A-Level Chemistry

Alcohol Production

Question Paper

Time available: 79 minutes
Marks available: 76 marks

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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(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}.

(5)

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

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

(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

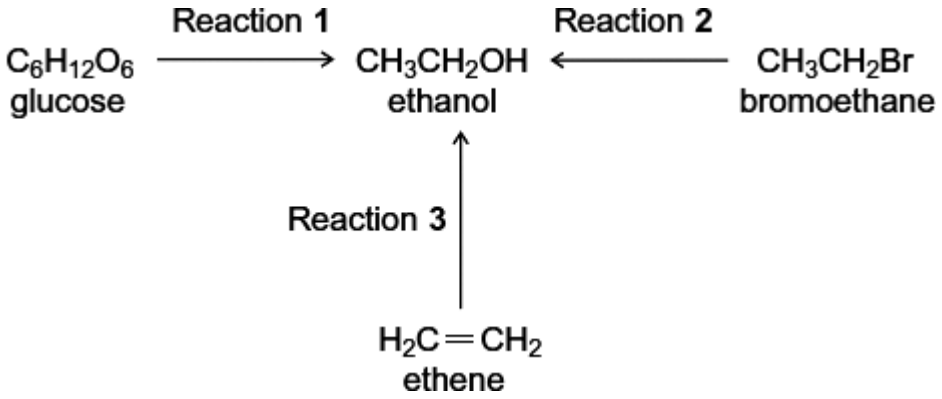
Use the data in the table above and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.

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

(3)

(Total 15 marks)

3. 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.

(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.

(6)

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

$$H_2C{=}CH_2 \xrightarrow{\text{Reaction 3}} CH_3CH_2OH$$

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.

(4)

(Total 15 marks)

4. 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.

(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.

(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.

(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)

5. In Europe, some of the glucose from crops is fermented to produce ethanol.

Use of a carbon-neutral fuel leads to no net emissions of carbon dioxide to the atmosphere.

(a) The ethanol produced by fermentation of glucose may be regarded as a carbon-neutral fuel.

Justify this statement. Include the relevant chemical equations in your answer.

(4)

Coffee beans from South America are exported to Europe in an outer layer called silverskin.

The waste silverskin can be fermented to produce a solution containing propanone, ethanol and butan-1-ol.

(b) Suggest why ethanol produced in Europe using silverskin from South America is less likely to be carbon-neutral than ethanol produced from crops grown in Europe.

(1)

(c) **Table 1** shows the enthalpies of combustion of the three fuels from the fermentation of silverskin.

Table 1

Fuel	**Standard enthalpy of combustion / kJ mol^{-1}**	**Energy released per mole of CO_2 produced / kJ**
ethanol, $C_2H_5OH(l)$	–1371	
butan-1-ol, $C_4H_9OH(l)$	–2673	
propanone, $C_3H_6O(l)$	–1786	

One way to measure a fuel's environmental impact is to measure the amount of energy released per mole of CO_2 produced.

Complete **Table 1**.

Use your answers to deduce the fuel with the lowest environmental impact by this measure.

_____

_____

(2)

(d) A student investigated the combustion of propanone (C_3H_6O) using calorimetry.

A copper calorimeter containing water was heated by the complete combustion of some propanone. The student did not record the final temperature of the water.

Table 2 shows the student's results.

Table 2

Mass of propanone burned / g	1.18
Mass of water / g	260
Initial temperature of water / °C	22.3
Final temperature of water / °C	Not recorded

Use the results in **Table 2** to calculate a value for final temperature of the water in the experiment.

Assume that no heat was lost in the experiment and that the heat capacity of the calorimeter is negligible.

For propanone, enthalpy of combustion = –1786 kJ mol^{-1}

For water, specific heat capacity = 4.18 J g^{-1} K^{-1}

Final temperature of water _____ °C

(4)

(e) Butan-1-ol can be added to petrol for cars.

An equation for the complete combustion of gaseous butan-1-ol is shown.

$$C_4H_9OH(g) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g) \quad \Delta H = -2504\ kJ\ mol^{-1}$$

Table 3 shows some mean bond enthalpy data.

Table 3

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

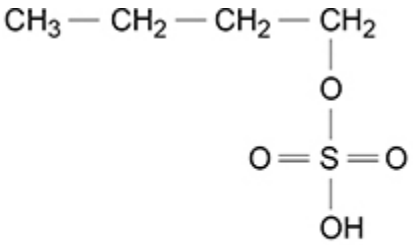
Use these data to calculate a value for the mean C–C bond enthalpy in gaseous butan-1-ol.

C–C bond enthalpy _____ kJ mol^{-1}

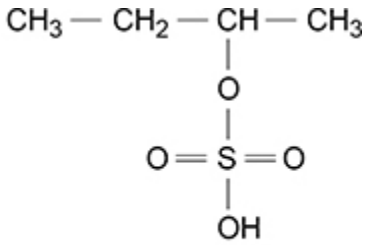
(3)

Butan-1-ol can be manufactured by reacting steam with but-1-ene in the presence of the catalyst, concentrated sulfuric acid.

In the first part of this process, but-1-ene reacts with concentrated sulfuric acid to form compounds **W** and **X**.



Compound **W**



Compound **X**

Butan-1-ol is then made from compound **W**.

(f) Name and outline a mechanism to show the conversion of but-1-ene into compound **W** in the first part of this process.

Name of mechanism _____

Outline of mechanism

(5)

(g) There is a very low yield of butan-1-ol from but-1-ene in this manufacturing process.

Explain why.

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(2)

(Total 21 marks)