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

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

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

(4)

(b) Ethanol is formed by the fermentation of glucose.
A student carried out this fermentation reaction in a beaker using an aqueous solution of glucose at a temperature of 25 °C in the presence of yeast.

Write an equation for the reaction occurring during fermentation.

.....

(1)

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

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

Advantage .....

.....

Disadvantage .....

.....

(2)

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

How does this contamination occur?

.....

.....

(1)

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

Difference 1 .....

.....

Difference 2 .....

.....

(2)
(Total 10 marks)

2 Ethanol is an important fuel.

(a) A dilute aqueous solution of ethanol can be produced by the fermentation of an aqueous solution of glucose.
It is claimed that the ethanol obtained from this solution is a carbon-neutral biofuel.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for this reaction to produce a good yield of ethanol.

Name a process used to produce a much more concentrated solution of ethanol from a dilute aqueous solution.

State the meaning of the term **carbon-neutral** in the context of this biofuel.

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(Extra space) .....

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(5)

(b) A student carried out a laboratory experiment to determine the enthalpy change when a sample of ethanol was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 75.0 g of water increased by 5.50 °C when 2.40×10^{-3} mol of pure ethanol 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 ethanol is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Deduce **two** reasons why the student's value for the standard enthalpy of combustion of ethanol is different from a Data Book value of –1279 kJ mol^{-1}.

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(Extra space).....

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(5)

(c) Mean bond enthalpies can be used to calculate enthalpies of reaction.

(i) Give the meaning of the term **mean bond enthalpy**.

.....

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(2)

(ii) Consider the mean bond enthalpy data in the following table.

	C — H	**C — C**	**C — O**	**O=O**	**C=O**	**O — H**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	to be calculated	805	463

Use the data in the table above and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.

$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$ $\Delta H = -1279$ kJ mol^{-1}

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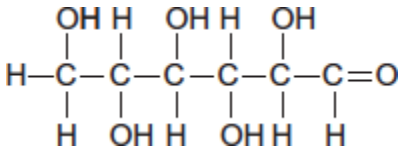
(3)

(Total 15 marks)

3 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.

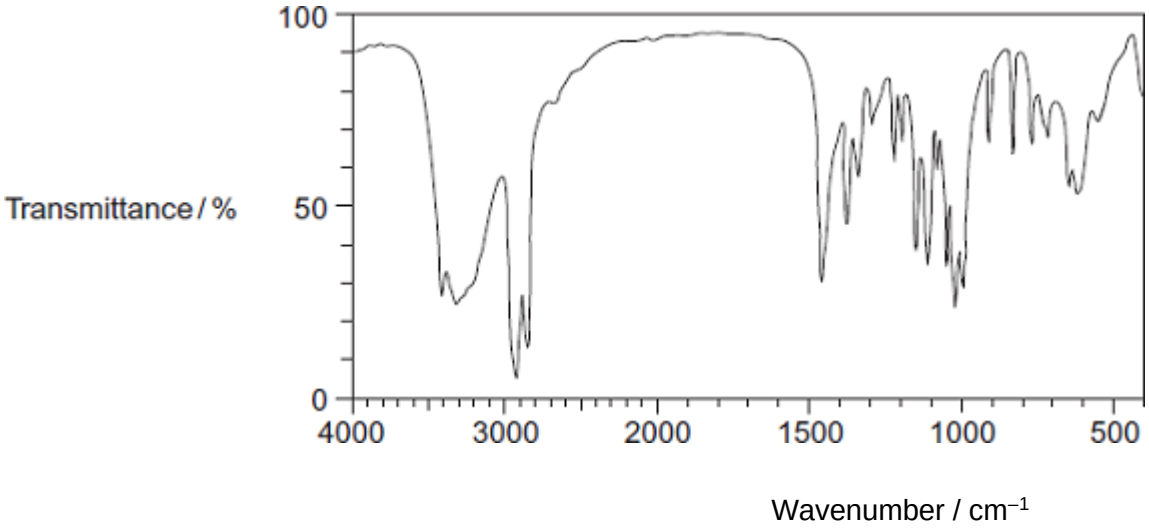


(i) Deduce the empirical formula of glucose.

.....

(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.

.....

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(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) .....

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(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)

4 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**.

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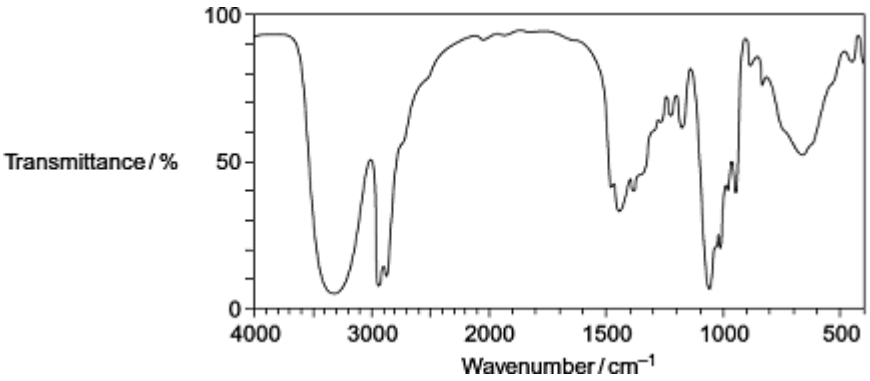
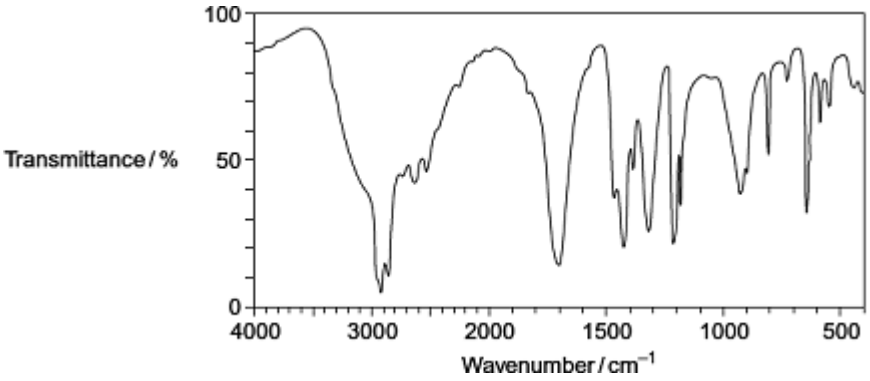
(3)

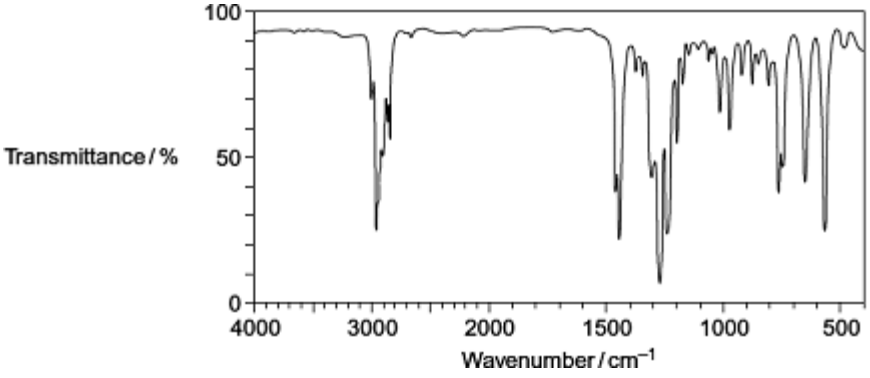
(ii) The infrared spectra shown are those of three compounds.

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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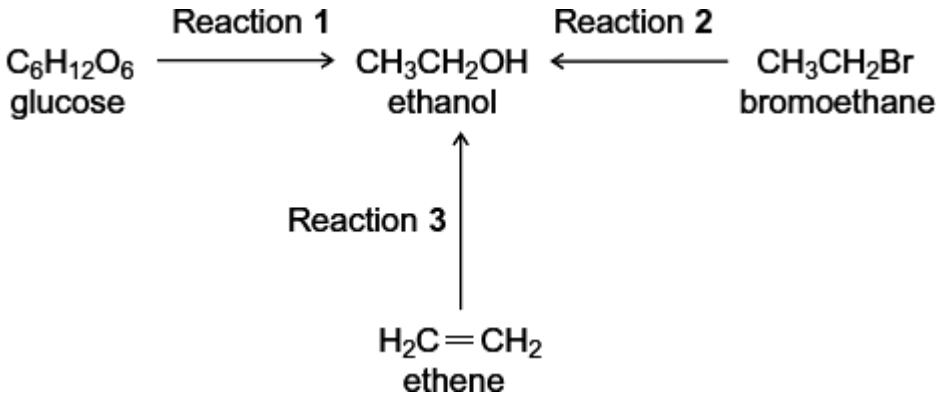
(3)
(Total 15 marks)

5 Three different ways of producing ethanol are shown below.



(a) Reaction **1** produces a 15% aqueous solution of ethanol.
It is claimed that the ethanol produced in this way is a carbon-neutral biofuel.

Write an equation for Reaction **1** and name the process.

Write an equation for the complete combustion of ethanol.

Explain why the ethanol produced by this process may **not** be a *carbon-neutral* biofuel.

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(Extra space) .....

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(5)

(b) Give a reagent and conditions for Reaction **2**.

$CH_3CH_2Br \xrightarrow{\text{Reaction 2}} CH_3CH_2OH$

Name and outline a mechanism for Reaction **2**.

Suggest **one** reason, other than safety, why this method is **not** used in industry to make ethanol.

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(Extra space) .....

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(6)

(c) Reaction **3** is used in industry.

Identify a suitable catalyst for Reaction **3**.

Identify the type of reaction.

Give **two** conditions, in addition to the presence of a catalyst, necessary for Reaction **3** to produce a high yield of ethanol.

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(Extra space) .....

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(4)
(Total 15 marks)

6 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**.

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(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)

7 Glucose, produced during photosynthesis in green plants, is a renewable source from which ethanol can be made. Ethanol is a liquid fuel used as a substitute for petrol.
The processes involved can be summarised as follows.

Process **1** Photosynthesis in green plants
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Process **2** Fermentation of glucose to form ethanol

Process **3** Complete combustion of ethanol
$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

(a) State **three** essential conditions for the fermentation of aqueous glucose in Process **2**.

Write an equation for the reaction that takes place during this fermentation.

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(4)

(b) It has been claimed that there is no net carbon (greenhouse gas) emission to the atmosphere when ethanol made by Process **2** is used as a fuel.

State the term that is used to describe fuels of this type.

Use the equations for Processes **1, 2** and **3** to show why it can be claimed that there is no net emission of carbon-containing greenhouse gases.

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(3)

(c) Use the information from the equation for Process **3** above and the mean bond enthalpies from the table below to calculate a value for the enthalpy change for this process.

	C–H	C–C	C–O	O–H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	+412	+348	+360	+463	+743	+496

Give **one** reason why the value calculated from mean bond enthalpies is different from the value given in a data book.

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(4)

(d) A student carried out a simple laboratory experiment to measure the enthalpy change for Process **3**. The student showed that the temperature of 200 g of water increased by 8.0 °C when 0.46 g of pure ethanol was burned in air and the heat produced was used to warm the water.

Use these results to calculate the value, in kJ mol^{-1}, obtained by the student for this enthalpy change. (The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Give **one** reason, other than heat loss, why the value obtained from the student's results is less exothermic than a data book value.

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(4)
(Total 15 marks)

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

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

Draw the displayed formula for butan-2-ol.

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

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

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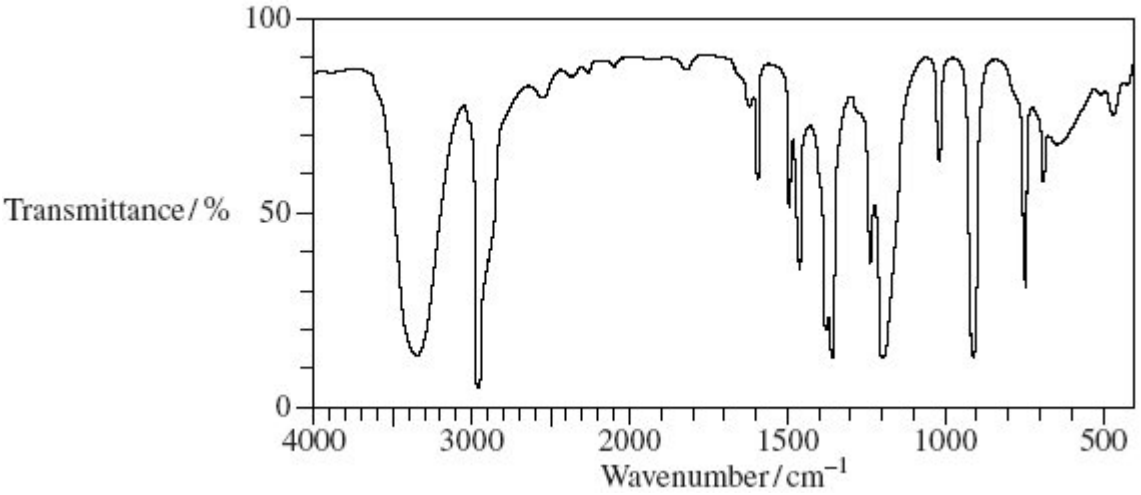
(3)

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



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

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

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(3)

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

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

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

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

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(4)

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

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

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

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

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(5)
(Total 15 marks)

9 Carbon monoxide and hydrogen are used in the manufacture of methanol. An equilibrium is established according to the following equation.

$$CO(g) + 2H_2(g) \rightleftharpoons^{\text{Cu catalyst}} CH_3OH(g) \qquad \Delta H = -9l \text{ kJ mol}^{-1}$$

(a) Give **two** features of a reaction at equilibrium.

Feature 1 .....

.....

Feature 2 .....

.....

(2)

(b) Explain why an increase in temperature causes a decrease in the equilibrium yield of methanol.

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.....

(2)

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

.....

.....

(1)

(ii) State the effect, if any, of the copper catalyst on the position of this equilibrium at a fixed temperature.

.....

(1)

(d) Two methods are used to produce carbon monoxide from natural gas. Equations for these two methods are shown below.

Method 1 $CH_4 + H_2O \rightarrow 2CO + 3H_2$

Method 2 $CH_4 + CO_2 \rightarrow 2CO + 2H_2$

The manufacture of methanol from these sources of carbon monoxide has been described as carbon neutral.

(i) .....

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(1)

(ii) Show how combining the equations from these two methods can lead to the 1:2 mol ratio of carbon monoxide to hydrogen required for this synthesis of methanol.

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(1)

(Total 8 marks)

10 Many naturally-occurring organic compounds can be converted into other useful products.

(a) Glucose, $C_6H_{12}O_6$, can be fermented to make ethanol, which can then be dehydrated to make the unsaturated compound, ethane.

(i) Write an equation for the fermentation of glucose to form ethanol.

.....

(ii) Identify a catalyst for the dehydration of ethanol to form ethene. Write an equation for this reaction.

Catalyst .....

Equation .....

(3)

(b) Vegetable oils, which contain unsaturated compounds, are used to make margarine. Identify a catalyst and a reagent for converting a vegetable oil into margarine.

Catalyst .....

Reagent .....

(2)

(c) Oleic acid can be obtained from vegetable oils. Oleic acid is an example of an unsaturated compound.

$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

oleic acid

(i) Deduce the molecular formula and the empirical formula of oleic acid.

Molecular formula .....

Empirical formula .....

(ii) State what is meant by the term *unsaturated*.

.....

(iii) Identify a reagent for a simple chemical test to show that oleic acid is unsaturated. State what you would observe when oleic acid reacts with this reagent.

Reagent ….....

Observation with oleic acid ……..

.....

(5)
(Total 10 marks)

11 Glucose can be used as a source of ethanol. Ethanol can be burned as a fuel or can be converted into ethene.

$C_6H_{12}O_6 \rightarrow CH_3CH_2OH \rightarrow H_2C=CH_2$

glucose ethanol ethene

(a) Name the types of reaction illustrated by the two reactions above.

Glucose to ethanol .....

Ethanol to ethene .....

(2)

(b) (i) State what must be added to an aqueous solution of glucose so that ethanol is formed.

.....

(ii) Identify a suitable catalyst for the conversion of ethanol into ethene.

.....

(2)

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

.....

(ii) Give **one** advantage of using ethanol as a fuel compared with using a petroleum fraction.

.....

(2)

(d) Most of the ethene used by industry is produced when ethane is heated to 900°C in the absence of air. Write an equation for this reaction.

.....

(1)

(e) Name the type of polymerisation which occurs when ethene is converted into poly(ethene).

.....

(1)
(Total 8 marks)

12 (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.

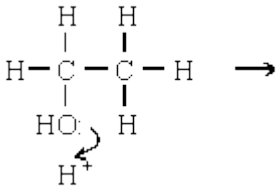
(2)

(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)

13 (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 $C_4H_{10}O$

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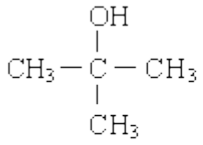
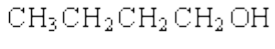
(3)

(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)

14 Ethanol is produced commercially by fermentation of aqueous glucose, $C_6H_{12}O_6$
State **two** conditions, other than temperature, which are necessary for fermentation.
Explain why neither a low temperature nor a high temperature is suitable for this reaction.
Give **two** advantages of this method of production over that by the direct hydration of ethene.
Write an equation for the production of ethanol by fermentation and an equation for the complete combustion of ethanol.

(Total 8 marks)

15 Which one of the following is **not** a suitable method for the preparation of ethanol?

A oxidation of ethane

B hydration of ethene

C reduction of ethanal

D hydrolysis of bromoethane

(Total 1 mark)

Mark schemes

1

(a) Percentage of oxygen by mass = 100 – 40.9 – 4.5 = 54.6

1

	C	H	O
%			
Divide by A_r	$\frac{40.9}{12}$	$\frac{4.5}{1}$	$\frac{54.6}{16}$
	= 3.41	= 4.5	= 3.41

1

Divide by smallest =	$\frac{3.41}{3.41} = 1$	$\frac{4.5}{3.41} = 1.32$	$\frac{3.41}{3.41} = 1$
Nearest whole number ratio =	1 × 3	1.32 × 3	1 × 3
	= 3 : 3.96 : 3		
Nearest integer ratio =	3 :	4 :	3

1

Empirical formula $C_3H_4O_3$

Empirical formula mass = 88 = molecular formula mass

Therefore, molecular formula is same as the empirical formula - $C_3H_4O_3$

1

(b) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

1

(c) Advantage – ethanol is produced at a faster rate

1

Disadvantage – more energy is used / required in the reaction

1

(d) Air gets in / oxidation occurs

1

(e) Alcohol OH absorption in different place (3230–3550 cm^{-1}) from acid OH absorption (2500–3000 cm^{-1})

1

The C=O in acids has an absorption at 1680–1750 cm^{-1}

1

[10]

2 (a)

M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH (**2**C_2H_5OH) + **2**CO_2

*Penalise C_2H_6O for ethanol in **M1**.*

M2 and **M3**

*Mark **M2** and **M3** independently.*

Any **two** conditions **in any order** for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

  A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.

  Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.

M4 (fractional) distillation or GLC

Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).

M5 Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO_2 emission to the atmosphere

OR

There is no change in the total amount / level of carbon dioxide / CO_2 present in the atmosphere

*For **M5** – must be about CO_2 and the atmosphere.*

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

5

(b) **M1** q = m c ΔT (this mark for correct mathematical formula)

*Full marks for **M1**, **M2** and **M3** for the correct answer.*

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

M2 = (75 × 4.18 × 5.5)

1724 (J) **OR** 1.724 (kJ) **OR** 1.72 (kJ) **OR** 1.7 (kJ)

(also scores **M1**)

*Ignore incorrect units in **M2**.*

M3 Using 0.0024 mol

therefore ΔH = **− 718** (kJ mol^{-1})

(Accept a range from −708 to −719 but do not penalise more than 3 significant figures)

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718 gains two marks**.*

*If units are quoted in **M3** they must be correct.*

*If ΔT = 278.5, CE for the calculation and penalise **M2** and **M3**.*

M4 and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the (2.40 × 10^{-3} mol) ethanol is burned / reaction is incomplete

*If c = 4.81 (leads to 1984) penalise **M2** ONLY and mark on for **M3** = − 827*

5

(c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in breaking / dissociating (a) covalent bond(s)

Ignore bond making.

M2 averaged for that type of bond over different / a range of molecules / compounds

Ignore reference to moles.

2

(ii) **M1**

∑ B(**reactants**) − ∑ B(**products**) = ΔH

OR

Sum of bonds broken − Sum of bonds formed = ΔH

OR

B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O)
– 4B(C=O) – 6B(O–H) = ΔH = −1279

Correct answer gains full marks.

*Credit **1 mark for − 496** (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 a correct method; this requires either a correct cycle with $2CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

M2 (also scores **M1**)
348+360+463+5(412)+ 3B(O=O)

(**3231**) (or **2768** if O–H cancelled)
− 4(805) − 6(463) = ΔH = − 1279

(**5998**) (or **5535** if O–H cancelled)

3B(O=O) = **1488** (kJ mol^{-1})

*Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998 (or 5535) OR** bonds broken includes the calculated value of **3231 (or 2768)**.*

M3

B(O=O) = **496** (kJ mol^{-1})

Award 1 mark for −496

Students may use a cycle and gain full marks

3

[15]

3 (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***

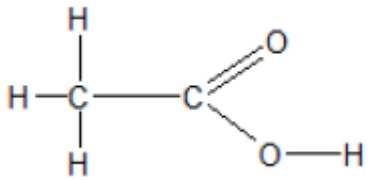
Either order
M2 (enzymes from) yeast or zymase

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 Acidified potassium or sodium dichromate

*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)
orange to green

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

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

*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 <u>about this process</u> from**

Subject to weather / climate

Ignore "batch"

OR

Depletes <u>food</u> supply OR the land use <u>for</u> (specified) <u>food</u>

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 <u>that requires separation / further processing</u>

1

[13]

4 (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)

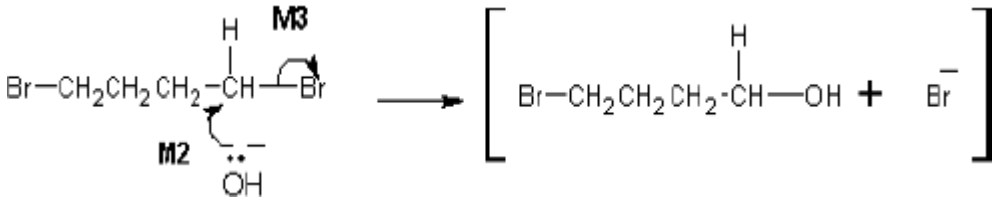
OR

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** <u>fermentation</u>

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

Three conditions <u>in any order</u> 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 <u>acidified potassium or sodium dichromate</u>

*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]

5 (a) **M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2
($2C_2H_5OH$)

Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise C_2H_6O once only

M2 fermentation

M3 CH_3CH_2OH + **3**$O_2 \longrightarrow$ **2**CO_2 + **3**H_2O
(C_2H_5OH)

M4 A specified process e.g. planting / harvesting / transport / extracting sugar / distilling ethanol solution / fertiliser production etc.

M5 The specified process uses / burns (fossil) fuel that releases CO_2

For M5, "releases / increases carbon emissions" is insufficient as an alternative to releases CO_2

5

(b) **M1** sodium or potassium hydroxide / NaOH / KOH

Mark on to M2 from hydroxide ion

M2 depends on correct M1

Ignore OH^- if KOH/ OH^-

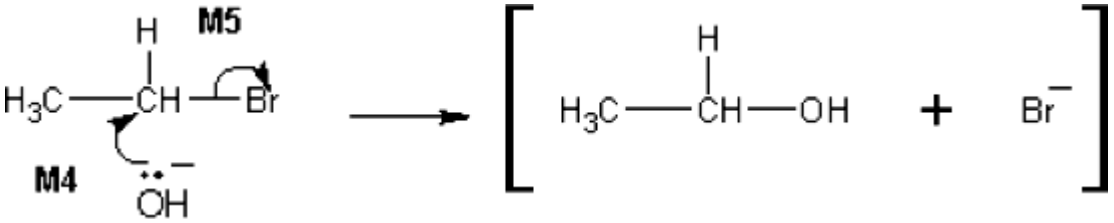
warm / heat / reflux <u>and</u> aqueous or (aq) or water

For M2 ignore "dilute"

For M2 penalise T > 100 °C

M3 <u>nucleophilic substitution</u>

Acidified KOH/NaOH or H_2SO_4 with KOH/NaOH loses M1 and M2



For M3, both words required

NB The arrows here are double-headed

M4 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 M4 if covalent NaOH / KOH is used

Penalise one mark from M4 or M5 if half-headed arrows are used

M5 must show the movement of a pair of electrons from the

C— Br bond to the Br atom. Mark M5 independently provided it is from their <u>original molecule.</u>

Penalise M5 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 M4 and M5, award full marks for an S_N1 mechanism

For M4 and M5, maximum 1 of 2 marks if wrong reactant is used.

Penalise M5 if an extra arrow is drawn from the Br of the C–Br bond to, for example, K^+span>

Do not penalise the use of "sticks"

M6 One statement from

- The yield is (very) low / not a high yield OR elimination occurs / ethene formed
- The rate of reaction slow
- <u>Bromoethane</u> has to be manufactured / made first
- <u>Bromoethane</u> is expensive

For M6 ignore references to other costs and expenses

6

(c) **M1** <u>concentrated</u> phosphoric acid / <u>conc</u>. H_3PO_4 ***OR*** <u>concentrated</u> sulfuric acid / conc. H_2SO_4

Answers in any order

Ignore reference to support medium in M1

M2 hydration or (electrophilic) addition

For M3 and M4 <u>any two</u> from

Do not apply the list principle to these three chosen criteria in M3 and M4

- <u>Excess</u> ethene

  OR <u>Excess</u> steam / water / H_2O

  OR remove the ethanol as it forms

  OR recycle the ethene

- <u>Specified</u> Pressure

  50 atm ≤ P ≤ 100 atm

  OR 5000 kPa ≤ P ≤ 10000 kPa

  OR 5 MPa ≤ P ≤ 10 MPa

- <u>High</u>Temperature unless they give a value that is not in the ranges given here;

  OR 300 °C ≤ T ≤ 600 °C

  OR 570 K ≤ T ≤ 870 K

  Accept a reference to "low temperature" if they specify a correct temperature range or a correct temperature in the range

4

[15]

6 (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

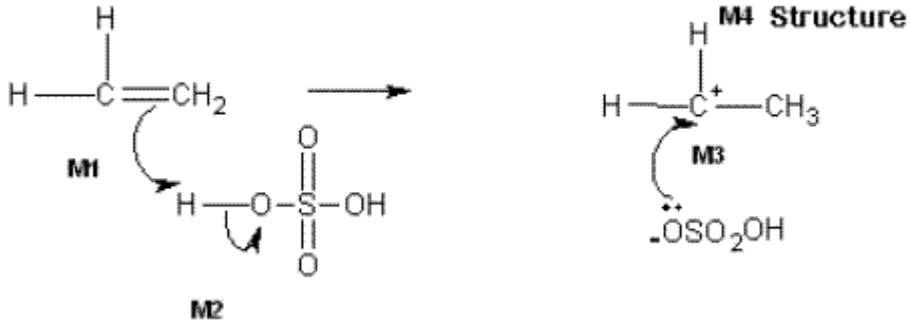
to speed up the reaction/increase the rate (of reaction)

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

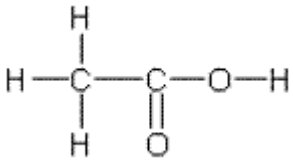
Do not penalise the use of "sticks"

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]

7 (a) **Three conditions in any order for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$

OR

$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

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

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up (to form glucose or in photosynthesis)

1

M3 6 (mol/molecules) CO_2/carbon dioxide given out due to **2** (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

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

(Sum of) bonds broken – (Sum of) bonds made/formed = Δ*H*

OR

(Σ) $B_{reactants}$ – (Σ) $B_{products}$ = Δ*H*

(where B = bond enthalpy/bond energy)

For M1 there must be a correct mathematical expression using ΔH or "enthalpy change"

M2 Reactants = (+) 4719

OR

Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.

Ignore units.

M2 is for either value underlined

M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are not specific for this reaction *OR* they are average values from many different compounds/molecules

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol

therefore ΔH = **– 669** kJ mol^{-1} OR – **670** $kJmol^{-1}$

OR **–668.8** kJ mol^{-1}

Award M1, M2 and M3 for correct answer to the calculation

Penalise M3 ONLY if correct answer but sign is incorrect

In M1, do not penalise incorrect cases in the formula

If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3

If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770

Ignore incorrect units in M2

M4 Incomplete combustion

Do not forget to award this mark. Mark independently

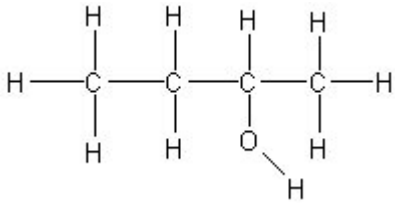
4

[15]

8

(a) **M1**

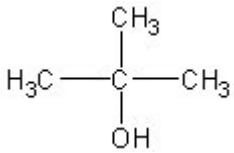
Displayed formula for butan-2-ol



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 <u>primary or 1°</u> (alcohol)

M2 <u>Displayed formula</u> (ONLY) for butanal $CH_3CH_2CH_2CHO$

M3 <u>Displayed formula</u> (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 <u>both</u> correctly given but not displayed, credit one mark out of two.

M4 Oxidation (oxidised) OR Redox

M5 <u>orange to green</u>

Both colours required for M5
Ignore states

5

[15]

9

(a) **M1** <u>Concentrations</u> of reactants and products remain constant

For M1
NOT "equal concentrations"
NOT "amount"

1

M2 Forward <u>rate</u> = Reverse / backward <u>rate</u>

Credit the use of [ ] for concentration
Ignore dynamic, ignore closed system

1

(b) **M1** The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction.

1

M2 The equilibrium responds by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
Promotes the endothermic reaction by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
<u>Temperature increase is opposed</u> (by shift to the left)
OR
Change is opposed by <u>absorbing heat</u> / <u>lowering temperature</u>.

1

(c) (i) A substance that speeds up / alters the rate but is unchanged at the end / not used up.

<u>Both ideas needed</u>
Ignore references to activation energy and alternative route.

1

(ii) None OR no change OR no effect OR nothing OR Does not affect it / the position (of equilibrium) OR (The position is) the same or unchanged.

1

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

OR

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

OR

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

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

Ignore carbon monoxide

1

(ii) A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio.

$$2\,(CH_4 + H_2O \rightarrow CO + 3H_2)$$
$$CH_4 + CO_2 \rightarrow 2CO + 2H_2$$
$$3CH_4 + 2H_2O + CO_2 \rightarrow 4CO + 8H_2$$

Ratio = 1 : 2

1

[8]

10 (a) (i) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$;

(penalise C_2H_6O once only in this question)

1

(ii) Concentrated H_2SO_4 OR concentrated H_3PO_4 OR Al_2O_3;

(penalise aqueous or dilute as a contradiction)

1

$C_2H_5OH \rightarrow C_2H_4 + H_2O$ OR $C_2H_5OH \rightarrow H_2C = CH_2 + H_2O$;

(penalise $CH_2{\cdot}CH_2$ and CH_2-CH_2 and CH_2 : CH_2 for ethene)

1

(b) Nickel OR Ni OR platinum OR Pt OR palladium OR Pd;

1

Hydrogen OR H_2;

1

(c) (i) $C_{18}H_{34}O_2$ Only;

1

$C_9H_{17}O$ Only;

(empirical formula is not consequential on molecular formula)

1

(ii) (An unsaturated compound) contains (at least) <u>one double bond</u>

OR

Contains C=C;

(must be a positive statement)

1

(iii) M1: Bromine water

OR

Br_2(aq)

OR

Bromine

OR

Br_2;

(penalise "bromide water", but mark on)

1

M1: decolourised or goes colourless

OR

from brown/red/orange/yellow to colourless;

(Must be "colourless" not "clear" for M2)
(chemical error if no reagent or wrong reagent, loses both marks)
(credit $KMnO_4$ for M1, (purple) to colourless for M2 (if acidified) OR (purple) to brown/brown precipitate (if alkaline or unspecified) (No credit for hydrogen or iodine as reagents)

1

[10]

11 (a) M1 fermentation

1

M2 dehydration or elimination

1

(b) (i) yeast OR zymase OR an enzyme

1

(ii) concentrated sulphuric or phosphoric acid

(penalise aqueous or dilute as a contradiction)

1

(c) (i) primary or 1°

1

(ii) sugar or glucose or ethanol is renewable
OR ethanol does not contain sulphur-containing impurities
OR ethanol produces less pollution or is less smoky or less CO/C

(the objective is a positive statement about ethanol)
(penalise the idea that ethanol is an infinite source or vague statements that ethanol has less impurities) (penalise the idea that ethanol produces no pollution)

1

(d) $C_2H_6 \rightarrow C_2H_4 + H_2$

1

(e) Addition

(ignore self or chain as a preface to "addition ")
(penalise additional)

1

[8]

12 (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

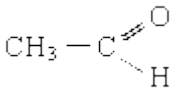
Disadvantage:
slow
low yield
significant land use
has to be distilled
labour intensive

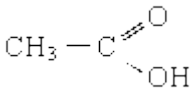
any one
Ignore yeast
NOT (unqualified) batch production
NOT impure product

3

(b) (i)

Structure of aldehyde *Structure of carboxylic acid*

 **(1)**

 **(1)**

NOT CH_3CHO **NOT CH_3COOH**

Penalise incorrect R group once

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

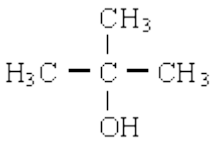
Conditions: acidified or sulphuric acid **(1) Can be with reagent M2**
(heat under reflux) **(1) M3**

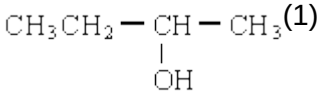
Or correct formula for M1 and M2

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)



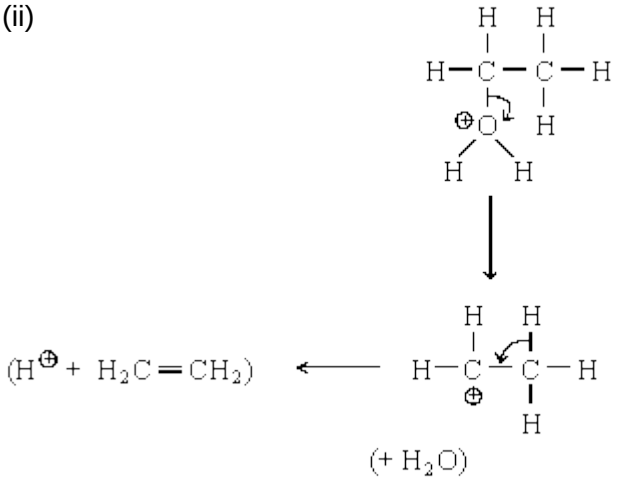
(ii)  (1)

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]

13

(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)**

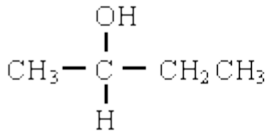
If arithmetic error in any result lose M3

If percentage composition calculation done zero

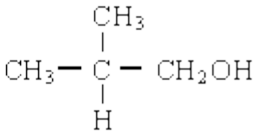
3

(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

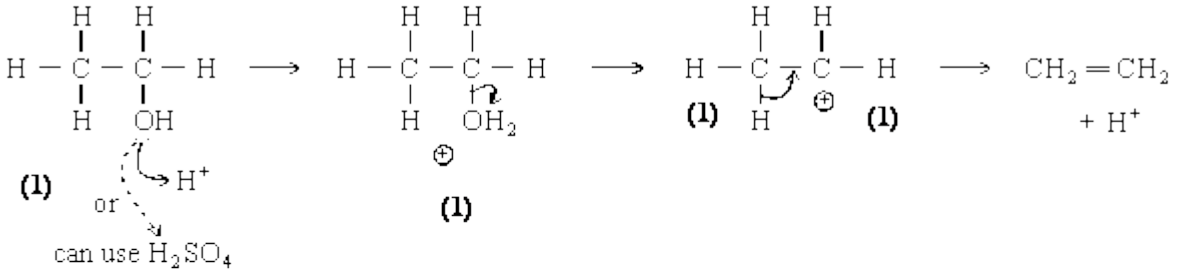
5

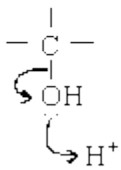
(d) *Advantage*: Fast reaction OR pure product OR continuous process
OR cheap on manpower OR high yield, 100% alcohol **(1)**
Disadvantage: High technology OR ethene from non renewable source
OR expensive equipment not just costly **(1)**

Not answers based on fermentation

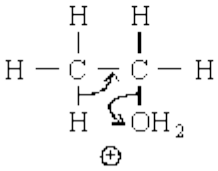
2

(e)





scores M1 only



scores M2 & M4
but not carbocation mark, M3.

4

[18]

14 Condition = two from yeast (*anywhere in question*)
Air excluded **or** sterile / clean **(2)**

Ignore references to pressure / temperature / aqueous / dark / high alcohol conc

Temperature too low inactivates / deactivates enzymes **or** reaction too slow **(1)**
Temperature too high destroys **or denatures** yeast / enzymes **(1)**

Not kills enzymes; not deactivates here

Advantage 1 = sugar / glucose / carbohydrate is renewable resource / source **(1)**
Advantage 2 = production uses low level technology / cheap equipment **(1)**

Ignore references to energy
Do not allow contra-arguments about ethene

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$ balanced **(1)**

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ balanced **(1)**

Allow C_2H_6O but penalise C_2H_5HO once

[8]

15 A

[1]