Q1. 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 .....

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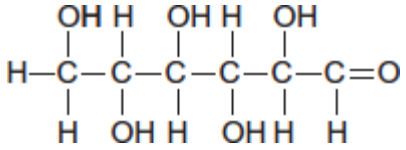
Difference 2 .....

.....

(2)
(Total 10 marks)

Q2. 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.

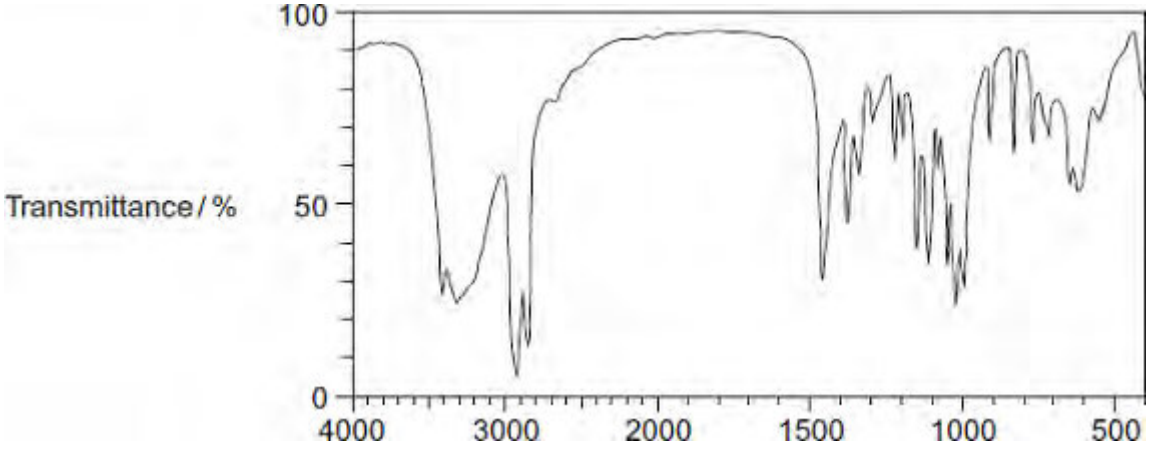


(i) Deduce the empirical formula of glucose.

.....

(1)

(ii) Consider the infrared spectrum of solid glucose.



Wavenumber / cm^{-1}

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.

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(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)

Q3. 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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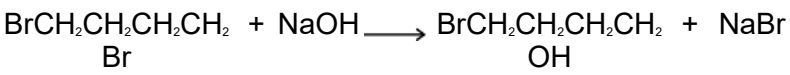
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(2)

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



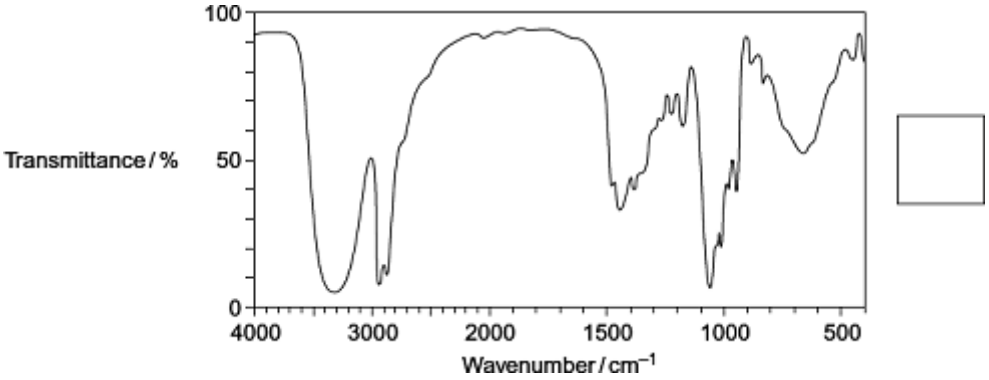
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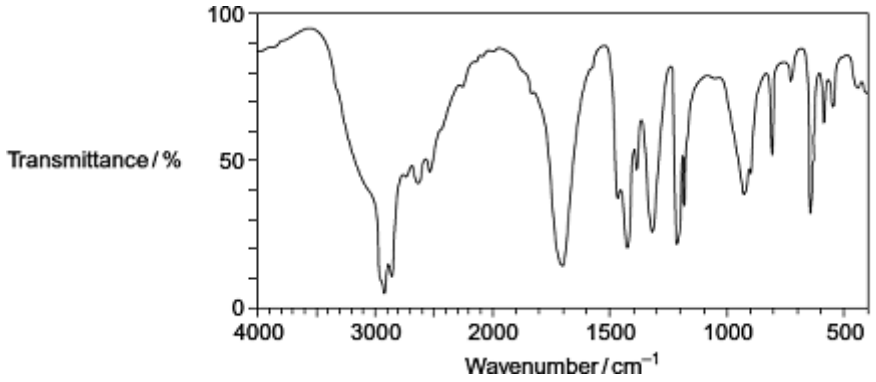
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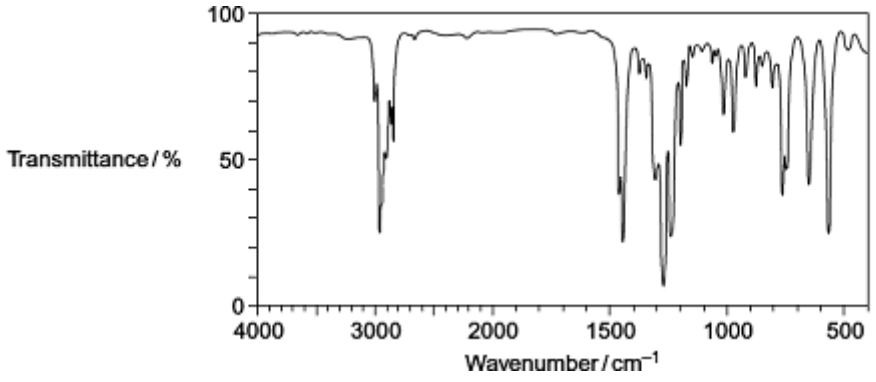
(ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutaneCompound **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)

Q4. 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)

Q1. Which statement about ethanal is correct?

A It reacts with Tollens' reagent to form silver. ⬭

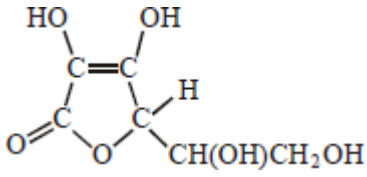
B It has a higher boiling point than ethanol. ⬭

C Its empirical and molecular formulas are different. ⬭

D It belongs to a homologous series with general formula $C_nH_{2n+1}O$ ⬭

(Total 1 mark)

Q2. 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)

Q3. Which one of the following reactions will produce an organic compound that has optical isomers?

A dehydration of butan-2-ol by heating with concentrated sulphuric acid

B reduction of pentan-3-one by warming with $NaBH_4$

C addition of Br_2 to 3-bromopropene

D reduction of 2,3-dimethylpent-2-ene with H_2 in the presence of a nickel catalyst

(Total 1 mark)

Q4. Which one of the following is **not** a correct general formula for the non-cyclic compounds listed?

A alcohols $C_nH_{2n+2}O$

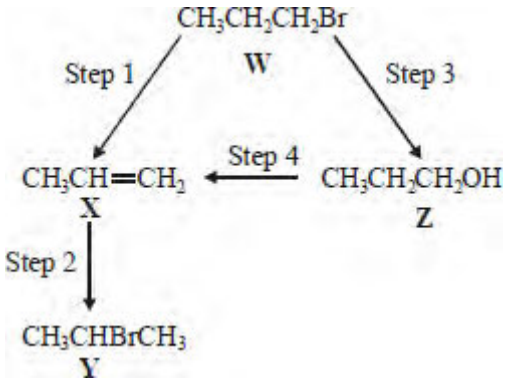
B aldehydes $C_nH_{2n+1}O$

C esters $C_nH_{2n}O_2$

C primary amines $C_nH_{2n+3}N$

(Total 1 mark)

Q5. 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.

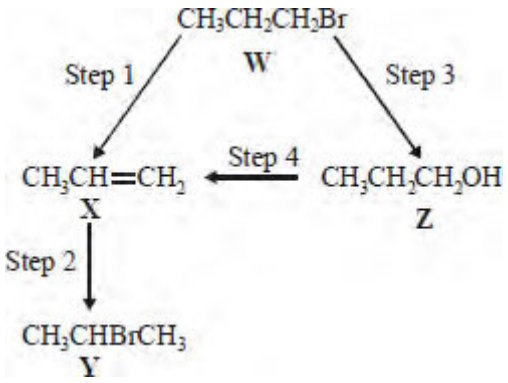
B Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.

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

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

(Total 1 mark)

Q6. For this question refer to the reaction scheme below.



Which one of the following reagents would **not** bring about the reaction indicated?

A Step 1 : alcoholic KOH

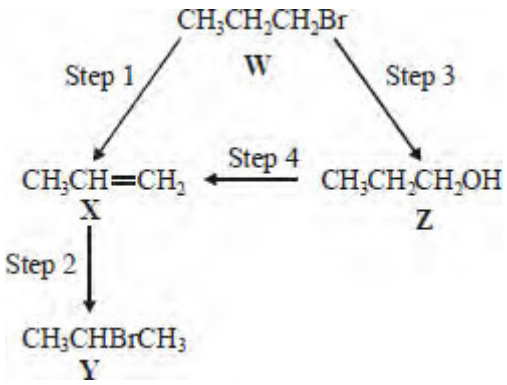
B Step 2 : aqueous Br_2

C Step 3 : aqueous NaOH

C Step 4 : concentrated H_2SO_4

(Total 1 mark)

Q7. For this question refer to the reaction scheme below.



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

A **W** and **Y** are structural isomers.

B **Z** is a primary alcohol.

C **Y** gives two peaks in its proton n.m.r. spectrum.

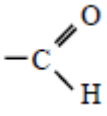
C **X** has geometrical isomers.

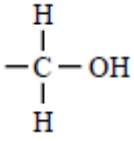
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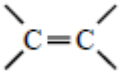
Q8. Certain chemical tests were performed on the pain-relief drug ibuprofen. The results of these tests are given in the table below.

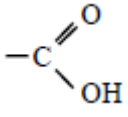
Test	**Result**
Aqueous sodium carbonate	Effervescence
Bromine water	Remained orange
Acidified potassium dichromate(VI) and heat	Remained orange
Fehling's solution and heat	Remained blue

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

A 

B 

C 

D 

(Total 1 mark)

Q9. Which one of the following mechanisms is **not** involved in the reaction sequence below?

$CH_3CH_3 \rightarrow CH_3CH_2Cl \rightarrow CH_3CH_2OH \rightarrow CH_2{=}CH_2 \rightarrow CH_3CH_2Br$

A electrophilic addition

B electrophilic substitution

C nucleophilic substitution

D free-radical substitution

(Total 1 mark)

Q10. Which one of the following alcohols forms a mixture of alkenes when dehydrated?

A propan-1-ol

B propan-2-ol

C pentan-1-ol

D pentan-2-ol

(Total 1 mark)

Q11. Which one of the following isomers is not oxidised under mild reaction conditions?

A $(CH_3)_2CHCH(OH)COCH_3$

B $(CH_3)_2C(OH)CH_2COCH_3$

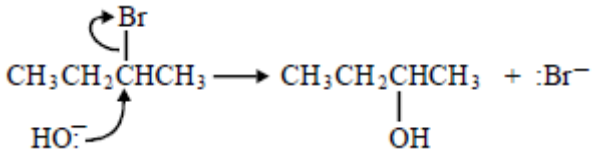
C $(CH_3)_2CHCH(OH)CH_2CHO$

D $(CH_3)_2C(OH)CH_2CH_2CHO$

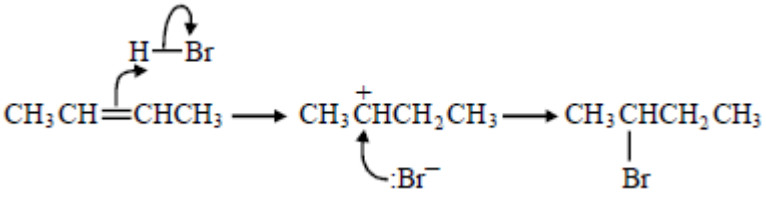
(Total 1 mark)

Q12. In which of the following is a curly arrow used incorrectly?

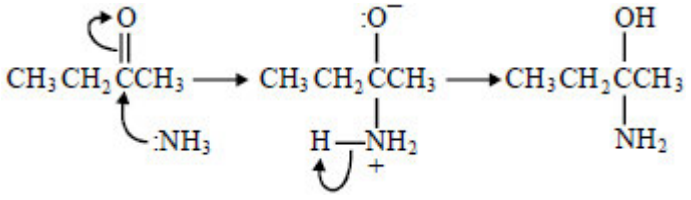
A



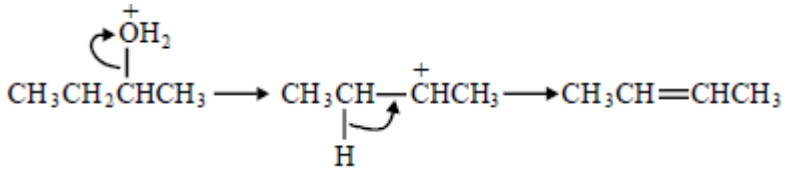
B



C



D



(Total 1 mark)

Q13. CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

Q14. 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)

Q15. 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)

Q16. 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)

Q1. Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH=CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

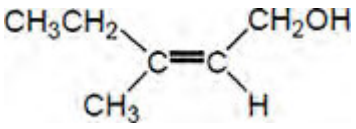
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

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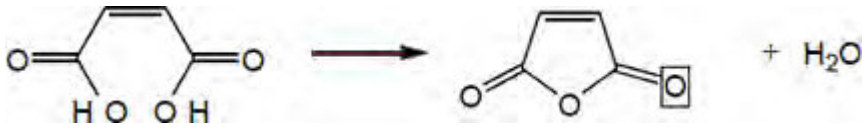
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(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment,10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

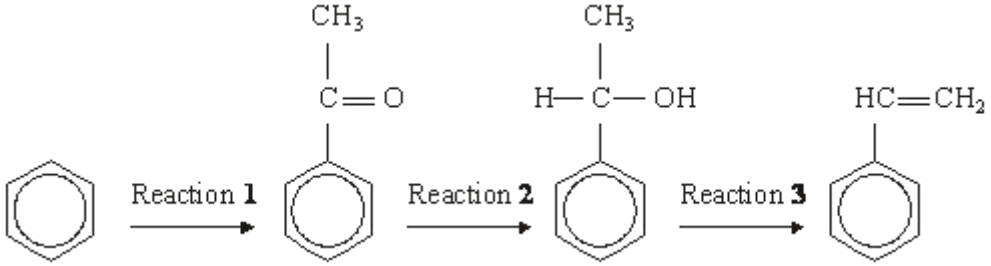
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(2)
(Total 10 marks)

Q2. A possible synthesis of phenylethene *(styrene)* is outlined below.



(a) In Reaction **1**, ethanoyl chloride and aluminium chloride are used to form a reactive species which then reacts with benzene.

Write an equation to show the formation of the reactive species.
Name and outline the mechanism by which this reactive species reacts with benzene.

(6)

(b) $NaBH_4$ is a possible reagent for Reaction **2**.
Name and outline the mechanism for the reaction with $NaBH_4$ in Reaction **2**.
Name the product of Reaction **2**.

(6)

(c) Name the type of reaction involved in Reaction **3** and give a reagent for the reaction.

(2)
(Total 14 marks)

Q3. 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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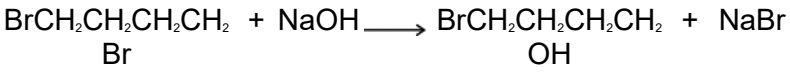
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(2)

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



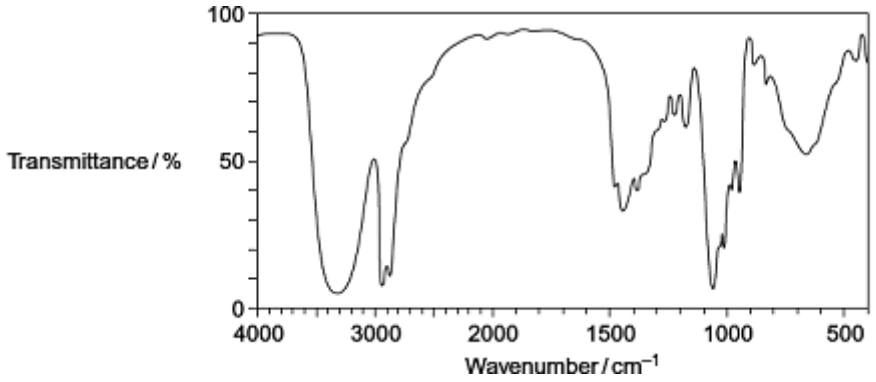
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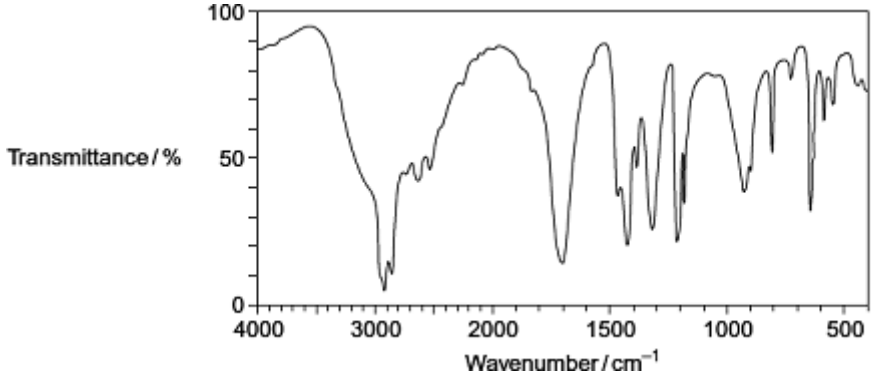
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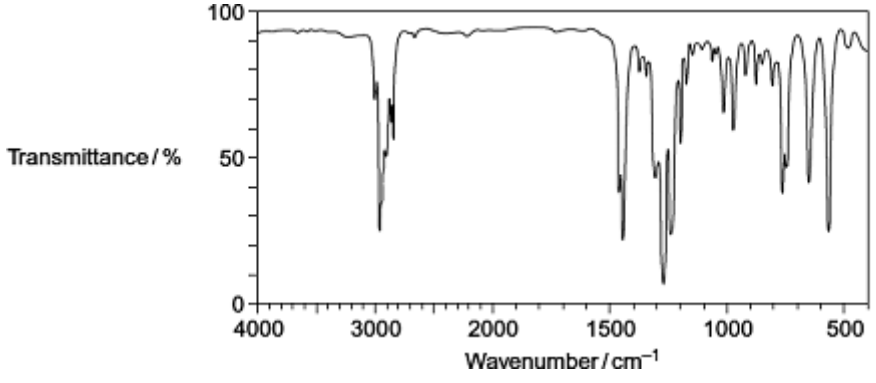
(ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutaneCompound **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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(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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(3)
(Total 15 marks)

Q4. The following instructions are from an experimental procedure for the preparation of cyclohexene from cyclohexanol and concentrated phosphoric acid.
Read these instructions and answer the questions that follow.

1 Place 25 cm^3 of cyclohexanol into a round-bottomed flask with some porous pot to act as anti-bumping granules. Add 10 cm^3 of concentrated phosphoric acid carefully while shaking the flask. Cool the flask under the tap if it gets too hot.
Make sure the reagents are thoroughly mixed.

2 Set up an apparatus for simple distillation using this flask.

3 Warm the flask, gently at first, for about 15 minutes. Then increase the heating so that cyclohexene begins to distil over. Collect the fraction that distils below 95 °C.

(a) State the purpose of the anti-bumping granules.

.....

.....

(1)

(b) Name the part of the distillation apparatus where cyclohexene vapour is changed back into a liquid.
Draw a simple diagram of this part of the apparatus.

Name .....

Diagram

(2)
(Total 3 marks)

Q5. 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)

Q1. 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)

Q2. 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)

Q3. 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

.....

.....

(3)

(b) Propane and propene

Reagent .....

Observation with propane

.....

.....

Observation with propene

.....

.....

(3)

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent .....

Observation with aqueous silver nitrate

.....

.....

Observation with aqueous sodium nitrate

.....

.....

(3)

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent .....

Observation with aqueous magnesium chloride

.....

.....

Observation with aqueous barium chloride

.....

.....

(3)
(Total 12 marks)

Q4.(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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.....

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.....

.....

(3)

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

.....

.....

.....

.....

.....

.....

(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

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

.....

.....

.....

.....

.....

.....

.....

(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 .....

.....

.....

Reason 2 .....

.....

.....

(2)

(Total 15 marks)

Q5. 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)

Q6. Which statement about ethanal is correct?

A It reacts with Tollens' reagent to form silver. ⬭

B It has a higher boiling point than ethanol. ⬭

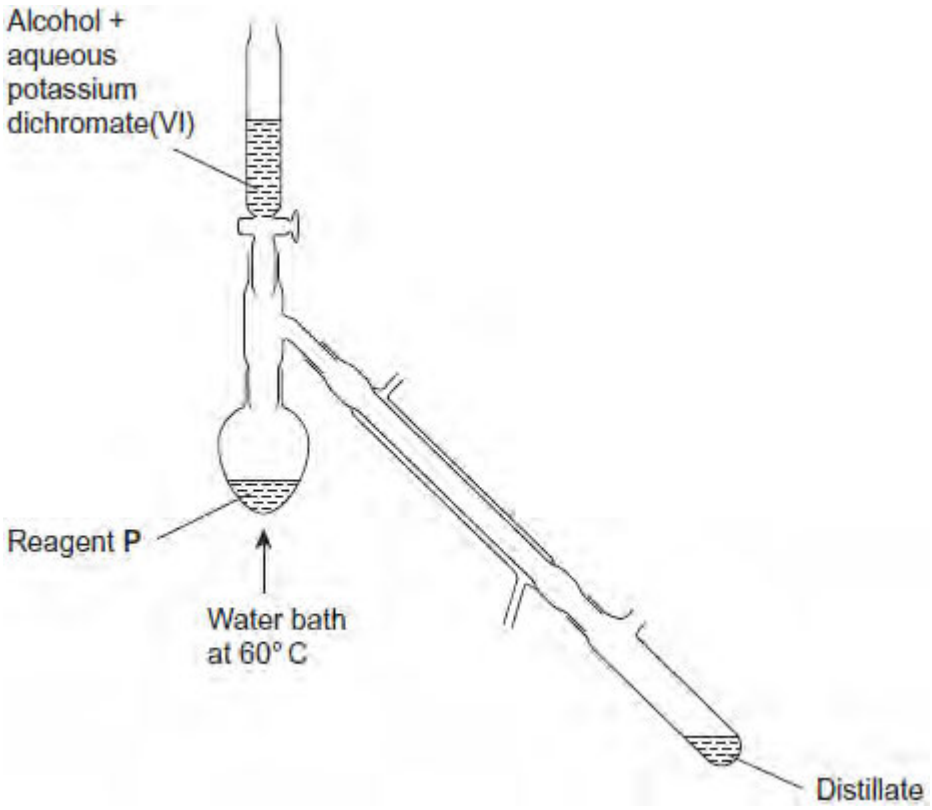
C Its empirical and molecular formulas are different. ⬭

D It belongs to a homologous series with general formula $C_nH_{2n+1}O$ ⬭

(Total 1 mark)

Q7. 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)