(VI) is heated in a conical flask in a water bath.

(a) Explain why a water bath is used to heat the mixture.

.....

.....

(1)

(b) Describe the colour change which would be observed.

.....

.....

(1)
(Total 2 marks)

21 (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.

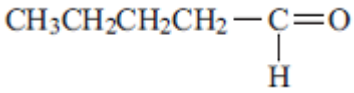
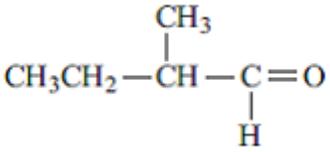
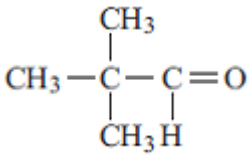
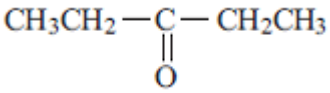
(i) **A** and **B** have the molecular formula C_3H_8O. **A** has a broad absorption band at 3300 cm^{-1} in its infra-red spectrum, but **B** does not.

(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)

22 There are **seven** isomeric carbonyl compounds with the molecular formula $C_5H_{10}O$.
The structures and names of some of these isomers are given below.

Structure	Name
	pentanal
	2-methybutanal
	2, 2-dimethypropanal
	
	pentan-2-one

(a) (i) Complete the table.

(ii) **Two** other isomeric carbonyl compounds with the molecular formula $C_5H_{10}O$ are not shown in the table. One is an aldehyde and one is a ketone. Draw the structure of each.

isomeric aldehyde *isomeric ketone*

(4)

(b) Pentanal, $CH_3CH_2CH_2CH_2CHO$, can be oxidised to a carboxylic acid.

(i) Write an equation for this reaction. Use [O] to represent the oxidising agent.

.....

(ii) Name the carboxylic acid formed in this reaction.

.....

(2)

(c) Pentanal can be formed by the oxidation of an alcohol.

(i) Identify this alcohol.

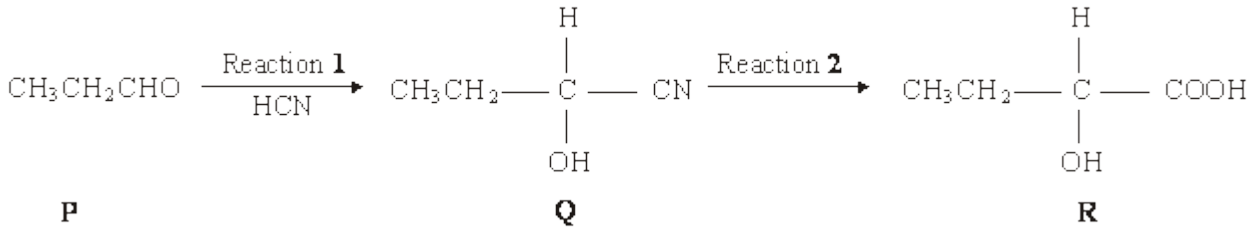
.....

(ii) State the class to which this alcohol belongs.

.....

(2)
(Total 8 marks)

23 Consider the sequence of reactions below.



P **Q** **R**

(a) Name and outline a mechanism for Reaction **1**.

Name of mechanism .....

Mechanism

(5)

(b) (i) Name compound **Q**

.....

(ii) The molecular formula of **Q** is C_4H_7NO. Draw the structure of the isomer of **Q** which shows geometrical isomerism and is formed by the reaction of ammonia with an acyl chloride.

(3)

(c) Draw the structure of the main organic product formed in each case when **R** reacts separately with the following substances:

(i) methanol in the presence of a few drops of concentrated sulphuric acid;

(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

(3)
(Total 11 marks)

24 Some alcohols can be oxidised to form aldehydes, which can then be oxidised further to form carboxylic acids.
Some alcohols can be oxidised to form ketones, which resist further oxidation.
Other alcohols are resistant to oxidation.

(a) Draw the structures of the **two** straight-chain isomeric alcohols with molecular formula, $C_4H_{10}O$

(2)

(b) Draw the structures of the oxidation products obtained when the two alcohols from part (a) are oxidised separately by acidified potassium dichromate(VI). Write equations for any reactions which occur, using [O] to represent the oxidising agent.

(6)

(c) Draw the structure and give the name of the alcohol with molecular formula $C_4H_{10}O$ which is resistant to oxidation by acidified potassium dichromate(VI).

(2)
(Total 10 marks)

25 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

.....

(ii) The singlet peak at δ = 3.33

.....

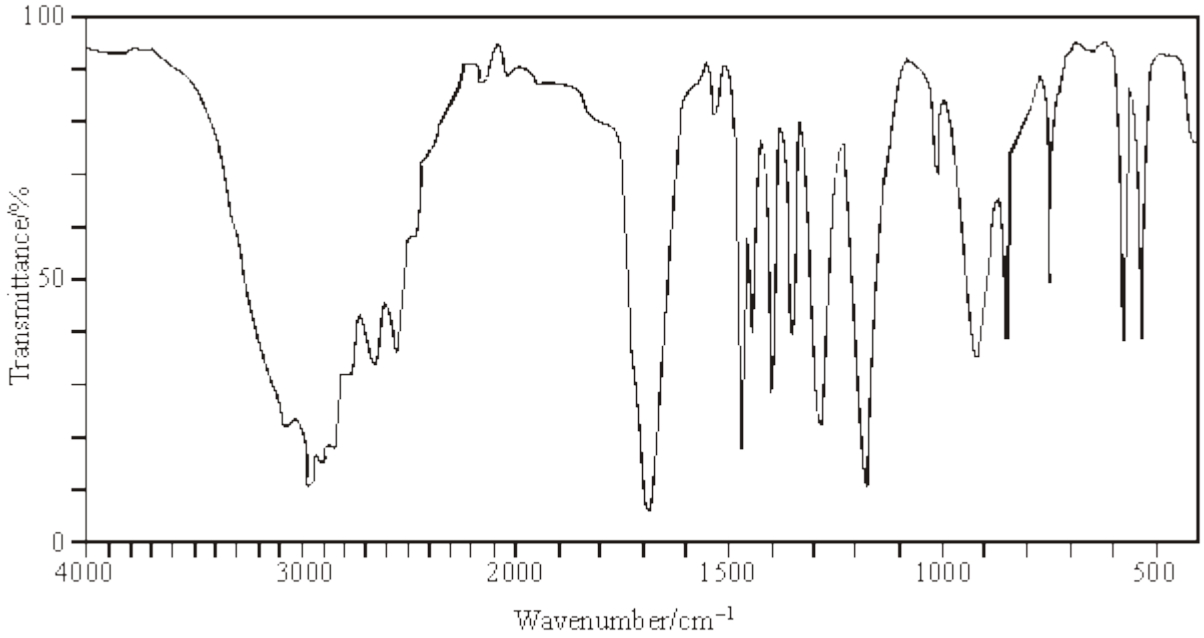
(iii) Two triplet peaks.

.....

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

(4)

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



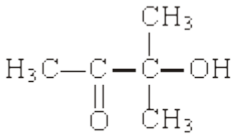
(i) What can be deduced from the broad absorption centred on 3000 cm^{-1} in the infra-red spectrum of **X**?

.....

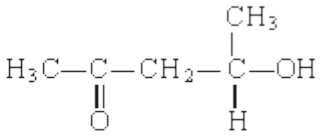
(ii) Given that the proton n.m.r. spectrum of **X** contains only two peaks with the integration ratio 9:1, deduce the structure of **X**.

(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.

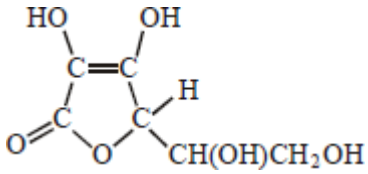
Reagents .....

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

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

(3)
(Total 9 marks)

26 Which one of the following is **not** a correct statement about vitamin C, shown below?



A It is a cyclic ester.

B It can form a carboxylic acid on oxidation.

C It decolourises a solution of bromine in water.

D It is a planar molecule.

(Total 1 mark)

27 Consider the following reaction schemes involving two alcohols, **A** and **B**, which are position isomers of each other.

$CH_3CH_2CH_2CH_2OH \rightarrow CH_3CH_2CH_2CHO \rightarrow CH_3CH_2CH_2COOH$

A butanal butanoic acid

$CH_3CH_2CH(OH)CH_3 \rightarrow CH_3CH_2COCH_3$

B **C**

(a) State what is meant by the term *position isomers*.

.....

.....

.....

(2)

(b) Name compound **A** and compound **C**.

*Compound **A*** .....

*Compound **C*** .....

(2)

(c) Each of the reactions shown in the schemes above is of the same type and uses the same combination of reagents.

(i) State the type of reaction.

.....

(ii) Identify a suitable combination of reagents.

.....

(iii) State how you would ensure that compound **A** is converted into butanoic acid rather than into butanal.

.....

.....

(iv) Draw the structure of an isomer of compound **A** which does not react with this combination of reagents.

(v) Draw the structure of the carboxylic acid formed by the reaction of methanol with this combination of reagents.

(6)

(d) (i) State a reagent which could be used to distinguish between butanal and compound **C**.

.....

(ii) Draw the structure of another aldehyde which is an isomer of butanal.

(2)
(Total 12 marks)

28 (a) (i) Give a suitable reagent and state the necessary conditions for the conversion of propan-2-ol into propanone. Name the type of reaction.

Reagent .....

Conditions .....

Type of reaction .....

(ii) Propanone can be converted back into propan-2-ol. Give a suitable reagent and write an equation for this reaction.
(Use [H] to represent the reagent in your equation.)

Reagent .....

Equation

.....

(5)

(b) Propanal is an isomer of propanone.

(i) Draw the structure of propanal.

(ii) A chemical test can be used to distinguish between separate samples of propanone and propanal. Give a suitable reagent for the test and describe what you would observe with propanone and with propanal.

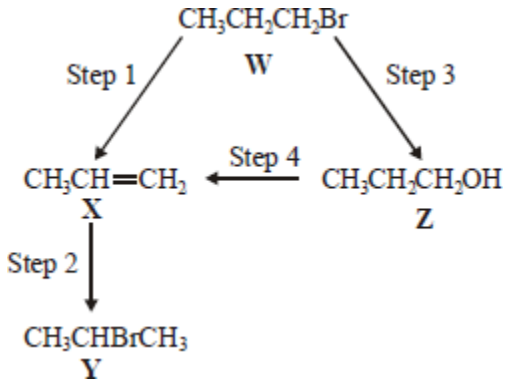
Test reagent .....

Observation with propanone .....

Observation with propanone .....

(4)
(Total 9 marks)

29 For this question refer to the reaction scheme below.



Which one of the following statements is **not** correct?

A Reaction of **W** with sodium cyanide followed by hydrolysis of the resulting product gives propanoic acid.

B Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.

C **Z** reacts with ethanoic acid to produce the ester propyl ethanoate.

C **W** undergoes addition polymerisation to form poly(propene).

(Total 1 mark)

30 (a) One of the isomers in part (a) is resistant to oxidation by acidified potassium dichromate(VI).

(i) Identify this isomer.

.....

(ii) This isomer can be dehydrated. Give a suitable dehydrating agent and write an equation for this dehydration reaction.

Dehydrating agent.....

Equation .....

(3)

(b) (i) Identify the isomer in part (a) which can be oxidised to a ketone. Give the structure of the ketone formed.

Isomer .....

Structure of the ketone

(ii) Identify **one** of the isomers in part (a) which can be oxidised to an aldehyde. Give the structure of the aldehyde formed.

Isomer .....

Structure of the aldehyde

(iii) Give a reagent that can be used in a test to distinguish between a ketone and an aldehyde. State what you would observe in the test.

Reagent .....

Observation with ketone .....

.....

Observation with aldehyde .....

.....

(7)

(c) Butan-1-ol can be oxidised to form a carboxylic acid. Using [O] to represent the oxidising agent, write an equation for this reaction and name the product.

Equation .....

Name of product .....

(2)
(Total 12 marks)

31 (a) Ethanol can be manufactured by the direct hydration of ethene and by the fermentation of sugars.

(i) State what is meant by the term *hydration.*

.....

(ii) Give **one** advantage and **one** disadvantage of manufacturing ethanol by fermentation rather than by hydration.

Do **not** include energy consumption or cost.

Advantage .....

.....

Disadvantage .....

.....

(3)

(b) Ethanol can be oxidised to an aldehyde and to a carboxylic acid.

(i) Draw the structure of this aldehyde and of this carboxylic acid.

Structure of aldehyde *Structure of carboxylic acid*

(ii) Give a suitable reagent and reaction conditions for the oxidation of ethanol to form the carboxylic acid as the major product.

Reagent .....

Conditions .....

.....

(5)

(c) (i) Draw the structure of an alcohol containing four carbon atoms which is resistant to oxidation.

(ii) Draw the structure of an alcohol containing four carbon atoms which can be oxidised to a ketone.

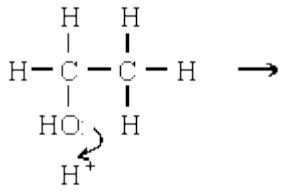
(2)

(d) In the presence of a catalyst, ethanol can be dehydrated to ethene.

(i) Give a suitable catalyst for use in this reaction.

.....

(ii) Complete the mechanism for this dehydration reaction.



(5)
(Total 15 marks)

32 (a) An alcohol containing carbon, hydrogen and oxygen only has 64.9% carbon and 13.5% hydrogen by mass. Using these data, show that the empirical formula of the alcohol is $C_4H_{10}O$

.....

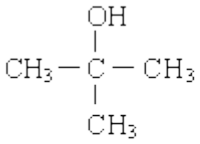
.....

.....

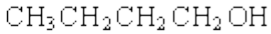
.....

(3)

(b) The structural formulae of two of the four possible alcohols of molecular formula $C_4H_{10}O$ are shown below.



Isomer 1



Isomer 2

(i) What type of alcohol is Isomer 1? Suggest a reason why this type of alcohol is not easily oxidised.

Type of alcohol .....

Reason .....

(ii) Draw the structural formulae of the two remaining alcohols of molecular formula $C_4H_{10}O$

Isomer 3 *Isomer 4*

(4)

(c) Isomer 2 was oxidised by adding it dropwise to acidified potassium dichromate(VI) solution and immediately distilling off the product. When this product was treated with Fehling's solution, a red precipitate was formed.

(i) State the type of product distilled off during the oxidation by acidified potassium dichromate(VI) solution.

.....

(ii) Write an equation for the oxidation by potassium dichromate(VI), showing clearly the structure of the organic product. Use [O] to represent the oxidising agent.

.....

(iii) Name and draw a structure for the organic product formed by the reaction with Fehling's solution.

Name .....

Structure .....

(5)

(d) State **one** advantage and **one** disadvantage of the production of ethanol by the hydration of ethene compared to the fermentation of glucose.

Advantage .....

Disadvantage .....

(2)

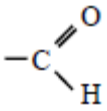
(e) Outline a mechanism for the dehydration of ethanol to form ethene in the presence of an acid catalyst.

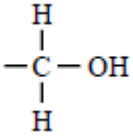
(4)
(Total 18 marks)

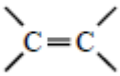
33 Certain chemical tests were performed on the pain-relief drug ibuprofen. The results of these tests are given in the table below.

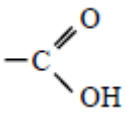
Test	Result
Aqueous sodium carbonate	Effervescence
Bromine water	Remained orange
Acidified potassium dichromate(VI) and heat	Remained orange
Fehling's solution and heat	Remained blue

Which one of the following functional groups do these results suggest that ibuprofen contains?

A 

B 

C 

D 

(Total 1 mark)

34 Which one of the following isomers is not oxidised under mild reaction conditions?

A $(CH_3)_2CHCH(OH)COCH_3$

B $(CH_3)_2C(OH)CH_2COCH_3$

C $(CH_3)_2CHCH(OH)CH_2CHO$

D $(CH_3)_2C(OH)CH_2CH_2CHO$

(Total 1 mark)

35 Which one of the following does **not** represent an oxidation?

A propene → propane

B propan-l-ol → propanal

C propan-l-ol → propanoic acid

D propanal → propanoic acid

(Total 1 mark)

36 Which one of the following **cannot** be produced by oxidation of propan-l-ol?

A carbon dioxide

B propanone

C propanal

D propanoic acid

(Total 1 mark)

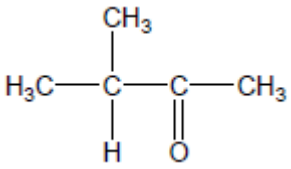
Mark schemes

1

(a) 3-methylbutan-2-ol

1

(b)



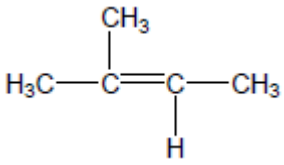
Allow $(CH_3)_2CHCOCH_3$

1

(c) Elimination

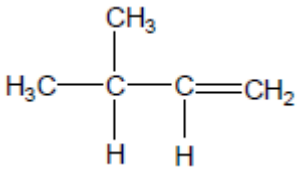
1

(d)



Allow $(CH_3)_2C=CHCH_3$

1



Allow $(CH_3)_2CHCH=CH_2$

1

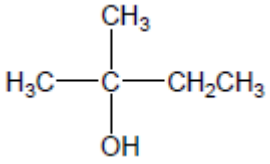
(e) Position

1

(f) C B A

1

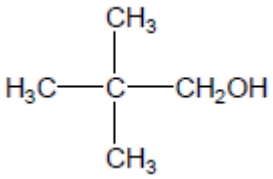
(g)



Allow $(CH_3)_2C(OH)CH_2CH_3$

1

(h)



Allow $(CH_3)_3CCH_2OH$

1

[9]

2 (a) A mixture of liquids is heated to boiling point for a prolonged time

1

Vapour is formed which escapes from the liquid mixture, is changed back into liquid and returned to the liquid mixture

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

(b) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

1

(c) Mixture heated in a suitable flask / container

A labelled sketch illustrating these points scores the marks

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable cooled collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

(d) Hydrogen bonding in ethanol and ethanoic acid or no hydrogen bonding in ethanal

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:

Add Tollens' reagent / ammoniacal silver nitrate / aqueous silver nitrate followed by 1 drop of aqueous sodium hydroxide, then enough aqueous ammonia to dissolve the precipitate formed

OR

Add Fehling's solution

1

Warm

M2 and M3 can only be awarded if M1 is given correctly

1

Result with Tollen's reagent:

Silver mirror / black precipitate

OR

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

M5 can only be awarded if M4 is given correctly

OR

Reagent; add ethanol and concentrated sulfuric acid and warm

Result; no sweet smell / no oily drops on the surface of the liquid,

hence no acid present

[16]

3

(a) **M1** acidified potassium dichromate or $K_2Cr_2O_7$ / H_2SO_4

OR $K_2Cr_2O_7$ / H^+ ***OR*** acidified $K_2Cr_2O_7$

M2 (orange to) green solution ***OR*** goes green

M3 (solution) remains orange or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*For **M2** ignore dichromate described as "yellow" or "red"*

*For **M3** ignore "nothing (happens)" or "no observation"*

Alternative using $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate or $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 colourless solution ***OR*** goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

*For **M1***

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green*

3

(b) **M1** (Shake with) Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent)

M2 (stays) orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

M3 decolourised / goes colourless / loses its colour / orange to colourless

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on***

*No credit for combustion observations; **CE = 0***

*For **M2 in every case***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear"

***OR* as alternatives**

Use $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 (stays) <u>purple</u> or no reaction or no (observed) change

M3 decolourised / goes colourless / loses its colour

Use iodine

M1 iodine or I_2 / KI or iodine solution

M2 no change

M3 decolourised / goes colourless / loses its colour

Use concentrated sulfuric acid

M1 <u>concentrated</u> H_2SO_4

M2 no change

M3 brown

***For M1**, it must be a whole reagent and / or correct formula*

For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3

With potassium manganate(VII)

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green</u>*

Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent as those used for other reagents.

3

(c) **M1** Any soluble chloride including hydrochloric acid (ignore concentration)

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble iodide including HI

M2 yellow precipitate or yellow solid / yellow suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble bromide including HBr

M2 cream precipitate or cream solid / cream suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 NaOH or KOH or any soluble carbonate

M2 brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate / solid / suspension with carbonate)

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If no reagent or incorrect reagent or insoluble chloride in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Allow chlorine water

*If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on***

*For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives)*

*For **M3***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

3

(d) **M1** Any <u>soluble</u> <u>sulfate</u> including (dilute or aqueous) sulfuric acid

M2 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

M3 <u>white precipitate</u> or <u>white solid / white suspension</u>

*If no reagent or incorrect reagent or insoluble sulfate in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates

*If concentrated sulfuric acid or incomplete reagent (e.g. sulfate ions) or inaccurate attempt at formula of chosen sulfate, **penalise M1 only and mark on***

*For **M3 (or M2 in the alternative)** require the word "white" and some reference to a solid.*

Ignore "cloudy solution" OR "suspension"

*For **M2 (or M3 in the alternative)***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" <u>on its own</u>

Ignore "dissolves"

***OR* as an alternative**

M1 NaOH or KOH

M2 <u>white precipitate</u> or <u>white solid / white suspension</u>

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, **penalise M1 only and mark on***

*If **M1** uses NH_3 (dilute or concentrated) **penalise M1 only and mark on***

3

[12]

4 (a) (i) $\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{3}CH_3COCH_3 + \mathbf{3}CO_2 + \mathbf{3}H_2O$

Or multiples

1

(ii) to speed up the reaction

OR

(provide a) catalyst or catalyses the reaction or biological catalyst

OR

<u>release / contain / provides</u> an <u>enzyme</u>

Ignore "fermentation"

Ignore "to break down the glucose"

Not simply "enzyme" on its own

1

(b) (i) $CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

Any <u>correct</u> representation for the two organic structures. Brackets not essential.

Not "sticks" for the structures in this case

1

(ii) Secondary (alcohol) OR 2° (alcohol)

1

(c) **M1** $q = m\ c\ \Delta T$

OR $q = 150 \times 4.18 \times 8.0$

Award full marks for <u>correct answer</u>

*In **M1**, do not penalise incorrect cases in the formula*

M2 = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ)
(also scores M1)

M3 This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown.
Using 0.00450 mol

therefore ΔH = **<u>− 1115</u>** ($kJ\ mol^{-1}$)

***OR* <u>− 1114.6</u> to <u>− 1120</u>** ($kJ\ mol^{-1}$)

Range (+)1114.6 to (+)1120 gains 2 marks

BUT − 1110 gains 3 marks and +1110 gains 2 marks

AND − 1100 gains 3 marks and +1100 gains 2 marks

Award full marks for correct answer

*In **M1**, do not penalise incorrect cases in the formula*

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect;*
(+)1114.6 to (+)1120 gains 2 marks

*Penalise **M2** for arithmetic error and mark on*

If $\Delta T = 281$; score $q = m\ c\ \Delta T$ only

*If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = − 1283*

*Ignore incorrect units in **M2***

*If units are given in **M3** they <u>must be either kJ or kJ mol^{-1}</u> in this case*

3

(d) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

M2 is <u>burned / combusts / reacts</u> <u>completely</u> in <u>oxygen</u>

OR

<u>burned / combusted / reacted in excess oxygen</u>

M3 with (all) <u>reactants and products /</u> (all) <u>substances in standard / specified states</u>

OR

(all) <u>reactants and products /</u> (all) <u>*substances in normal states under standard conditions*</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

*For **M3***

Ignore reference to 1 atmosphere

3

(e) **M1**

Σ B **(reactants)** − Σ B **(products)** = Δ*H*

OR

Sum of bonds broken − Sum of bonds formed = Δ*H*

OR

2B(C−C) + B(C=O) + 6B(C−H) + 4B(O=O) (LHS)

− 6B(C=O) − 6B(O−H) (RHS) = Δ*H*

M2 (also scores **M1**)

2(348)+805+6(412)+4(496) [LHS = **5957**]

(696) (2472) (1984)

− 6(805) − 6(463) [RHS = (−) **7608**] = Δ*H*

(4830) (2778)

OR using only bonds broken and formed (**5152 − 6803**)

M3

Δ*H*= **− 1651** (kJ mol^{-1})

Candidates may use a cycle and gain full marks.

Correct answer gains full marks

Credit 1 mark for (+) 1651 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication / addition error; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1***

Allow a maximum of one mark if the only scoring point is LHS = 5957 (or 5152) OR RHS = 7608 (or 6803)

Award 1 mark for + 1651

3

(f) **For the two marks M1 and M2, <u>any two</u> from**

- <u>heat</u> loss or not all <u>heat</u> transferred to the apparatus or <u>heat</u> absorbed by the apparatus or (specific) heat capacity of the apparatus not considered
- incomplete combustion / not completely burned / reaction is not complete
- The idea that the water may end up in the gaseous state (rather than liquid)
- reactants and / or products may not be in standard states.
- MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states
- MBE <u>do not refer to specific compounds</u> OR MBE <u>values vary with different compounds / molecules</u> OR are average / mean values taken <u>from a range of compounds / molecules</u>

Apply the list principle but ignore incomplete reasons that contain correct chemistry

Ignore "evaporation"

Ignore "faulty equipment"

Ignore "human error"

Not enough simply to state that "MBE are mean / average values"

2

[15]

5

(a) H_2SO_4

Allow H_3PO_4 or HCl

1

(b) Dichromate / Cr(VI) reduced or Cr(III) formed.

Allow Cr^{6+} and Cr^{3+}

1

(c) The alcohol is flammable

Allow enables temperature to be controlled

1

(d) Tollens'

1

Silver mirror
OR Fehling's
Red precipitate
OR Benedict's
Red precipitate

1

[5]

6 Acidified potassium dichromate

Accept words or formulae.

Accept acidified potassium permanganate.

Accept Lucas reagent (conc HCl, $ZnCl_2$) (cloudy in 5 mins for 2°, instantly for 3°).

Mark on for incomplete reagent.

Incorrect reagent CE = 0 / 3

Inclusion of Tollen's etc with acidified potassium dichromate is incorrect reagent.

Not no reaction.

Either

Obs with 2-methylpropan-2-ol

No visible change

1

Obs with butan-2-ol

Orange to green (both colours needed)

1

or

Obs with 2-methylpropan-2-ol orange

Obs with butan-2-ol green

[3]

7 (a) Structure for 3-methylbut-1-ene

$H_2C=CHCH(CH_3)_2$

Any correct structural representation.

Credit "sticks" and require the double bond.

1

(b) Structure for 2-methylpropan-2-ol

$(CH_3)_3COH$

Any correct structural representation.

Credit "sticks".

1

(c) Structure for propene

$H_2C=CHCH_3$

Any correct structural representation.

Credit "sticks" and require the double bond.

1

(d) Structure for 2-aminobutane

$CH_3CH_2CH(NH_2)CH_3$

Any correct structural representation.

Credit "sticks".

1

[4]

8 (a) (i) CH_2O

Atoms in any order

Accept a clear indication that $C_6H_{12}O_6$ yields CH_2O as the answer

1

(ii) No peak / no absorption / no C=O in the **range 1680 to 1750** (cm^{-1}) (suggesting no evidence of C=O)

Allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption

Ignore references to other wavenumbers

1

(b) M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2

Penalise (C_2H_6O)

*Allow multiples of the equation in **M1***

Either order

M2 (enzymes from) yeast or zymase

M3 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K

*For **M2** and **M3***

Ignore "aqueous"

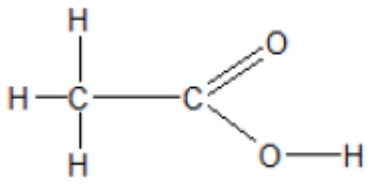
Ignore "anaerobic / absence of oxygen"

Ignore "controlled pH"

Ignore "warm"

3

(c) (i) Displayed formula for CH_3COOH



All bonds must be drawn out, but ignore bond angles

1

(ii) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

Ignore state symbols

Negative charge on electron not essential

Accept multiples

Accept electrons subtracted from RHS

1

(iii) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

(C_2H_6O or C_2H_5OH)

Ignore state symbols

Negative charge on electron not essential

Accept multiples

Accept electrons subtracted from LHS

1

(iv) M1 <u>Acidified potassium or sodium dichromate</u>

*For **M1**, it must be a whole reagent and / or correct formulae*

OR H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$ etc.

Do not penalise incorrect attempt at formula if name is correct or vice versa

OR correct combination of formula and name

If oxidation state given in name, it must be correct, but mark on from an incorrect attempt at a correct reagent.

M2 (requires an attempt at M1)
<u>orange to green</u>

*Credit **acidified** potassium chromate(VI) / <u>H_2SO_4 + K_2CrO_4</u>*

Possible alternative
M1 (acidified) potassium manganate(VII) ***OR*** $KMnO_4$ / H_2SO_4
M2 <u>purple to colourless</u>

*Other alternatives will be accepted but **M2** is dependent on **M1** in every case*
__M2__ requires an attempt at a correct reagent for __M1__
Ignore reference to states

2

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere / air

The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere / air

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air.

Answer must refer to the atmosphere or air

OR

There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere / air

1

(ii) Renewable / sustainable ONLY

Ignore references to global warming or greenhouse gases

1

(iii) **Any one statement about this process from**

Subject to weather / climate

Ignore "batch"

OR

Depletes food supply OR the land use for (specified) food

OR

Requires use of / uses more fossil fuels

OR

Not carbon-neutral OR CO_2 produced during a named process (eg harvest, transport etc.)

OR

Slow process / slow rate of reaction / takes a long time (to grow crops)

OR

This route leads to the production of a mixture of water and ethanol / impure ethanol that requires separation / further processing

1

[13]

9 (a) **M1 Safety (in Process 1)**

Sodium hydroxide / alkali is corrosive / harmful / caustic or sodium hydroxide is alkali(ne)

Ignore references to chromium compounds

OR

Bromine compounds are toxic / poisonous

"Carbon-neutral" alone is insufficient for ***M2***

M2 Environmental

Ignore references to greenhouse gases

Process 2 could be used as a carbon sink / for carbon capture

OR

uses waste / recycled CO_2 / CO_2 from the factory / CO_2 from the bioethanol (or biofuel) production

OR

reduces or limits the amount of CO_2 released / given out (into the atmosphere)

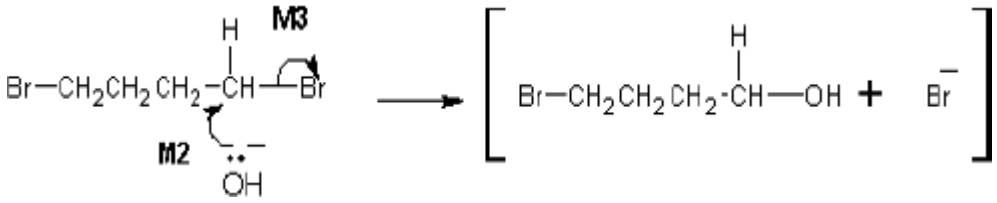
OR

Process 2 uses renewable glucose / renewable resource(s)

2

(b) (i) M1 <u>nucleophilic substitution</u>

*For **M1, both words** required*



M2 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom.

*Penalise **M2** if covalent NaOH / KOH is used*

*Penalise one mark from **M2** or **M3** if half-headed arrows are used*

M3 must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from the <u>original molecule</u>

*Penalise **M3** for formal charge on C of the C–Br or incorrect partial charges on C–Br*

Penalise once only for a line and two dots to show a bond.

For **M2** and **M3** award full marks for an S_N1 mechanism

*For **M2** and **M3**, maximum 1 of 2 marks for the mechanism if wrong reactant is used.*

*Penalise **M3** if an extra arrow is drawn from the Br of the C–Br bond*

to, for example, K^+

Accept the correct use of "sticks

NB The arrows here are double-headed

3

(ii) **M1** B

M2 C

M3 A

3

(c) **M1** fermentation

*Mark **M2** to **M4** independently*

Three conditions in any order for M2 to M4

Penalise "bacteria" and "phosphoric acid" using the list principle

M2 (enzymes from) yeast or zymase

M3 25°C ≤ T ≤ 42°C OR 298 K ≤ T ≤ 315 K

Ignore reference to "aqueous" or "water", "closed container", "pressure, "lack of oxygen",

"concentration of ethanol" and "batch process" (i.e. not part of the list principle)

M4 anaerobic / no oxygen / no air OR neutral pH

4

(d) **M1** primary OR 1° (alcohol)

Mark independently

M2 acidified potassium or sodium dichromate

*For **M2**, it must be a whole reagent and/or correct formulae*

OR H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$

Do not penalise incorrect attempt at formula if name is correct or vice versa

Accept phonetic spelling

If oxidation state given in name, it must be correct.

*For **M2** accept acidified potassium manganate(VII)*

OR correct combination of formula and name

M3

$HOCH_2CH_2CH_2CH_2OH + \mathbf{4}[O] \longrightarrow HOOCCH_2CH_2COOH + \mathbf{2}H_2O$

*For **M3** structures must be correct and not molecular formula*

3

[15]

10 (Mix the alcohol with warm) $K_2Cr_2O_7$ / H^+ allows 3° identification by lack of reaction

Scheme must allow the alcohol to be distinguished to get all marks.

1

Distillation of initial product needed for 1° / 2°

If distillation stage not clear then max. 2 (M1 and M3).

Awareness of correct reactions / lack of reaction relating to each class of alcohol is worth 1 mark.

1

Effect of Tollens' / Fehling's on oxidation product to identify 1° or 2° (by default)

Reacting Tollens' / Fehling's with alcohols directly is incorrect and gains no M2 or M3.

Detailed observations relating to the reactions are not needed but should be penalised where incorrect.

1

[3]

11 (a) Pentan-2-one

ONLY but ignore absence of hyphens

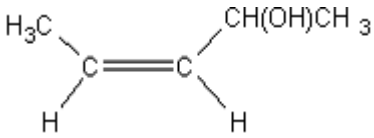
1

(b) Functional group (isomerism)

Both words needed

1

(c) (i)



Award credit provided it is obvious that the candidate is drawing the Z / cis isomer

The group needs to be $CHOHCH_3$ but do not penalise poor C–C bonds or absence of brackets around OH

Trigonal planar structure not essential

1

(ii) Restricted rotation (about the C=C)

OR

No (free) rotation (about the C=C)

1

(d)

M1 Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Do not credit Ag^+, $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)*	**M1** Fehling's (solution) / Benedict's *(Penalise $Cu^{2+}(aq)$ or $CuSO_4$ but mark M2 and M3)*
M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u>	**M2** <u>Red solid/precipitate</u> *(Credit <u>orange</u> or <u>brown solid</u>)*
M3 (stays) colourless OR no (observed) change / no reaction	**M3** (stays) blue OR no (observed) change / no reaction

*If **M1** is blank CE = 0, for the clip*

Check the partial reagents listed and if M1 has a <u>totally</u> <u>incorrect</u> reagent, CE = 0 for the clip

Allow the following alternatives

***M1** (acidified) potassium dichromate(VI) (solution); mark on from incomplete formulae or incorrect oxidation state*

***M2** (turns) green*

M3 (stays) orange / no (observed) change / no reaction

OR

***M1** (acidified) potassium manganate(VII) (solution);*

mark on from incomplete formulae or incorrect oxidation state

***M2** (turns) colourless*

***M3** (stays) purple / no (observed) change / no reaction*

*In all cases for **M3***

Ignore "nothing (happens)"

Ignore "no observation"

3

(e) (i) **Spectrum is for Isomer 1**

or named or correctly identified

The explanation marks in (e)(ii) depend on correctly identifying Isomer 1.

The identification should be unambiguous but candidates should not be penalised for an imperfect or incomplete name. They may say "the alcohol" or the "alkene" or the "E isomer"

1

(ii) **If Isomer 1 is correctly identified, award <u>any two</u> from**

- (Strong / broad) absorption / peak in the range **<u>3230 to 3550</u>** cm^{-1} or specified value <u>in this range</u> or **<u>marked correctly</u>** on spectrum
  <u>and</u>
  (characteristic absorption / peak for) <u>OH</u> group /**<u>alcohol</u>** group

- No absorption / peak in range **<u>1680 to 1750</u>** cm^{-1} or absence <u>marked correctly</u> on spectrum
  <u>and</u>
  (No absorption / peak for a) **<u>C=O</u>** group / **<u>carbonyl</u>** group / **<u>carbon-oxygen double bond</u>**

- Absorption / peak in the range **<u>1620 to 1680</u>** cm^{-1} or specified value <u>in this range or marked correctly</u> on spectrum
  <u>and</u>

  (characteristic absorption / peak for) **<u>C=C</u>** group / **<u>alkene</u>** / **<u>carbon-carbon double bond</u>**

  If 6(e)(i) is incorrect or blank, CE=0

  Allow the words "dip" OR "spike" OR "trough" OR "low transmittance" as alternatives for absorption.

  Ignore reference to other absorptions e.g. C-H, C-O

2

[10]

12 (a) (i) Green

Ignore shades of green.

1

(ii) <u>Excess</u> acidified potassium dichromate(VI)

1

Reflux (for some time)

1

In the diagram credit should be given for

- a vertical condenser

  Lose M3 and M4 for a distillation apparatus.

1

- an apparatus which would clearly work

  Do not allow this mark for a flask drawn on its own.

  Penalise diagrams where the apparatus is sealed.

1

(iii) Distillation

1

Immediately (the reagents are mixed)

1

(b) Keep away from naked flames

Allow heat with water-bath or heating mantle.

If a list is given ignore eye protection, otherwise lose this mark.

1

(c) (i) Tollens' or Fehling's reagents

*Incorrect reagent(s) loses **both** marks.*

Accept mis-spellings if meaning is clear.

1

Silver mirror / red ppt. formed

Accept 'blue to red' but not 'red' alone.

1

(ii) Sodium carbonate (solution) / Group II metal

Allow indicator solutions with appropriate colours.

Accept any named carbonate or hydrogen carbonate.

1

Effervescence / evolves a gas

Accept 'fizzes'.

1

(d) Propanoic acid

If this mark is lost allow one mark if there is reference to stronger intermolecular forces in the named compound.

Lose M1 and M3.

1

Contains hydrogen bonding

1

Some comparison with other compounds explaining that the intermolecular forces are stronger in propanoic acid

1

[15]

13 (a) **M1** $AgNO_3$ OR silver nitrate OR any soluble silver salt

M2 remains colourless or no reaction or no (observed) change or no precipitate

M3 white precipitate or white solid/white suspension

An insoluble silver salt OR Tollens' OR ammoniacal silver nitrate or $HCl/AgNO_3$ is CE = 0 for the clip

For M1

Credit acidified (or HNO_3) silver nitrate for M1 and mark on

If silver ions or incorrect formula for silver nitrate, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M2

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For M3

Ignore "cloudy solution" OR "suspension"

3

(b) **M1** any soluble sulfate by name or formula e.g. sodium sulfate or sulfuric acid.

M2 white precipitate or white solid/white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate

OR as an alternative

M1 NaOH/KOH

M2 remains colourless or no reaction or no (observed) change

M3 white precipitate or white solid/white suspension

An insoluble sulfate OR conc H_2SO_4 is CE = 0 for the clip

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For the M1 soluble sulfate

If sulfate ions or incorrect formula for the chosen sulfate, penalise M1 but mark M2 and M3

For the M1 NaOH/KOH

If ammonia, then CE = 0

If hydroxide ions or incorrect formula for the chosen hydroxide, penalise M1 but mark M2 and M3

For no (observed) change in both alternatives

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For the white precipitate in both alternatives

Ignore "cloudy solution" OR "suspension"

3

(c) **M1** ammonia (can be dilute or concentrated)

M2 dissolves OR soluble OR (forms a) colourless solution OR goes colourless

M3 does not dissolve OR not soluble OR remains as a solid OR no (observed) change OR no reaction OR yellow solid remains

OR if concentrated ammonia has been used, accept yellow solid turns white.

OR as an alternative using conc sulfuric acid

M1 concentrated sulfuric acid OR c(onc) H_2SO_4

M2 misty/white fumes/gas

OR remains white

OR no change (in colour)

M3 turns black (solid)

OR purple fumes/gas

OR correct reference to H_2S observation (e.g. bad egg smell)

For M1

If incorrect formula or "ammonium", penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M3

Ignore "nothing"

Ignore "no observation"

For the alternative using sulfuric acid

If dilute sulfuric acid or "aq" (alone) or the idea of concentrated not included CE = 0

If incorrect formula, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

3

(d) **M1** acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$

OR $K_2Cr_2O_7/H^+$ OR acidified $K_2Cr_2O_7$

M2 (orange to) green solution OR goes green

M3 (solution) remains orange or no reaction or no (observed) change

Alternative using $KMnO_4/H_2SO_4$

M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$

OR $KMnO_4/H^+$ OR acidified $KMnO_4$

M2 colourless solution OR goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M1

If "dichromate" or "dichromate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

For M2 ignore dichromate described as "yellow" or "red"

For M3

Ignore "nothing"

Ignore "no observation"

For M1

If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

Credit alkaline $KMnO_4$ for possible full marks but M2 gives brown precipitate or solution goes green

3

[12]

14 (a) (i) Hexan-1-ol1

ONLY

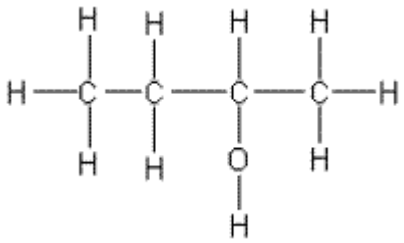
1

(ii) Homologous (series)

ONLY

1

(iii) Displayed formula for butan-2-ol



All bonds must be drawn out including the O–H bond

Ignore bond angles

1

(iv) $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$

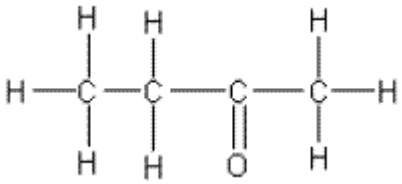
Require this whole equation <u>as written or formulae drawn out</u>

Penalise "sticks"

1

(v) <u>Displayed formula</u> for butanone

(credit possible enols, ethers and cyclic structures for C_4H_8O)



<u>All bonds</u> must be drawn out

Ignore bond angles

1

(b) **M1** q = m c ΔT OR calculation 175 × 4.18 × 8

M2 = **5852** (J) OR 5.85 (kJ) OR 5.9 (kJ) (This also scores M1)

M3 0.005 mol, therefore ΔH = **<u>–1170</u>** (kJ mol^{-1})

OR ΔH = **<u>–1170.4</u>** (kJ mol^{-1})

OR ΔH = **<u>–1200</u>** (kJ mol^{-1})

Award full marks for correct answer

In M1, do not penalise incorrect cases in the formula

Ignore incorrect units in M2

Penalise M3 ONLY if correct answer but sign is incorrect OR value is in J mol^{-1}

If $m = 5 \times 10^{-3}$ OR if ΔT = 281, CE and only allow one mark for correct mathematical formula for M1

If c = 4.81 (leads to 6734) penalise M2 ONLY and mark on for M3 = <u>–1350 (–1347)</u>

3

(c) (i) **M1** The enthalpy change (or heat change at constant pressure) when 1 mol of a compound/substance/alcohol

M2 is burned completely in oxygen

OR burned in excess oxygen

M3 with all reactants and products/all substances in standard states

OR

all reactants and products/all substances in normal states under standard conditions OR 100 kPa/1 bar and a specified T/298 K

For M3

Ignore reference to 1 atmosphere

3

(ii) **M1 (could be scored by a correct mathematical expression)**

M1 $\Delta H = \Sigma \Delta H_f$ (**products**) – .$\Sigma \Delta H_f$ (**reactants**)

OR a correct cycle of balanced equations

M2 = 4(–394) + 5(–286) – (–327)

(This also scores M1)

M3 = **– 2679** (kJ mol^{-1}) OR **–2680** (kJ mol^{-1})

Award 1 mark ONLY for (+) 2679 OR (+) 2680

Correct answer to calculation gains full credit

Credit 1 mark if + 2679 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2)*
- *If no AE, check for correct method; this requires either a correct cycle with $4CO_2$ and $5H_2O$ OR a clear statement of M1 which could be in words and scores only M1*

3

(d) (i) **M1 This is about the change in formula up the series**

Each alcohol in the series (compared with the previous one)

increases by/has an extra CH_2

OR

has one more C-C and two more C-H

M2 This is about the reaction and bond breaking/making

Combustion of each alcohol in the series breaks one

more C-C and two more C-H compared with the previous one
AND forms one more mol CO_2 and one more mol H_2O

OR

A statement in which there is the idea that the extra OR additional OR difference in number of bonds broken and formed (as the series increases) is the same OR has the same difference in energy

N.B. If the first statement here for M2 is given, both marks score

2

(ii) **For the two marks M1 and M2**

heat loss or heat absorbed by the apparatus

OR

incomplete combustion/not completely burned

OR

The idea that the water may end up in the gaseous state (rather than liquid) OR reactants and/or products may not be in standard states.

2

[18]

15 (a) to neutralise stomach acidity

OR

as an antacid

OR

eases indigestion/heartburn

Ignore milk of magnesia

Credit suitable reference to indigestion/laxative/relief of constipation

1

(b) (i) an <u>electron acceptor</u>

OR

(readily) <u>gains/accepts/receives electron(s)</u>

NOT an electron pair acceptor

Ignore removes/takes away/attracts electrons

1

(ii) Br_2 ONLY

Ignore "bromine"

Apply the list principle

1

(iii) $H_2SO_4 + \mathbf{2}H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

OR

$SO_4^{2-} + 4H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

Ignore state symbols

Ignore absence of negative charge on electron

Or multiples of equations

1

(c) (i) (acid) catalyst

OR

catalyses (the reaction)

OR

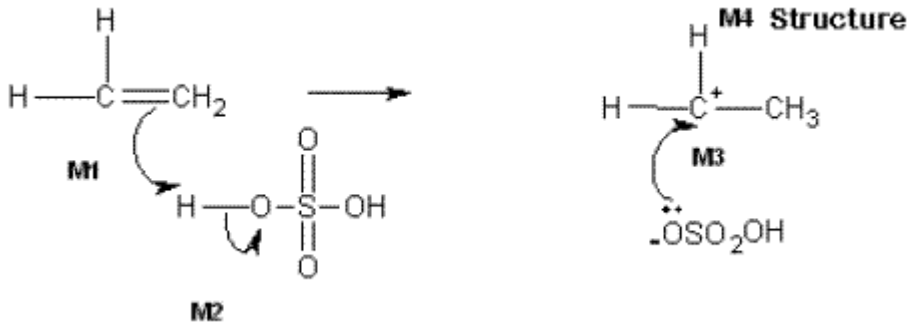
to speed up the reaction/increase the rate (of reaction)

Ignore "provides H^+ ions"

Accept phonetic spelling

1

(ii)



M1 must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H_2SO_4 (or accept H_2SO_3 here)

M1 could be to an H^+ ion and M2 an independent O – H bond break on a compound with molecular formula for H_2SO_4 or H_2SO_3

M2 must show the breaking of the O ─ H bond.

M3 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom.

M4 is for the structure of the carbocation.

NB The arrows here are double-headed

M2 Ignore partial charges unless wrong

M3 NOT HSO_4^-

For M3, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion

OR <u>correctly</u> drawn out with the negative charge placed correctly on oxygen

Max 3 marks for wrong reactant

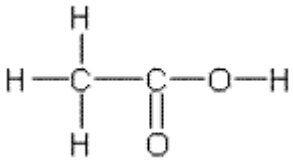
Do not penalise the use of "sticks"

4

(iii) Primary ***OR*** 1° (alcohol)

1

(iv) Displayed formula for ethanoic acid, CH_3COOH



All the bonds must be drawn out and this includes the O — H bond

Ignore bond angles.

1

[11]

16 Add Tollens / Fehling's / Benedict's reagent / ir spectra

Accept any other chemically correct reagent and observation

1

Silver mirror / blue to red ***OR*** red precipitate (with ethanal) / peak at 1700 cm^{-1} (in ethanal)

Must have correct test to access second mark
Accept 'silver'. Do not accept 'silver solution'
Give one mark for 'silver mirror test' and 'silver mirror'
Accept correct answer based on n.m.r. spectra

1

[2]

17 Figure 2

1

Further oxidation will occur / ethanoic acid formed

Do not accept 'poor yield' without qualification

Can gain this mark if logic correct but has chosen wrong Figure

1

[2]

18 (a) Functional group (isomerism)

1

(b)

M1 Tollens' (reagent) (*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens'*) (*Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3*)	**M1** Fehling's (solution) or Benedict's solution (*Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3*)
M2 silver mirror **OR** black solid/precipitate *(NOT silver precipitate)*	**M2** Red solid/precipitate (*Credit orange or brown solid*)
M3 (stays) colourless or no change or no reaction	**M3** (stays) blue or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct reagent, penalising M1

No reagent, CE=0

Allow the following alternatives
M1 *(acidified) potassium dichromate(VI) (solution)*
M2 *(turns) green*
M3 *(stays) orange/no change*
OR
M1 *(acidified) potassium manganate(VII) (solution)*
M2 *(turns) colourless*
M3 *(stays) purple/no change*

For M3
Ignore "nothing (happens)"
Ignore "no observation"

3

(c) (Both have) C=O ***OR*** a carbonyl (group)

1

(d) (i) (Free-) radical substitution ONLY

Penalise "(free) radical mechanism"

1

(ii) **Initiation**

$Cl_2 \rightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation

$Cl\bullet + CH_3CH_2CH_3 \rightarrow \bullet CH_2CH_2CH_3 + HCl$

OR C_3H_8

Penalise incorrect position of dot on propyl radical once only.

Penalise $C_3H_7\bullet$ once only

Second propagation

$Cl_2 + \bullet CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2Cl + Cl\bullet$

OR

C_3H_7Cl

Accept $CH_3CH_2CH_2\bullet$ with the radical dot above/below/to the side of the last carbon.

Termination (must make C_6H_{14})

$2 \bullet CH_2CH_2CH_3 \rightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$

Use of the secondary free radical might gain 3 of the four marks

4

(e) M_r = 44.06352 (for propane)

M_r = 43.98982 (for carbon dioxide)

Mark independently

M1 a correct value for both of these M_r values.

M2 a statement or idea that two peaks appear (in the mass spectrum)

OR

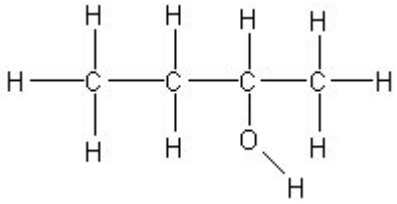
two molecular ions are seen (in the mass spectrum).

2

[12]

19 (a) **M1**

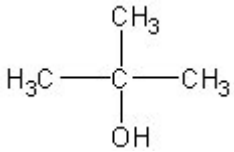
Displayed formula for butan-2-ol



M1 displayed formula must have all bonds drawn out, including the O—H but ignore angles

Penalise "sticks"

M2 Alcohol **X** is



M2 structure must be clearly identifiable as 2-methylpropan-2-ol and may be drawn in a variety of ways.

M3 Alcohol **Y** is named (2)-methylpropan-1-ol ONLY

M3 must be correct name, but ignore structures

3

(b) **M1** The infrared spectrum shows an absorption/peak in the range 3230 to 3550 (cm^{-1})(which supports the idea that an alcohol is present)

In M1, allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption.

M2 Reference to the 'fingerprint region' or below 1500 (cm^{-1})

M3 Match with or same as known sample/database spectra

Check the spectrum to see if alcohol OH is labelled and credit.

OR

M2 Run infrared spectra (of the alcohols)

M3 Find which one matches or is the same as this spectrum.

3

(c) **M1** balanced equation

$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2CH_2OH + \mathbf{2}CO_2 + H_2O$

or C_4H_9OH

Or multiples for M1 and M3

In M1 and M3 penalise use of $C_4H_{10}O$ or butan-2-ol once only

M2 Any one from

- excess/adequate/sufficient/correct amount of/enough/plenty/ a good supply of oxygen or air
- good mixing of the fuel and air/oxygen

For M2, do not accept simply "oxygen" or "air" alone

Ignore reference to "temperature"

M3 $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \rightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$

or C_4H_9OH

M4 A biofuel is a fuel produced from (renewable) biological (re)source(s)

OR

(renewable) (re)source(s) from (a specified) plant(s)/fruit(s)/tree(s)

In M4

Ignore references to "carbon neutral"

Ignore "sugar" and "glucose"

4

(d) **M1** butan-1-ol is a primary or 1° (alcohol)

M2 Displayed formula (ONLY) for butanal $CH_3CH_2CH_2CHO$

M3 Displayed formula (ONLY) for butanoic acid $CH_3CH_2CH_2COOH$

M2 and M3 displayed formula must have all bonds drawn out including the O—H but ignore angles.

If butanal and butanoic acid formulae are both correctly given but not displayed, credit one mark out of two.

M4 Oxidation (oxidised) OR Redox

M5 orange to green

Both colours required for M5

Ignore states

5

[15]

20 (a) Eliminate / reduce <u>fire</u> risk;

Allow ethanol flammable / burns / combusts.

1

(b) <u>Orange to green</u>;

Need full colour change to score mark.

1

[2]

21 (a) Allow 1 mark each for any correctly drawn primary, secondary and tertiary alcohol of molecular formula C_4H_8O

3

Tertiary alcohol cannot be oxidised

1

(b) Region 1500–400 cm^{-1}

1

exact match to spectrum of known compound

1

(c)

A

$CH_3CH_2CH_2OH$ or $CH_3CH(OH)CH_3$ **(1)**

B

$CH_3CH_2–O–CH_3$ **(1)**

C

one alkene e.g.

$CH_2=CHCH_2CH_2CH_3$

$CH_3–CH=CH–CH_2CH_3$

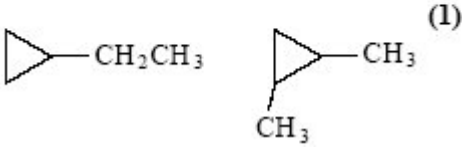
$(CH_3)_2C=CHCH_3$

$H_2C=C(CH_3)CH_2CH_3$

D

one cycloalkane e.g.

(1)



(1)

etc

E

CH_3CH_2CHO **(1)**

F

CH_3COCH_3 **(1)**

6

[12]

22 (a) (i) M1 pentan-3-one only

1

M2 $CH_3CH_2CH_2COCH_3$

(insist on C=O being drawn out)

(penalise use of C_3H_7)

1

(ii) *aldehyde* $(CH_3)_2CHCH_2\underline{CHO}$

1

ketone $(CH_3)_2CH\underline{CO}CH_3$

1

(insist on a clear structure for the C=O of the functional groups, but do not be too harsh on the vertical bonds between carbon atom son this occasion)

(If both structures correct, but wrong way around, award one mark)

(ignore names)

(b) (i) $CH_3CH_2CH_2CH_2\underline{CHO} + [O] \rightarrow CH_3CH_2CH_2CH_2\underline{COOH}$

(accept C_4H_9CHO going to C_4H_9COOH)

(insist on a balanced equation – for example do not credit [O] over the arrow alone)

1

(ii) pentanoic acid

(credit pentan–1–oic acid)

1

(c) (i) $CH_3CH_2CH_2CH_2CH_2OH$ OR pentan–1–ol

(If both a structure and a formula are given, credit either correct one of these provided the other is a good, if imperfect, attempt)

1

(ii) Primary

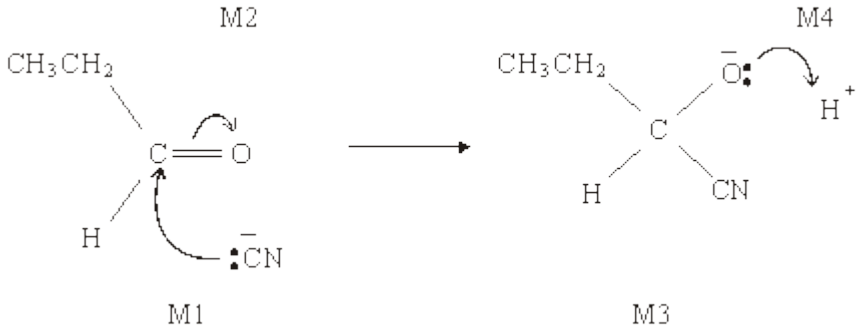
(credit 1^o or 1)

1

[8]

23 (a) nucleophilic addition

1

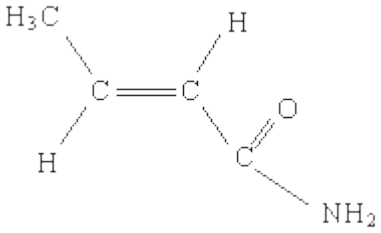


4

(b) (i) 2-hydroxybutanenitrile

1

(ii)

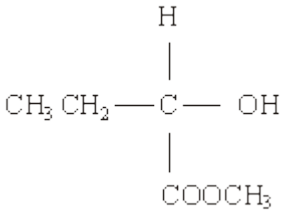


(allow 1 for amide even if not C_4H_7NO, i.e. $RCONH_2$)

(if not amide, allow one for any isomer of C_4H_7NO which shows geometric isomerism)

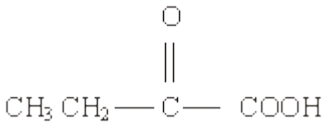
2

(c) (i)



1

(ii)



1

(iii) $CH_3CH=CHCOOH$

1

[11]

24 (a) M1: $CH_3CH_2CH_2CH_2OH$;

1

M2: $CH_3CH(OH)CH_2CH_3$;

(penalise incorrect alcohols in part (a), but mark consequentially in part (b) and in part (c), if relevant)
(if three alcohols drawn, award MAX. 1 mark)

1

(b) M1, M2 and M3: Correct structures for butanal, butanone and butanoic acid;

(award these structure marks wherever the structures appear, but insist that the C=O is shown in each structure and additionally, the C-O in the carboxylic acid

3

M4: balanced equation for the reaction of butan-1-ol with [O] to produce butanal and water;

1

M5: balanced equation for the reaction of butan-1-ol with [O] to produce butanoic acid and water

OR

balanced equation for the reaction of butanal with [O] to produce butanoic acid;

1

M6: balanced equation for the reaction of butan-2-ol with [O] to produce butanone and water;

(Credit condensed structures or molecular formulas in each equation, provided it is obvious to which reaction the equation refers) (Insist that whatever formula is used in each equation that it is a conventional representation of the compound; for example penalise $CH_3CH_2CH_2COH$ for butanal)

1

(c) M1: Correct structure for 2-methylpropan-2-ol;
M2: 2-methylpropan-2-ol

1

OR

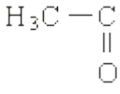
methylpropan-2-ol;

(penalise on every occasion in parts (a) and (c), structures for the alcohols that are presented with the alcohol functional group as C-H-O)

1

[10]

25 (a) (i)



or $RCOCH_3$;

(or description in words)
(ignore trailing bonds)

1

(ii) $H_3C—O$ or $ROCH_3$;

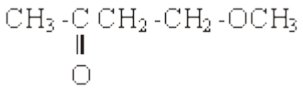
(allow 1 if both (i) and (ii) give CH_3- or H_3C– only)

1

(iii) CH_2CH_2 or two <u>adjacent</u> methylene groups;

1

(iv)



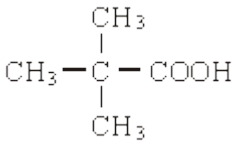
OR

$CH_3COCH_2CH_2OCH_3$;

1

(b) (i) OH <u>in acids</u> or (carboxylic) acid present

(ii)



(c)

reagent	$K_2Cr_2O_7$ /H^+	$KMnO_4$ /H^+
Y	no reaction	no reaction
Z	orange to green or turns green	purple to colourless or turns colourless

5

[9]

26 D

[1]

27 (a) Compounds with the same molecular formula

1

but different structures due to different positions of the same functional group on the same carbon skeleton/chain

1

(b) Compound A is butan-1-ol only

1

Compound C is butanone or butan-2-one

(penalise but-1-ol, but allow repeat error for but-2-one)
(credit butane-1-ol)

1

(c) (i) oxidation or redox

1

(ii) $K_2Cr_2O_7$ or potassium dichromate(VI)

(penalise the dichromate ion or incorrect oxidation state, but mark on)

1

acidified or H_2SO_4 (or other identified strong acid)

(penalise H^+)

(do not credit the acid unless M1 has been correctly attempted)

1

(iii) (heat under) reflux

OR use excess oxidising agent

1

(iv) correctly drawn structure of 2-methylpropan-2-ol

(insist on clearly drawn C-C and C-0 bonds)

1

(v) correctly drawn structure of methanoic acid

(insist on C-0 and C=O displayed in the formula)

1

(d) (i) Tollens' reagent or this whole reagent specified
(ammoniacal silver nitrate)
OR Fehling's solution
OR acidified potassium dichromate(VI)

1

(ii) correctly drawn structure of methylpropanal

(insist on C-H and C=O of aldehyde displayed in the formula)

1

[12]

28

(a) (i) Potassium (OR sodium) dichromate(VI) OR correct formula
OR potassium manganate(VII)

(Oxidation state not needed, but must be correct if included)

(Penalise errors in the formula or oxidation state, but mark conditions)

1

Acidified OR H_2SO_4 / HCl (*NOT with* $KMnO_4$) / H_3PO_4 / HNO_3

(Ignore heat or reflux)

(Credit "acidified" as part of reagent)

1

Oxidation or redox

1

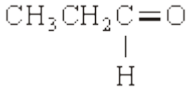
(ii) $NaBH_4$ OR $LiAlH_4$ OR H_2/Ni

1

$CH_3COCH_3 + 2[H] \rightarrow CH_3CH(OH)CH_3$

(Credit H_2 *in the equation if* H_2 *has been chosen as reagent)*

1

(b) (i) 

(Structure must show aldehyde structure)

(Credit C_2H_5 *as alternative to* CH_3CH_2*)*

(ii)

M1 Tollens' reagent OR ammoniacal silver nitrate OR $AgNO_3 + NH_3$	OR Fehling's solution	OR <u>acidified</u> potassium dichromate

1

M2 stays colourless	stays blue	stays orange

1

(Provided reagent is correct, credit "no reaction", "no change", "nothing", "no observation" for M2)

M3 silver <u>mirror</u> / <u>deposit</u> OR black / grey <u>precipitate</u>	red / brown / orange <u>precipitate / solid</u>	goes green

1

(Credit other correct reagents and observation)

(For M1, penalise $AgNO_3$ alone, penalise $Ag(NH_3)_2^+$, penalise "potassium dichromate", etc., but, in each case, mark on and credit correct M2 and M3)

(If totally wrong reagent or no reagent, CE = no marks for M1,M2 or M3)

1

[9]

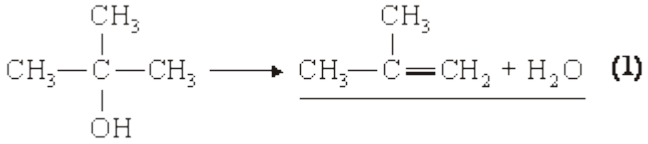
29 A

[1]

30 (a) (i) 2-methylpropan-2-ol **(1)** OR <u>the second one</u>

(ii) *Dehydrating agent*: conc H_2SO_4 OR conc H_3PO_4 OR Al_2O_3 **(1)** ignore <u>additional</u> (aq) **(1)**

Equation:



(1)

Allow C_4H_9OH in equation provided RHS is correct

if b(i) is blank, b(ii) equation must be full for credit i.e. NOT C_4H_9OH

Mark consequential on b(i)

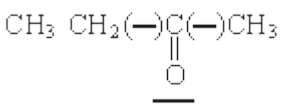
3

(b) (i) *Isomer*: butan-2-ol OR <u>the fourth one</u>

[look at name in table]

wrong isomer = CE

Structure of the ketone:



(1)

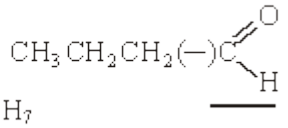
(ii) *Isomer*: butan-1-ol OR <u>the first one</u>

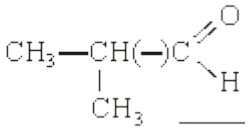
OR 2-methylpropan-1-ol OR <u>the third one</u>

[look at name in table]

Wrong isomer = CE

Structure of the aldehyde:

Either 

OR 

NOT C_3H_7

(iii)

Reagent	M1	Tollen's ($AgNO_3/NH_3$)	Fehling's
Observation with ketone	M2	Stays colourless no change	stays blue no change
Observation with aldehyde	M3	Silver mirror black ppt	red solid orange/red brown/ red ppt/solid

Other include(*)
$K_2Cr_2O_7$ / H_2SO_4
$KMnO_4/H_2SO_4$
Schiff's
Benedict's
Wrong reagent R
No reagent = CE
Penalise $AgNO_3$ [$Ag(NH_3)_2$] but allow M2 and M3 sequentially.

(*)		ketone	aldehyde
	$K_2Cr_2O_7$ / H_2SO_4 acidified	orange no change	green
	$KMnO_4/H_2SO_4$ acidified	purple no change	colourless (v. Pale pink)

Benedict's ≡ *Fehling's* ; *Schiff's colouless* → *pink with CHO violet*

7

(c) *Equation*: $CH_3CH_2CH_2CH_2OH$ (or C_4H_9OH) + 2[O] → $CH_3CH_2CH_2COOH$ (or C_3H_7COOH) + H_2O **(1)**

Name of product: butanoic acid **(1)**

Accept butaneoic acid

2

[12]

31 (a) (i) addition of water / steam **(1)**

Ignore "to the reaction"

(ii) *Advantage*: low technology
renewable feedstock / resource
allowed for use in drinks, perfumes
considered to be green **(1)**

any one
NOT "infinite" or "non-finite" resource

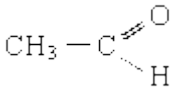
Disadvantage:
slow
low yield
significant land use
has to be distilled
labour intensive

any one
Ignore yeast
NOT (unqualified) batch production
NOT impure product

3

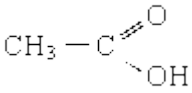
(b) (i)

Structure of aldehyde


(1)

NOT CH_3CHO

Structure of carboxylic acid


(1)

NOT CH_3COOH

Penalise incorrect R group once

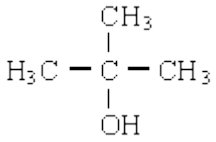
(ii) *Reagent*: sodium (/ potassium) dichromate (VI)
(VI not essential) (1) M1

Conditions: acidified or sulphuric acid **(1) Can be with reagent M2**
(heat under reflux) **(1) M3**

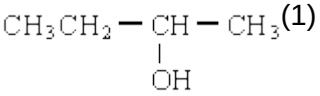
Or correct formula for M1 and M2
M2 depends on M1 (but M2 correct from $Cr_2O_7^{2-}$, $K_2Cr_2O_7^{2-}$ etc
M3 mark independent
Credit $KMnO_4$ for M1
Ignore T and P for M2

5

(c) (i)


(1)

(ii)

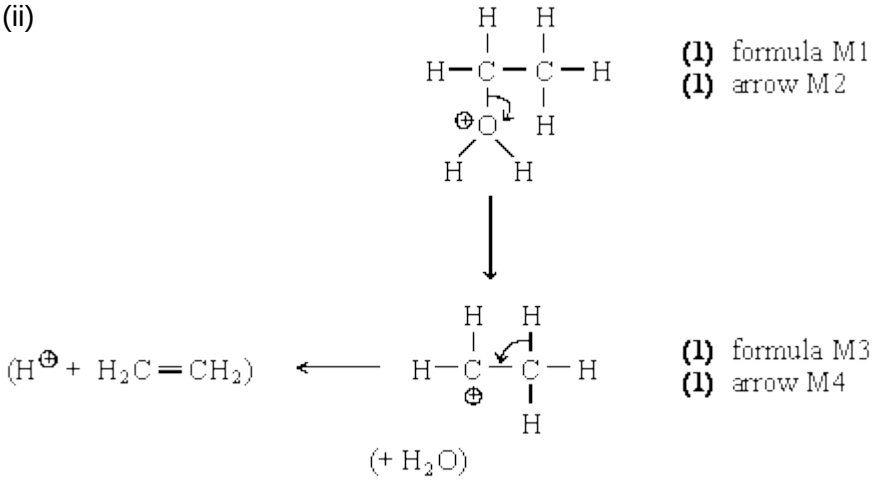

(1)

2

(d) (i) Al_2O_3 or H_2SO_4 or H_3PO_4 **(1)**

Name or formula

(ii)



(1) formula M1
(1) arrow M2
(1) formula M3
(1) arrow M4

For M1 the + can be on O or H if -OH_2 used
For M2 the arrow must go to the + or to oxygen
Synchronous loss without carbocation loses carbocation structure mark; can still score ¾ i.e. penalise M3

5

[15]

32

(a) % O = 21.6 % **(1)**

If % O not calculated only M2 available

C $\frac{64.9}{12}$ H $\frac{13.5}{1}$ O $\frac{21.6}{16}$ **(1)**

= 5.41 = 13.5 = 1.35

Ratio: 4 : 10: 1 (∴ $C_4H_{10}O$) **(1)**

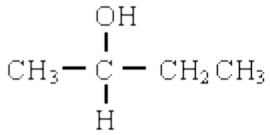
If arithmetic error in any result lose M3

If percentage composition calculation done zero

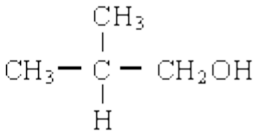
3

(b) (i) *Type of alcohol*: Tertiary **(1)**
Reason: No hydrogen atom on central carbon **(1)**

(ii)



(1)



(1)

Isomer 3 *Isomer 4*

Penalise missing bonds / incorrect bonds once per paper

4

(c) (i) Aldehyde **(1)**

Ignore named aldehydes or their structures,
penalise wrong named compound

(ii) $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$ **(1)**
Balanced **(1)**

$C_4H_{10}O$ is OK as a reactant
[O] can be over arrow
C_3H_7CHO not accepted for product, but $C_2H_5CH_2CHO$ is OK
If use C_3 or C_5 compounds no marks in (ii) C.E of wrong alcohol

(iii) *Name* Butanoic acid **(1)**
Structure: $CH_3CH_2CH_2COOH$ **(1)**
mark conseq. or as stated

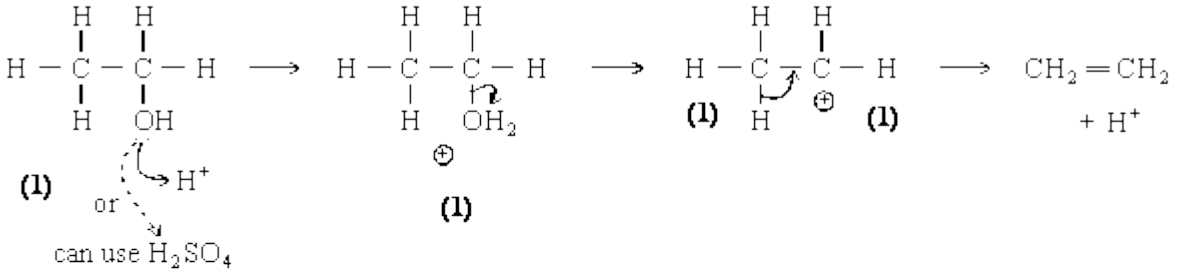
5

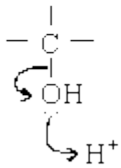
(d) *Advantage*: Fast reaction OR pure product OR continuous process
OR cheap on manpower OR high yield, 100% alcohol **(1)**
Disadvantage: High technology OR ethene from non renewable source
OR expensive equipment not just costly **(1)**

Not answers based on fermentation

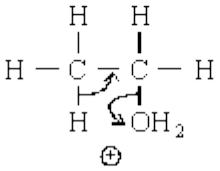
2

(e)





scores M1 only



scores M2 & M4
but not carbocation mark, M3.

4

[18]

33 D **[1]**

34 B **[1]**

35 A **[1]**

36 B **[1]**