**Q1.**          Ethanol is produced commercially by fermentation of aqueous glucose, C6H12O6State **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)**

**Q2.**          (a)     In the manufacture of margarine, unsaturated vegetable oils such as sunflower oil are hardened.

(i)      State the reagent and conditions used in this process.

*Reagent* ..............................................................................................

*Conditions* ...........................................................................................

.............................................................................................................

(ii)     Soft and hard margarines are obtained from the same vegetable oil. How does the structure and the melting point of a soft margarine differ from that of a hard one?

*Difference in structure* .........................................................................

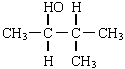
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*Difference in melting point* ...................................................................

.............................................................................................................

**(5)**

(b)     In the presence of reagent **X**, the alcohol shown below undergoes a reaction to form two isomeric alkenes.



(i)      Name this alcohol.

.............................................................................................................

(ii)     Give the name of the type of reaction involved in the formation of the two alkenes.

.............................................................................................................

(iii)     Suggest the identity of reagent **X**.

.............................................................................................................

(iv)    Give the structural formulae of the two isomeric alkenes.

*Alkene 1                                             Alkene 2*

**(5)**

**(Total 10 marks)**

**Q3.**          (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 C4H10O

......................................................................................................................

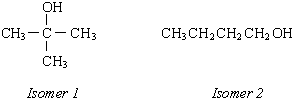
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**(3)**

(b)     The structural formulae of two of the four possible alcohols of molecular formula C4H10O are shown below.



(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 C4H10O

*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)**

**Q4.**          (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.

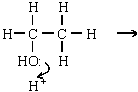
**(2)**

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

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

.............................................................................................................

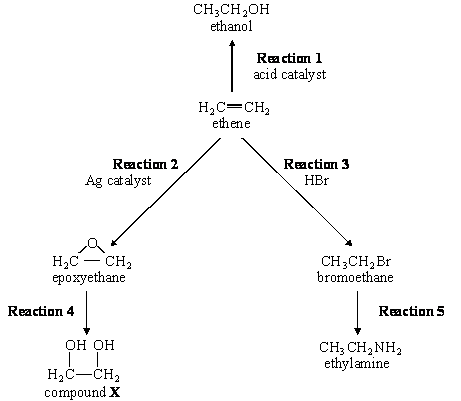
(ii)     Complete the mechanism for this dehydration reaction.



**(5)**

**(Total 15 marks)**

**Q5.**          Ethene can be converted into a variety of useful products as illustrated below.



(a)     Name and give a use for compound **X**.

**(2)**

(b)     Give a reagent for each of **Reactions 1**, **2**, **4** and **5**.

**(4)**

(c)     Outline a mechanism for **Reaction 3**.

**(4)**

(d)     Ethanol can be manufactured from ethene as shown in **Reaction 1** or by the fermentation of sugars. Outline the essential conditions and give an equation for the fermentation reaction. Compare the relative rates and the purity of the product obtained in each case by these two manufacturing processes.

**(5)**

**(Total 15 marks)**

**Q6.**          (a)     One of the isomers in part (a) is resistant to oxidation by acidified potassium dichromate(VI).

(i)      Identify this isomer.

.............................................................................................................

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

*Dehydrating agent*................................................................................

*Equation* ..............................................................................................

**(3)**

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

*Isomer* .................................................................................................

*Structure of the ketone*

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

*Isomer* .................................................................................................

*Structure of the aldehyde*

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

*Reagent* ..............................................................................................

*Observation with ketone* ......................................................................

.............................................................................................................

*Observation with aldehyde* ..................................................................

.............................................................................................................

**(7)**

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

*Equation* ......................................................................................................

*Name of product* ..........................................................................................

**(2)**

**(Total 12 marks)**

**Q7.**          The three compounds CH3CH2CH2CH2OH, (CH3)3COH and CH3CH2CH2CHO can be distinguished by use of the following three reagents

          1.      potassium dichromate(VI) acidified with dilute sulphuric acid  
2.      Tollens’ reagent  
3.      ethanoic acid, together with a small amount of concentrated sulphuric acid.

(a)     Identify which of these three organic compounds would reduce acidified potassium dichromate(VI). Give the structures of the organic products formed. Write a half-equation for the reduction of dichromate(VI) ions in acidic solution.

**(6)**

(b)     Identify which one of these three organic compounds would reduce Tollens’ reagent. Give the structure of the organic product formed. Write a half-equation for the reduction of Tollens’ reagent.

**(3)**

(c)     Identify which of these three organic compounds would react with ethanoic acid in the presence of concentrated sulphuric acid. In each case, give the structure of the organic product formed.

**(4)**

(d)     State the number of peaks in the proton n.m.r. spectra of CH3CH2CH2CH2OH and of (CH3)3COH. (Analysis of peak splitting is not required.)

**(2)**

**(Total 15 marks)**

**Q8.**          Ethene is an important starting point for the manufacture of plastics and pharmaceutical chemicals. Most of the ethene used by industry is produced by the thermal cracking of ethane obtained from North Sea gas (**Reaction 1**). It is also possible to make ethene either from chloroethane (**Reaction 2**) or from ethanol (**Reaction 3**).



(a)     Give essential conditions and reagents for each of **Reactions 2** and **3**.

**(4)**

(b)     Name and outline a mechanism for **Reaction 2**. Suggest a reason why chloroethane is **not** chosen by industry as a starting material to make ethene commercially.

**(5)**

(c)     Name and outline a mechanism for **Reaction 3**. Suggest why this route to ethene may become used more commonly in the future as supplies of North Sea gas begin to run out.

**(6)**

**(Total 15 marks)**

**Q9.**          (a)     (i)      Give a suitable reagent and state the necessary conditions for the conversion of propan-2-ol into propanone. Name the type of reaction.

*Reagent* ..............................................................................................

*Conditions* ...........................................................................................

*Type of reaction* ...................................................................................

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

*Reagent* ...............................................................................................

*Equation*

.............................................................................................................

**(5)**

(b)     Propanal is an isomer of propanone.

(i)      Draw the structure of propanal.

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

*Test reagent* .........................................................................................

*Observation with propanone* ................................................................

*Observation with propanone* ................................................................

**(4)**

**(Total 9 marks)**

**Q10.**          (a)     Ethanol, C2H5OH, can be made from glucose, C6H12O6

(i)      Write an equation to represent this reaction.

.............................................................................................................

(ii)     Give the name of this process for making ethanol.

.............................................................................................................

**(2)**

(b)     Ethanol can be used as a fuel in the internal combustion engine of a motor car.

(i)      Write an equation for the complete combustion of ethanol.

.............................................................................................................

(ii)     Identify a pollutant produced when ethanol is burned in a limited supply of air.

.............................................................................................................

(iii)     Nitrogen monoxide, NO, is a pollutant gas produced by motor cars. Write an equation to represent a reaction occurring in the catalytic converter which decreases the amount of this pollutant.

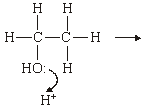
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**(3)**

(c)     Ethene can be formed by the dehydration of ethanol using concentrated sulphuric acid.  
Name and complete a mechanism for this reaction.

*Name of mechanism …..*..............................................................................

*Mechanism*

**

**(5)**

(d)     Epoxyethane is manufactured from ethene. Give a suitable catalyst for this manufacturing process. Write an equation for the reaction, clearly showing the structure of epoxyethane.

*Catalyst* ........................................................................................................

*Equation*

......................................................................................................................

**(3)**

**(Total 13 marks)**

**Q11.**          Glucose can be used as a source of ethanol. Ethanol can be burned as a fuel or can be converted into ethene.

C6H12O6   →   CH3CH2OH   →   H2C=CH2

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)**

**Q12.**          Consider the following reaction schemes involving two alcohols, **A** and **B**, which are position isomers of each other.

CH3CH2CH2CH2OH  →  CH3CH2CH2CHO  →  CH3CH2CH2COOH  
**A**butanal                    butanoic acid

CH3CH2CH(OH)CH3  →  CH3CH2COCH3**B                                     C**

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

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(2)**

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

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

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

**(2)**

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

(i)      State the type of reaction.

.............................................................................................................

(ii)     Identify a suitable combination of reagents.

.............................................................................................................

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

.............................................................................................................

.............................................................................................................

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

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

**(6)**

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

.............................................................................................................

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

**(2)**

**(Total 12 marks)**

**Q13.**          Some alcohols can be oxidised to form aldehydes, which can then be oxidised further to form carboxylic acids.  
Some alcohols can be oxidised to form ketones, which resist further oxidation.  
Other alcohols are resistant to oxidation.

(a)     Draw the structures of the **two** straight-chain isomeric alcohols with molecular formula, C4H10O

**(2)**

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

**(6)**

(c)     Draw the structure and give the name of the alcohol with molecular formula C4H10O which is resistant to oxidation by acidified potassium dichromate(VI).

**(2)**

**(Total 10 marks)**

**Q14.**          Many naturally-occurring organic compounds can be converted into other useful products.

(a)     Glucose, C6H12O6, 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.

CH3(CH2)7CH=CH(CH2)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)**

**Q15.**          Glucose, C6H12O6, can be converted into ethanol. Ethanol can be used as a fuel or can be converted into ethene by acid-catalysed dehydration. Most of the ethene used by industry is formed by the thermal cracking of alkanes.

(a)     State **four** essential conditions for the conversion of glucose into ethanol. Name the process and give an equation for the reaction which takes place. Write an equation for the complete combustion of ethanol.

**(7)**

(b)     Explain what is meant by the term *dehydration*. Identify a catalyst which could be used in the acid-catalysed dehydration of ethanol. Write an equation for the reaction which takes place.

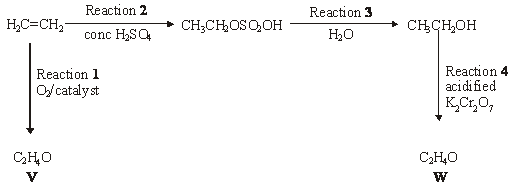
**(3)**

(c)     State what is meant by the term *cracking*. Describe what happens during the thermal cracking of alkanes and name the type of reactive intermediate. Give an essential condition for this process. Write an equation for the thermal cracking of butane to give ethene as one of the products.

**(5)**

**(Total 15 marks)**

**Q16.**         Consider the following reaction scheme, which leads to the formation of two compounds **V**and **W**.



(a)     Give a suitable catalyst for Reaction **1** and name compound **V**.

*Catalyst .*......................................................................................................

*Name of compound* ***V*** ..................................................................................

**(2)**

(b)     Name and outline a mechanism for Reaction **2**.

*Name of mechanism* ....................................................................................

*Mechanism*

**(5)**

(c)     In Reaction **4**, compound **W** is distilled from the reaction mixture.

(i)      Name compound **W** and draw its structure.

*Name* ..................................................................................................

*Structure*

(ii)     Name the type of reaction shown by Reaction **4**.

.............................................................................................................

**(3)**

**(Total 10 marks)**

**Q17.**         There are **seven** isomeric carbonyl compounds with the molecular formula C5H10O.  
The structures and names of some of these isomers are given below.

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

(a)     (i)      Complete the table.

(ii)     **Two** other isomeric carbonyl compounds with the molecular formula C5H10O are not shown in the table. One is an aldehyde and one is a ketone. Draw the structure of each.

*isomeric aldehyde*                           *isomeric ketone*

**(4)**

(b)     Pentanal, CH3CH2CH2CH2CHO, can be oxidised to a carboxylic acid.

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

.............................................................................................................

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

.............................................................................................................

**(2)**

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

(i)      Identify this alcohol.

.............................................................................................................

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

.............................................................................................................

**(2)**

**(Total 8 marks)**

**Q18.**          (a)     In industry, ethanol is made from ethene in an acid-catalysed reaction. Name the type of reaction. Write an equation and identify a suitable catalyst for this reaction.

*Type of reaction*...........................................................................................

*Equation*.......................................................................................................

*Catalyst* ........................................................................................................

**(3)**

(b)     Ethanol burns completely in a plentiful supply of air, but incomplete combustion occurs if the air supply is limited.

(i)      Identify a **solid** pollutant produced by burning ethanol in a limited supply of air.

.............................................................................................................

(ii)     Write an equation for the incomplete combustion of ethanol to produce the solid pollutant that you have identified in part (b)(i).

.............................................................................................................

**(2)**

**(Total 5 marks)**

**Q19.**         (a)     Alcohols can be classed as primary, secondary or tertiary. Draw possible structures for a primary, a secondary and a tertiary alcohol which have the molecular formula C4H8O.  
Which of the structures you have drawn cannot be oxidised by potassium dichromate in acid solution?

**(4)**

(b)     Explain what is meant by the fingerprint region of an infra-red spectrum. State how it is used to confirm the identity of organic molecules such as the primary, secondary and tertiary alcohols of molecular formula C4H8O.

**(2)**

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

(i)      **A** and **B** have the molecular formula C3H8O. **A** has a broad absorption band at 3300 cm–1 in its infra-red spectrum, but **B** does not.

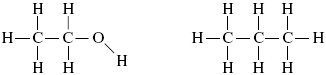
(ii)     **C** and **D** have the molecular formula C5H10. **C** has a weak absorption band at 1650 cm–1 in its infra-red spectrum, but **D** does not.

(iii)     **E** and **F** have the molecular formula C3H6O and both have strong absorption bands at about 1700 cm–1 in their infra-red spectra. **E** reacts with Tollens’ reagent but **F** does not.

**(6)**

**(Total 12 marks)**

**Q20.**          (a)     Two organic compounds with similar relative molecular masses are shown below.



Ethanol                                      Propane

(i)      State the type of bond present between the C and H atoms in both of these molecules. Explain how this type of bond is formed.

Type of bond .......................................................................................

Explanation .........................................................................................

**(2)**

(ii)     State the strongest type of intermolecular force present in each compound.

Liquid ethanol ......................................................................................

Liquid propane ….................................................................................

**(2)**

(b)     Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol interacts with one molecule of water in the solution. Include partial charges and all lone pairs. The ethanol molecule has been drawn for you.



**(3)**

(c)     Ethanol was the fuel used in the first mass-produced car, the Model T Ford.

(i)      Write an equation which shows how ethanol burns completely in air to form carbon dioxide and water as the only products.

.............................................................................................................

**(1)**

(ii)     Suggest **one** environmental problem caused by incomplete combustion of ethanol in a car engine.

.............................................................................................................

.............................................................................................................

**(1)**

(iii)     Suggest **one** economic problem for the car user caused by incomplete combustion of ethanol in the car engine.

.............................................................................................................

.............................................................................................................

**(1)**

(d)     Propane is also used as a fuel, although sometimes it can be contaminated with sulfur-containing impurities. When this propane burns, these impurities form sulfur dioxide.

(i)      State how the sulfur dioxide can be removed from the waste gases produced when this propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient.

How removed .....................................................................................

.............................................................................................................

Reason for less than 100% efficiency .................................................

.............................................................................................................

**(2)**

(ii)     Although propane has a boiling point of –42 °C, it is usually supplied as a liquid for use in camping stoves. Suggest why it is supplied as a liquid.

.............................................................................................................

.............................................................................................................

**(1)**

**(Total 13 marks)**

**Q21.**          There are **four** isomeric alcohols with the molecular formula C4H10O

(a)     Two of these are butan-l-ol (CH3CH2CH2CH2OH) 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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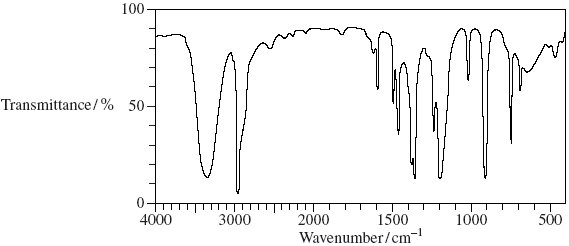
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**(3)**

(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 (C6H12O6) 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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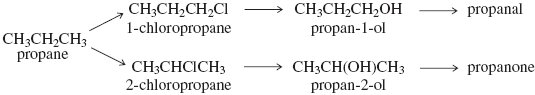
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**(5)**

**(Total 15 marks)**

**Q22.**          Consider the following scheme of reactions.



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

......................................................................................................................

**(1)**

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

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

Test reagent ................................................................................................

Observation with propanal ...........................................................................

Observation with propanone ........................................................................

**(3)**

(c)     State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 cm–1.  
You may find it helpful to refer to **Table 1** on the Data Sheet.

......................................................................................................................

**(1)**

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

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

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**(1)**

(ii)     Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane (CH3CH2CH2Cl).

Initiation step

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First propagation step

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Second propagation step

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A termination step to form a molecule with the empirical formula C3H7

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**(4)**

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

Use the data in the table to show how precise *M*r values can be used to prove that the sample contains both of these gases.

|  |  |
| --- | --- |
| Atom | Precise relative atomic mass |
| 12C | 12.00000 |
| 1H | 1.00794 |
| 16O | 15.99491 |

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**(2)**

**(Total 12 marks)**

**Q23.**          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  
6CO2 + 6H2O → C6H12O6 + 6O2

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

Process **3**                          Complete combustion of ethanol  
CH3CH2OH + 3O2 → 2CO2 + 3H2O

(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)**

**Q24.**          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 + H2SO4 → MgSO4 + 2H2O

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

Reaction **3**                    H2C=CH2 + H2O  CH3CH2OH

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

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**(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.

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**(1)**

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

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**(1)**

(iii)     Deduce the half-equation for the reduction of H2SO4 to SO2 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**                    H2C=CH2 + H2SO4 → CH3CH2OSO2OH

Stage **2**                    CH3CH2OSO2OH + H2O → CH3CH2OH + H2SO4

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

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**(1)**

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

**(4)**

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

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**(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)**

**Q25.**         A student devised an experiment to investigate the enthalpies of combustion of some alcohols. The student chose the following series of primary alcohols.

|  |  |
| --- | --- |
| **Name** | **Formula** |
| Methanol | CH3OH |
| Ethanol | CH3CH2OH |
| Propan-1-ol | CH3CH2CH2OH |
| Butan-1-ol | CH3CH2CH2CH2OH |
| Pentan-1-ol | CH3CH2CH2CH2CH2OH |
| Alcohol **X** | CH3CH2CH2CH2CH2CH2OH |
| Heptan-1-ol | CH3CH2CH2CH2CH2CH2CH2OH |

(a)     (i)      Name alcohol **X**.

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**(1)**

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

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**(1)**

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

**(1)**

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

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**(1)**

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

**(1)**

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

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

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**(3)**

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

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**(3)**

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CH3CH2CH2CH2OH(l) | O2(g) | CO2(g) | H2O(l) |
| Δ*H*f~~ο~~ / kJ mol–1 | –327 | 0 | –394 | –286 |
|  |  |  |  |  |

CH3CH2CH2CH2OH(l) + 6O2(g)  4CO2(g) + 5H2O(l)

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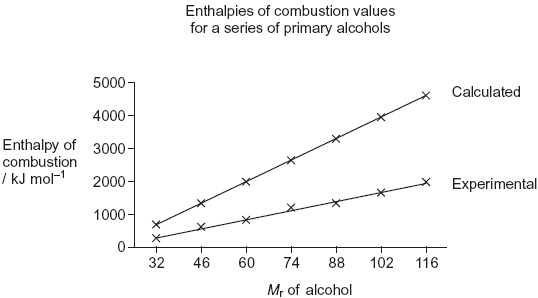
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**(3)**

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



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

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**(2)**

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

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**(2)**

**(Total 18 marks)**

**Q26.**          The following pairs of compounds can be distinguished by observing what happens in test-tube reactions.  
For each pair, give a suitable aqueous reagent that could be added separately to each compound.  
Describe what you would observe in each case.

(a)     NaF(aq) and NaCl(aq)

Reagent ......................................................................................................

Observation with NaF(aq) ...........................................................................

Observation with NaCl(aq) ..........................................................................

**(3)**

(b)     BaCl2(aq) and MgCl2(aq)

Reagent .......................................................................................................

Observation with BaCl2(aq) ..........................................................................

Observation with MgCl2(aq) ..........................................................................

**(3)**

(c)     AgCl(s) and AgI(s)

Reagent .......................................................................................................

Observation with AgCl(s) .............................................................................

Observation with AgI(s) ...............................................................................

**(3)**

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

Reagent …...................................................................................................

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

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

**(3)**

**(Total 12 marks)**

**Q27.**          The table below shows the structures of three isomers with the molecular formula C5H10O

|  |  |
| --- | --- |
| Isomer **1** | (*E*)-pent-3-en-2-ol |
| Isomer **2** | pentanal |
| Isomer **3** |  |

(a)     Complete the table by naming Isomer **3**.

**(1)**

(b)     State the type of structural isomerism shown by these three isomers.

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**(1)**

(c)     The compound (*Z*)-pent-3-en-2-ol is a stereoisomer of (*E*)-pent-3-en-2-ol.

(i)      Draw the structure of (*Z*)-pent-3-en-2-ol.

**(1)**

(ii)     Identify the feature of the double bond in (*E*)-pent-3-en-2-ol and that in  
(*Z*)-pent-3-en-2-ol that causes these two compounds to be stereoisomers.

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**(1)**

(d)     A chemical test can be used to distinguish between separate samples of Isomer **2** and Isomer **3**.  
Identify a suitable reagent for the test.  
State what you would observe with Isomer **2** and with Isomer **3**.

Test reagent ...............................................................................................

Observation with Isomer **2**...........................................................................

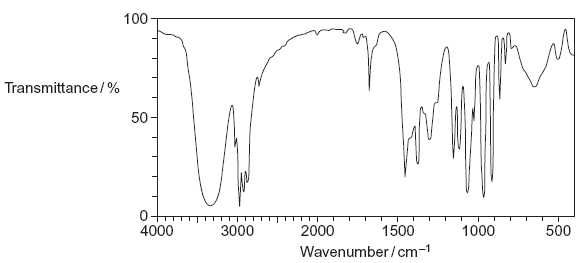
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Observation with Isomer **3**............................................................................

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**(3)**

(e)     The following is the infrared spectrum of one of the isomers **1**, **2** or **3**.



(i)      Deduce which of the isomers (**1**, **2** or **3**) would give this infrared spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

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**(1)**

(ii)     Identify two features of the infrared spectrum that support your deduction.  
In each case, identify the functional group responsible.

Feature 1 and functional group ...........................................................

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Feature 2 and functional group ...........................................................

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**(2)**

**(Total 10 marks)**

**Q28.**Chemists have to design synthetic routes to convert one organic compound into another.

Propanone can be converted into 2-bromopropane by a three-step synthesis.

Step 1: propanone is reduced to compound **L**.  
Step 2: compound **L** is converted into compound **M**.  
Step 3: compound **M** reacts to form 2-bromopropane.

Deduce the structure of compounds **L** and **M**.

For each of the three steps, suggest a reagent that could be used and name the mechanism.

Equations and curly arrow mechanisms are **not** required.

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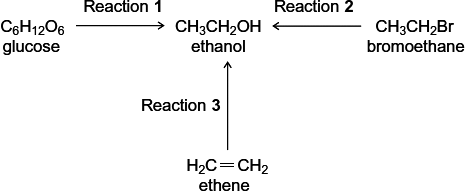
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**(Total 8 marks)**

**Q29.**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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**(5)**

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

|  |  |  |
| --- | --- | --- |
| CH3CH2Br |  | CH3CH2OH |

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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**(6)**

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

|  |  |  |
| --- | --- | --- |
| H2C =CH2 |  | CH3CH2OH |

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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**(4)**

**(Total 15 marks)**

**Q30.**The table shows the structures and names of three compounds with *M*r = 72.0

|  |  |  |
| --- | --- | --- |
| **Compound** | **Formula** | **Name** |
| **1** | CH3CH2CH2CHO | butanal |
| **2** | CH3CH2CH2CH2CH3 | pentane |
| **3** | CH3CH2COCH3 | butanone |

(a)     Explain why *M*r values, measured to five decimal places, cannot distinguish between compounds **1** and **3** but can distinguish between compounds **1** and **2**.

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**(2)**

(b)     A simple chemical test, using either Fehling’s solution or Tollens’ reagent, can be used to distinguish between compound **1** and compound **3**.  
Choose one of these two reagents and state what you would observe with each of compound **1** and compound **3**.

Chosen reagent .............................................................................................

Observation with compound **1**........................................................................

........................................................................................................................

Observation with compound **3**........................................................................

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**(2)**

**(Total 4 marks)**

**Q31.**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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**(2)**

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| BrCH2CH2CH2CH2Br | + | NaOH |  | BrCH2CH2CH2CH2OH | + | NaBr |

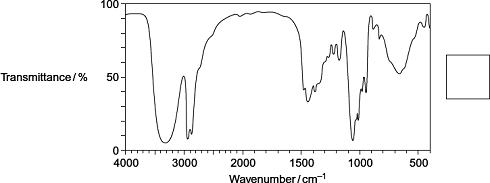
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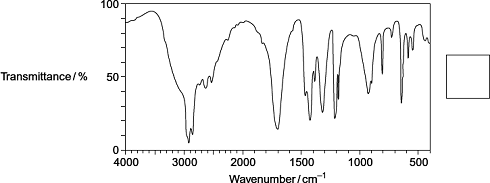
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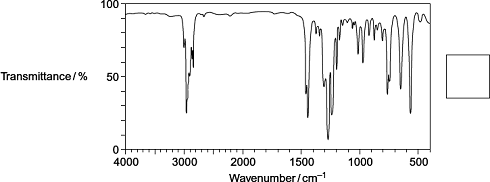
(ii)     The infrared spectra shown are those of three compounds.

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 (C6H12O6) 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 (HOOCCH2CH2COOH).

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

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**(3)**

**(Total 15 marks)**

**Q32.**The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, Ca5F(PO4)3

(a)     Complete the following equation for the manufacture of phosphorus.

....Ca5F(PO4)3   +   9SiO2   +   ....C      9CaSiO3   +   CaF2   +   ....CO   +   ....P

**(1)**

(b)     As the phosphorus cools, it forms white phosphorus, P4

Give the oxidation state of phosphorus in each of the following.

P4 .............................................................

H3PO4 ......................................................

**(2)**

(c)     Fertiliser grade phosphoric acid is manufactured from sulfuric acid and calcium phosphate.  
Use the following precise relative atomic mass data to show how mass spectrometry can be used to distinguish between pure sulfuric acid (H2SO4) and pure phosphoric acid (H3PO4) which both have *M*r = 98 to two significant figures.

|  |  |
| --- | --- |
| **Atom** | **Precise relative atomic mass** |
| 1H | 1.00794 |
| 16O | 15.99491 |
| 31P | 30.97376 |
| 32S | 32.06550 |

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**(1)**

(d)     Concentrated phosphoric acid is used as a catalyst in the hydration of propene to form the alcohol CH3CH(OH)CH3 as the main organic product.  
The industrial name for this alcohol is isopropyl alcohol.

(i)      State the meaning of the term *catalyst*.

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**(1)**

(ii)     State the meaning of the term *hydration*.

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**(1)**

(iii)     Write an equation for the hydration of propene to form isopropyl alcohol.  
Give the IUPAC name for isopropyl alcohol.

Equation ................................................................................................

IUPAC name ..........................................................................................

**(2)**

**(Total 8 marks)**

**Q33.**Methanol (CH3OH) is an important fuel that can be synthesised from carbon dioxide.

(a)     The table shows some standard enthalpies of formation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CO2(g) | H2(g) | CH3OH(g) | H2O(g) |
| ∆HfƟ/kJ mol–1 | – 394 | 0 | – 201 | – 242 |

(i)      Use these standard enthalpies of formation to calculate a value for the standard enthalpy change of this synthesis.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CO2(g) | + | 3H2(g) |  | CH3OH(g) | + | H2O(g) |

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**(3)**

(ii)     State why the standard enthalpy of formation for hydrogen gas is zero.

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**(1)**

(b)     State and explain what happens to the yield of methanol when the total pressure is increased in this synthesis.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CO2(g) | + | 3H2(g) |  | CH3OH(g) | + | H2O(g) |

Effect on yield ................................................................................................

Explanation ....................................................................................................

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*(Extra space)* .................................................................................................

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**(3)**

(c)     The hydrogen required for this synthesis is formed from methane and steam in a reversible reaction. The equation for this reaction is shown below.

CH4(g)   +   H2O(g)      C0(g)   +   3H2(g)           ∆H = +206 kJ mol–1

State and explain what happens to the yield of hydrogen in this reaction when the temperature is increased.

Effect on yield ................................................................................................

Explanation ....................................................................................................

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**(3)**

(d)     The methanol produced by this synthesis has been described as a carbon-neutral fuel.

(i)      State the meaning of the term *carbon-neutral*.

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*(Extra space)* ........................................................................................

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**(1)**

(ii)     Write an equation for the complete combustion of methanol.

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**(1)**

(iii)    The equation for the synthesis of methanol is shown below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CO2(g) | + | 3H2(g) |  | CH3OH(g) | + | H2O(g) |

Use this equation and your answer to part (d)(ii) to deduce an equation to represent the overall chemical change that occurs when methanol behaves as a carbon-neutral fuel.

Equation ...............................................................................................

**(1)**

(e)     A student carried out an experiment to determine the enthalpy change when a sample of methanol was burned.

The student found that the temperature of 140 g of water increased by 7.5 °C when 0.011 mol of methanol was burned in air and the heat produced was used to warm the water.

Use the student’s results to calculate a value, in kJ mol–1, for the enthalpy change when one mole of methanol was burned.  
(The specific heat capacity of water is 4.18 J K–1 g–1).

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*(Extra space)* .................................................................................................

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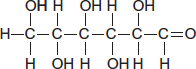
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**(3)**

**(Total 16 marks)**

**Q34.**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.

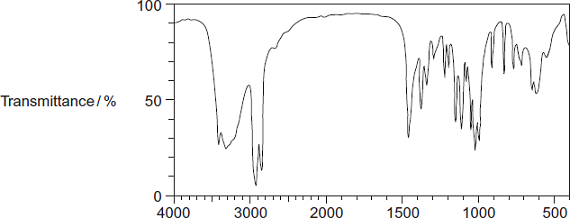


(i)      Deduce the empirical formula of glucose.

...............................................................................................................

**(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

CH3CH2OH(I) + O2(g)   CH3COOH(I) + H2O(I)

(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*.

...............................................................................................................

...............................................................................................................

...............................................................................................................

*(Extra space)* .......................................................................................

...............................................................................................................

**(1)**

(ii)     Other than carbon-neutrality, state the **main** advantage of the use of glucose from crops as the raw material for the production of ethanol.

...............................................................................................................

...............................................................................................................

**(1)**

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

...............................................................................................................

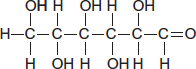
...............................................................................................................

**(1)**

**(Total 13 marks)**

**Q35.**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.

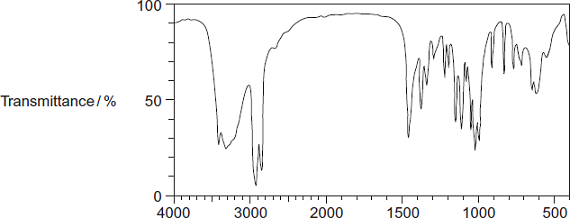


(i)      Deduce the empirical formula of glucose.

...............................................................................................................

**(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

CH3CH2OH(I) + O2(g)   CH3COOH(I) + H2O(I)

(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*.

...............................................................................................................

...............................................................................................................

...............................................................................................................

*(Extra space)* .......................................................................................

...............................................................................................................

**(1)**

(ii)     Other than carbon-neutrality, state the **main** advantage of the use of glucose from crops as the raw material for the production of ethanol.

...............................................................................................................

...............................................................................................................

**(1)**

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

...............................................................................................................

...............................................................................................................

**(1)**

**(Total 13 marks)**

**M1.**          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*

          C6H12O6 → 2CH3CH2OH + 2CO2 balanced **(1)**

          C2H5OH +3O2 → 2CO2 +3H2O balanced **(1)**

*Allow C2H6O but penalise C2H5HO once*

**[8]**

**M2.**          (a)     (i)      *Reagent:* Hydrogen of H2 **(1)***Conditions:* Ni (catalyst) *(Ignore Pt)* **(1)**100 – 200 °C or heat **(1)**

*Not ‘high temp’ or ‘warm’  
M1 = 0, M2 = 1 then M3 = 0 max  
or M1 = M2 = 0 then M3 = 0  
M3 tied to M1. Only award M3 if M1 earned*

(ii)     *Difference in structure:* soft margarine less hydrogenated or  
has more C=C bonds or is more unsaturated than hard  
margarine **(1)***Difference in melting point:* soft has lower melting point **(1)**

*Must be comparison*

**5**

(b)     (i)      3-methylbutan-2-ol **(1)**

*No alternatives*

(ii)     elimination or dehydration **(1)**

(iii)     (c) H2SO4 or (c) H3PO4 – name or correct formula **(1)**

(iv)



*Double bond must be shown  
Accept any correct unambiguous structures  
if but- 1-ene and but-2-ene offered, allow M2*

**5**

**[10]**

**M3.**          (a)     % O = 21.6 % **(1)**

*If % O not calculated only M2 available*

|  |  |  |
| --- | --- | --- |
| C | H | O  **(1)** |
| = 5.41 | = 13.5 | = 1.35 |

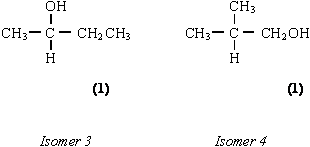
Ratio: 4 : 10: 1     ( C4H10O) **(1)**

*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)     

*Penalise missing bonds / incorrect bonds once per paper*

**4**

(c)     (i)      Aldehyde **(1)**

*Ignore named aldehydes or their structures,  
penalise wrong named compound*

(ii)     CH3CH2CH2CH2OH + [O] → CH3CH2CH2CHO + H2O **(1)**Balanced **(1)**

*C4H10O is OK as a reactant  
[O] can be over arrow  
C3H7CHO not accepted for product, but C2H5CH2CHO is OK  
If use C3 or C5 compounds no marks in (ii) C.E of wrong alcohol*

(iii)     *Name* Butanoic acid **(1)***Structure*: CH3CH2CH2COOH **(1)***mark conseq. or as stated*

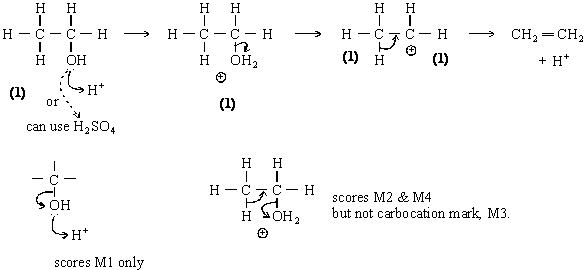
**5**

(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)



**4**

**[18]**

**M4.**          (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 CH3CHO** | **NOT CH3COOH** |

*Penalise incorrect R group once*

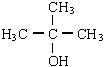
(ii)     *Reagent*: sodium (/ potassium) dichromate (VI)  
**(VI not essential) (1) M1**

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

*Or correct formula for M1 and M2  
M2 depends on M1 (but M2 correct from Cr2O72–, K2Cr2O72– etc  
M3 mark independent  
Credit KMnO4 for M1  
Ignore T and P for M2*

**5**

(c)     (i)

 (1)

(ii)

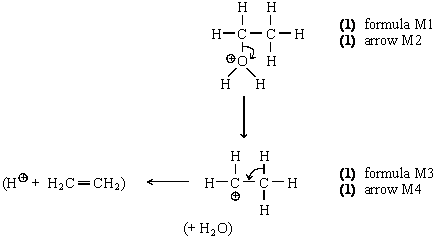
(1)

**2**

(d)     (i)      Al2O3 or H2SO4 or H3PO4 **(1)**

*Name or formula*

(ii)



*For M1 the + can be on O or H if ‑OH2 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]**

**M5.**          (a)     ethan(e)-1,2-diol OR 1,2-ethan(e)diol **(1)**antifreeze **(1)** OR production of Terylene / polyester  
                          feedstock for polyester / PET

*NOT surfactant NOT plasticizer NOT solvent NOT de-icer*

**2**

(b)     Reaction 1      H2O or steam **(1)**

Reaction 2      O2 **(1)** NOT air

*Ignore reaction 3*

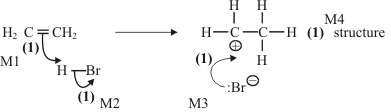
Reaction 4      H2O **(1)**

Reaction 5      NH3 **(1)**

*For Reaction 4; credit dil H2SO4 OR H2SO4(aq) OR HCl (aq) but NOT steam and NOT NaOH(aq)*

**4**

(c)



*Penalise M2 incorrect δ+ / δ–*

*Penalise δ– on alkene (M1)*

*Penalise dots on bonds once*

*Penalise M4 (structure) for use of wrong alkene*

*Penalise M1 for use of Br2*

**4**

(d)     WaterOR aqueous solution OR (aq) in equation **(1)**

**M1**

          Yeast OR enzyme/zymase OR T  45°C

*but T not below 20°C and allow warm*

*N.B. yeast and T=60°  con*

*Ignore pH*

*Ignore anaerobic / oxygen*

*Ignore time*

*Ignore pressure*

**M2**

          C6H12O6 → 2C2H5OH (or CH3CH2OH) + 2CO2

*Allow C12H22O11 if balanced equation*

*M4 OR M5 needs the use of good English and correct chemistry to gain credit*

**M3**

M4:             The rate of fermentation is slower **(1)**OR    The rate of hydration is faster

QoL  OR    (The rate of) fermentation is slow and  
          (the rate of) hydration is fast

*reference correctly to time rather than rate gains credit*

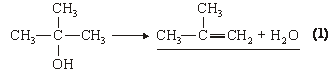
M5:             The product of fermentation is less pure or lower purity  
OR    The product of hydration is more pure or higher purity  
OR    The product of fermentation is impure and that of  
          hydration is pure  
OR    Specific reference to 10–15% versus 90–100%  
OR    correct reference to higher or lower yield

**5**

**[15]**

**M6.**          (a)     (i)      2-methylpropan-2-ol **(1)** OR the second one

(ii)     *Dehydrating agent*:  **(1)**

*Equation*: 

*Allow C4H9OH in equation provided RHS is correct*

*if b(i) is blank, b(ii) equation must be full for credit  
i.e. NOT C4H9OH*

*Mark consequential on b(i)*

**3**

(b)     (i)      *Isomer*: butan-2-ol OR the fourth one

*[look at name in table]*

*wrong isomer = CE*

*Structure of the ketone*:



(ii)     *Isomer*: butan-1-ol OR the first one  
            OR 2-methylpropan-1-ol OR the third one

*[look at name in table]*

*Wrong isomer = CE  
Structure of the aldehyde*:

Either 

(iii)

|  |  |  |  |
| --- | --- | --- | --- |
| *Reagent* | M1 | Tollen’s (AgNO3/NH3) | Fehling’s |
| *Observation with ketone* | M2 | Stays colourless no change | stays blue no change |
| *Observation with aldehyde* | M3 | Silver mirror black ppt | red solid orange/red brown/ red ppt/solid |

         Other include(\*)  
K2Cr2O7 / H2SO4KMnO4/H2SO4   
Schiff’s  
Benedict’s   
Wrong reagent R  
No reagent = CE  
Penalise AgNO3 [Ag(NH3)2] but allow M2 and M3 sequentially.

|  |  |  |  |
| --- | --- | --- | --- |
| (\*) | K2Cr2O7 / H2SO4 acidified | ketone | aldehyde |
|  |  | orange no change | green |
|  | KMnO4/H2SO4 acidified | purple no change | colourless (v. Pale pink) |
|  |  |  |  |

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

**7**

(c)     *Equation*: CH3CH2CH2CH2OH (or C4H9OH) + 2[O] → CH3CH2CH2COOH  
(or C3H7COOH) + H2O **(1)**

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

*Accept butaneoic acid*

**2**

**[12]**

**M7.**          (a)     K2Cr2O7/H2SO4 reuced by

         CH3CH2CH2CH2OH **(1)**

          oxidised to    CH3(CH2)2CHO **(1)**and               CH3(CH2)2COOH **(1)**

CH3CH2CH2CHO **(1)**

          oxidised to    CH3(CH2)2COOH **(1)**

Equation:    Cr2O72– + 14H+ + 6e– → 2Cr3+ + 7H2O **(1)**

*Note: Deduct one if all three compounds given as reducing agents.*

**6**

(b)     Tollens’ reduced by  
              CH3CH2CH2CHO **(1)**

          oxidised to    CH3(CH2)2COOH **(1)**

Equation     [Ag(NH3)2]+ + e– → Ag + 2NH3 **(1)**

**3**

(c)     CH3CH2CH2CH2OH **(1)**

          Product CH3CH2CH2CH2OOCCH3 **(1)**

(CH3)3COH

Product (CH3)3COOCCH3 **(1)**

**4**

(d)     CH3CH2CH2OH has five peaks **(1)**

(CH3)3COH has two peaks **(1)**

**2**

**[15]**

**M8.**          (a)     Reaction 2: NaOH OR KOH **(1)** M1     alcohol (ic) OR ethanol (ic)**(1)** M2

*ignore heat*

*Condition mark linked to correct reagent but award M2 if OH– or base or alkali mentioned*

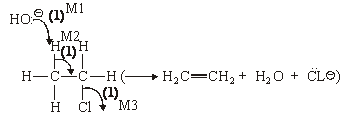
Reaction 3: concentrated H2SO4 OR H3PO4 M1 **(1)** heat **(1)** M2  
OR 150°C - 200°C

*Condition mark linked to correct reagent but award M2 if H2SO4 or H3PO4, but not concentrated*

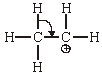
*Penalise reagent and condition if dilute H2SO4 / H3PO4*

**4**

(b)     Mechanism:



*Award M3  independently   
M1 and M2 must be to / from correct places*

*E1 mechanism possible in which M2 *

Name: of mechanism = elimination **(1)**

*NOT dehydrohalogenation*

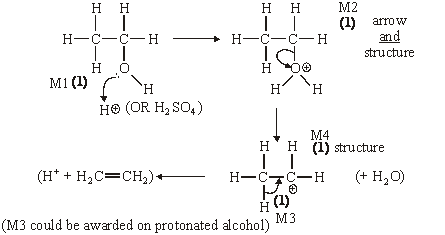
*Ignore “base” OR “nucleophilic” before elimination*

Reason: Reaction 2 has (very) low yield **(1)**

**5**

*QoL     OR chloroethane has to be made (from ethane)  
     OR chloroethane is expensive  
     OR chloroethane is not redily available*

(c)     Mechanism:



Name of mechanism = elimination **(1)**

*NOT dehydration alone*

Reason: Ethanol could come from (fermentation of) renewable

*QoL     sugars / glucose / carbohydrates / sources* ***(1)***

**6**

**[15]**

**M9.**          (a)     (i)      Potassium (OR sodium) dichromate(VI) OR correct formula  
OR potassium manganate(VII)

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

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

**1**

         Acidified OR H2SO4 / HCl (*NOT with KMnO4*) / H3PO4 / HNO3

*(Ignore heat or reflux)*

*(Credit “acidified” as part of reagent)*

**1**

         Oxidation or redox

**1**

(ii)     NaBH4 OR LiAlH4 OR H2/Ni

**1**

         CH3COCH3 + 2[H] → CH3CH(OH)CH3

*(Credit H2 in the equation if H2 has been chosen as reagent)*

**1**

(b)     (i)      

*(Structure must show aldehyde structure)*

*(Credit C2H5 as alternative to CH3CH2)*

(ii)

|  |  |  |  |
| --- | --- | --- | --- |
| M1    Tollens’ reagent OR ammoniacal silver nitrate OR AgNO3 + NH3 | OR Fehling’s solution | OR acidified potassium dichromate | **1** |

         M2 stays colourless      stays blue                 stays orange

**1**

*(Provided reagent is correct, credit “no reaction”, “no change”, “nothing”, “no observation” for M2)*

|  |  |  |  |
| --- | --- | --- | --- |
| M3   silver mirror / deposit OR black / grey precipitate | red / brown / orange precipitate / solid | goes green | **1** |

*(Credit other correct reagents and observation)*

*(For M1, penalise AgNO3 alone, penalise Ag(NH3), penalise “potassium dichromate”, etc., but, in each case, mark on and credit correct M2 and M3)*

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

**1**

**[9]**

**M10.**          (a)     (i)      C6H12O6 → 2C2H5OH + 2CO2

*(Or CH3CH2OH)*

*(Ignore state symbols in the equation)*

**1**

(ii)     Fermentation

**1**

(b)     (i)      C2H5OH + 3O2 → 2CO2 + 3H2O

*(Or C2H6O or CH3CH2OH)*

**1**

(ii)     CO or carbon monoxide or C or carbon ONLY

**1**

(iii)     2CO + 2NO → 2CO2 + N2OR 2NO → N2 + O2OR 2NO + C → N2 + CO2OR C8H18 + 25NO → 8CO2 + 12½N2 + 9H2O

*(In equation 2, allow additional O2 on both sides of the equation)*

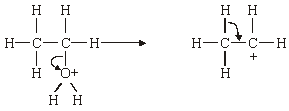
**1**

(c)     Elimination

*(Penalise additional words such as “electrophilic”)*

**1**

          M1 structure of protonated alcohol *(allow CH3CH2)*

**

**1**

          M2 arrow to show breakage of C – O bond on protonated alcohol

**1**

          M3 structure of carbocation (allow )

**1**

          M4 arrow from correct C – H bond on carbocation

*(penalise ‘sticks’ once only for structures M1 and M3)*

*(synchronous mechanism using correct structure required for M1, loses M3)*

**1**

(d)     Silver OR silver-based

*(NOT silver oxide)*

**1**

****

**1**

          M2 correct structure for epoxyethane

*(Allow CH2=CH2 or C2H4 in the equation)*

*(Credit the structure of epoxyethane independently)*

*(Credit M1 provided O2 has been used and the atoms balance, but the structure is poor e.g. C2H4O or CH2OCH2 but NOT CH3CHO)*

**1**

**[13]**

**M11.**          (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)     C2H6 →C2H4 + H2

**1**

(e)     Addition

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

**1**

**[8]**

**M12.**          (a)     Compounds with the same molecular formula

**1**

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

**1**

(b)     Compound A is butan-1-ol only

**1**

Compound C is butanone or butan-2-one

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

**1**

(c)     (i)      oxidation or redox

**1**

(ii)     K2Cr2O7 or potassium dichromate(VI)

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

**1**

         acidified or H2SO4 (or other identified strong acid)

*(penalise H+)*

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

**1**

(iii)     (heat under) reflux

OR use excess oxidising agent

**1**

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

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

**1**

(v)     correctly drawn structure of methanoic acid

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

**1**

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

**1**

(ii)     correctly drawn structure of methylpropanal

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

**1**

**[12]**

**M13.**          (a)     M1:    CH3CH2CH2CH2OH;

**1**

M2:    CH3CH(OH)CH2CH3;

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

**1**

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

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

**3**

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

**1**

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

OR

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

**1**

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

*(Credit condensed structures or molecular formulas in each equation, provided it is obvious to which reaction the equation refers) (Insist that whatever formula is used in each equation that it is a conventional representation of the compound; for example penalise CH3CH2CH2COH for butanal)*

**1**

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

**1**

OR

methylpropan-2-ol;

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

**1**

**[10]**

**M14.**          (a)     (i)      C6H12O6 →2C2H5OH + 2CO2;

*(penalise C2H6O once only in this question)*

**1**

(ii)     Concentrated H2SO4 OR concentrated H3PO4 OR Al2O3;

*(penalise aqueous or dilute as a contradiction)*

**1**

C2H5OH →C2H4 + H2O OR C2H5OH →H2C = CH2 + H2O;

*(penalise CH2.CH2 and CH2-CH2 and CH2 : CH2 for ethene)*

**1**

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

**1**

Hydrogen OR H2;

**1**

(c)     (i)      C18H34O2 Only;

**1**

C9H17O    Only;

*(empirical formula is not consequential on molecular formula)*

**1**

(ii)     (An unsaturated compound) contains (at least) one double bond

OR

         Contains C=C;

*(must be a positive statement)*

**1**

(iii)     M1: Bromine water

         OR

         Br2(aq)

         OR

         Bromine

         OR

         Br2;

*(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]**

**M15.**          (a)     **M1**: aqueous or solution in water or (aq) in the equation

**1**

**M2**: yeast or zymase

*(do not credit ‘an enzyme’ unless qualified)*

**1**

**M3**: anaerobic/absence of oxygen/absence of air or neutral pH/pH value 6 – 8

**1**

**M4**: T in the range 30 – 40 °C only

*(ignore references to pressure)*

*(ignore uv light)*

**1**

**M5**: fermentation

**1**

**M6**: C6H12O6 → 2CH3CH2OH + 2CO2

*(ignore state symbols but penalise M1 if the state symbol in the equation contradicts)*

**1**

**M7**: CH3CH2OH + 3O2 → 2CO2 + 3H2O

*(credit use of C2H5OH)*

*(penalise use of C2H6O once only in M6 or M7)*

**1**

(b)     **M1**: dehydration is the elimination of water or removal  
of combined water or qualified loss of/removal of water  
e.g. from a compound/molecule/alcohol or removal of  
H and O in the ratio 2:1 from a compound/ molecule/alcohol

*(do not credit ‘from a ‘substance’)*

*(do not credit ‘removal of water molecules’ unless qualified from a compound/molecule etc.)*

**1**

**M2**: Catalyst = concentrated H2SO4 or concentrated/oily/syrupy  
phosphoric acid or aluminium oxide/ pumice/porous pot

**1**

**M3**: CH3CH2OH → H2C=CH2 + H2O

*(credit use of C2H5OH)*

*(penalise use of C2H6O here unless already penalised in part(a).*

*Possible credit as repeat error)*

*(credit C2H4 and CH2=CH2 for ethene, but penalise CH2CH2, CH2.*

*CH2, CH2:CH2)*

*(ignore H2SO4 if it appears on both sides of equation)*

**1**

(c)     **M1**: large(r) to small(er) molecules/hydrocarbons/compounds  
or high(er) Mr alkanes to low(er) Mr alkanes (+ alkenes) (+ H2)

**1**

**M2**: breakage/homolysis/splitting of C–C/carbon chain/carbon skeleton

*(do not credit breaking C–H bonds alone, but ignore if accompanied by C–C)*

**1**

**M3**: reactive intermediate is (free/alkyl) radical or radical mechanism

*(do not credit ‘free radical substitution’ and penalise M3 as a contradiction if mentioned with free radical intermediates)*

**1**

**M4**: any T (or range) in the range 400 to 900°C or high temperature

*(ignore ‘pressure’)*

**1**

**M5**: CH3CH2CH2CH3 (OR C4H10) → H2C=CH2 + CH3CH3 (OR C2H6) or CH3CH2CH2CH3 (OR C4H10) → 2H2C=CH2 + H2

*(credit C2H4 and CH2=CH2 for ethene, but penalise CH2CH2,  
CH2.CH2, CH2:CH2 and note possible RE from part(b))*

**1**

**[15]**

**M16.**          (a)     Ag or silver or silver-based or silver on an alumina base

*(penalise specific silver compounds)*

**1**

epoxyethane

**1**

(b)     electrophilic addition

**1**

**M1**: curly arrow from C=C bond towards/alongside the  
side of H atom on H-OSO2OH

*(penalise M1 if arrow to H2SO4 OR to formal charge on H  
of H-O bond)*

*(ignore partial charges on H and O of H2SO4, but penalise  
if these are incorrect on the H atom being attacked)*

*(credit M1 and M2 if correct curly arrow to H+ provided  
the anion is present)*

**1**

**M2**: curly arrow from H–O bond towards/alongside the side of the  
O atom on H–OSO2OH

*(credit the arrow even if there are partial or formal charges on H and O but the structure of H2SO4 is correct)*

**1**

**M3**: correct structure of the carbocation

*(penalise use of ‘sticks’ in this structure)*

**1**

**M4**: curly arrow from lone pair on an individual oxygen atom of  
(correct formula for) hydrogensulphate ion towards/alongside C  
atom bearing the positive charge

*(insist that the an ion has the correct formula with a lone pair of electrons and a negative charge)*

**1**

(c)     (i)      ethanal

**1**

correct structure for ethanal

*(aldehyde functional group must be drawn out)*

**1**

(ii)     oxidation or redox

**1**

**[10]**

**M17.**          (a)     (i)      M1 pentan-3-one only

**1**

M2 CH3CH2CH2COCH3

*(insist on C=O being drawn out)*

*(penalise use of C3H7)*

**1**

(ii)     *aldehyde*         (CH3)2CHCH2CHO

**1**

*ketone*             (CH3)2CHCOCH3

**1**

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

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

*(ignore names)*

(b)     (i)      CH3CH2CH2CH2CHO + [O] → CH3CH2CH2CH2COOH

*(accept C4H9CHO going to C4H9COOH)*

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

**1**

(ii)     pentanoic acid

*(credit pentan–1–oic acid)*

**1**

(c)     (i)      CH3CH2CH2CH2CH2OH OR pentan–1–ol

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

**1**

(ii)     Primary

*(credit 1o or 1)*

**1**

**[8]**

**M18.**          (a)     hydration OR (electrophilic) addition

*(penalise incorrect words in front of the word “addition” e.g. “nucleophilic”)*

*(penalise “indirect hydration” but credit “direct hydration” or “steam hydration”)*

**1**

H2C=CH2 + H2O → CH3CH2OH

*(ignore state symbols)*

*(credit use of C2H5OH for ethanol)*

*(penalise use of C2H6O for ethanol on the first occasion)*

*(credit C2H4 and CH2=CH2 for ethene)*

*(penalise CH2CH2, CH2.CH2, CH2:CH2 for ethene on the first occasion)*

*(ignore H2SO4 OR extra H2O OR H+ if it appears on both sides)*

**1**

conc. H2SO4 OR conc. H3PO4

**1**

(b)     (i)      Carbon OR C

*(credit “soot” or “sooty”)*

*(penalise “coke” or “coal”)*

*(credit “carbon + carbon monoxide” provided it is clear that carbon is solid; penalise “carbon + carbon dioxide”)*

**1**

(ii)     CH3CH2OH + O2 → 2C + 3H2O  
OR  
CH3CH2OH + 1½O2 → C + CO + 3H2O

*(credit multiples of these equations)*

*(credit use of C2H5OH for ethanol)*

*(penalise use of C2H6O for ethanol, but note a possible repeat error from part (a) above)*

**1**

**[5]**

**M19.**          (a)     Allow 1 mark each for any correctly drawn primary, secondary and  
tertiary alcohol of molecular formula C4H8O

**3**

          Tertiary alcohol cannot be oxidised

**1**

(b)     Region 1500–400 cm–1

**1**

exact match to spectrum of known compound

**1**

(c)                       **A**                                               **B**       CH3CH2CH2OH                       CH3CH2–O–CH3 **(1)**or CH3CH(OH)CH3 **(1)**

**C**                                               **D**       one alkene e.g.                     one cycloalkane e.g.

|  |  |
| --- | --- |
| CH2=CHCH2CH2CH3  CH3–CH=CH–CH2CH3  (CH3)2C=CHCH3  H2C=C(CH3)CH2CH3 | **(1)** etc |

**E**                                                **F**      CH3CH2CHO **(1)**                         CH3COCH3 **(1)**

**6**

**[12]**

**M20.**          (a)     (i)      Covalent;

*If not covalent CE = 0.  
If blank, mark on.*

**1**

         Shared pair of electrons (one from each atom);

*Not shared electrons.*

**1**

(ii)     Hydrogen bonds / H bonds;

*Not just hydrogen.*

**1**

Van der Waals/London/dispersion forces/temporary  
induced dipole;

**1**

(b)     Showing all the lone pairs on both molecules;

*Allow showing both lone pairs on the O involved in the H-bond.*

**1**

          Showing the partial charges on O and H on both molecules;

*Allow showing both partial charges on the O and H of the other molecule involved in the H bond.*

**1**

          Showing the Hydrogen bond from the lone pair on O of one  
molecule to the delta + on the H of the other molecule;

**1**

(c)     (i)      C2H5OH + 3O2 → 2CO2 + 3H2O;

*Accept multiples.  
Allow C2H6O.*

**1**

(ii)     CO is (produced which is) toxic/ poisonous/C (may be produced)  
which is toxic/ C is a respiratory irritant/ C (particles) exacerbate  
asthma/C causes global dimming/ smog;

*Must relate to C or CO.  
Any mention of SO2 NO2 or other pollutants CE = 0.*

**1**

(iii)     More fuel needed (which costs more)/Wastes fuel/  
less fuel burnt (so need more to buy more)/engine gets sooty so  
need to pay for engine to be cleaned/Have to fit catalytic converter;

*Not just costs more.  
Not engine gets sooty unless qualified.*

**1**

(d)     (i)      (React) with CaO/ calcium oxide/quicklime/lime;

*Accept CaCO3/ calcium carbonate/limestone.  
Not chalk.*

**1**

All the sulfur dioxide may not react with the CaO or CaCO3 /  
may not have time to react/ incomplete reaction;

*Accept incomplete reaction.*

**1**

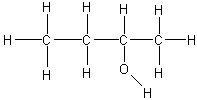
(ii)     Occupies a (much) smaller volume;

*Not easier to store or transport.*

**1**

**[13]**

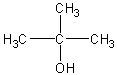
**M21.**          (a)     **M1**Displayed formula for butan-2-ol



*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  
C6H12O6 → CH3CH2CH2CH2OH + **2**CO2 + H2O  
                        or C4H9OH

*Or multiples for M1 and M3  
In M1 and M3 penalise use of C4H10O 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** CH3CH2CH2CH2OH + **6**O2 → **4**CO2 + **5**H2O  
or C4H9OH

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

***OR***

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

*In M4  
Ignore references to “carbon neutral”  
Ignore “sugar” and “glucose”*

**4**

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

**M2** Displayed formula (ONLY) for butanal CH3CH2CH2CHO

**M3** Displayed formula (ONLY) for butanoic acid CH3CH2CH2COOH

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

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

**M4** Oxidation (oxidised) OR Redox

**M5** orange to green

*Both colours required for M5  
Ignore states*

**5**

**[15]**

**M22.**          (a)     Functional group (isomerism)

**1**

(b)

|  |  |
| --- | --- |
| **M1** Tollens’ (reagent) (*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens’*) (*Ignore either AgNO3 or [Ag(NH3)2+] or “the silver mirror test” on their own, but mark M2 and M3*)  **M2** silver mirror  **OR**  black solid/precipitate *(NOT silver precipitate)*  **M3** (stays) colourless or no change or no reaction | **M1** Fehling’s (solution) or Benedict’s solution (*Ignore Cu2+(aq) or CuSO4 on their own, but mark on to M2 and M3*)  **M2** Red solid/precipitate (*Credit orange or brown solid*)      **M3** (stays) blue or no change or no reaction |

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

*No reagent, CE=0*

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

*For M3  
Ignore “nothing (happens)”  
Ignore “no observation”*

**3**

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

**1**

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

*Penalise “(free) radical mechanism”*

**1**

(ii)     **Initiation**Cl2 → 2Cl•

*Penalise absence of dot once only.*

**First propagation**Cl• + CH3CH2CH3 → •CH2CH2CH3 + HCl  
OR C3H8

*Penalise incorrect position of dot on propyl radical once only.*

*Penalise C3H7****•*** *once only*

**Second propagation**Cl2 + •CH2CH2CH3 → CH3CH2CH2Cl + Cl•

***OR***

C3H7Cl

*Accept CH3CH2CH2****•*** *with the radical dot above/below/to the side of the last carbon.*

**Termination (must make C6H14)**2 •CH2CH2CH3 → C6H14 or CH3CH2CH2CH2CH2CH3

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

**4**

(e)     *M*r = 44.06352 (for propane)  
*M*r = 43.98982 (for carbon dioxide)

*Mark independently*

**M1** a correct value for both of these *M*r values.

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

***OR***

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

**2**

**[12]**

**M23.**          (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**    C6H12O6  **2**C2H5OH + **2**CO2OR  
**2**C6H12O6  **4**C2H5OH + **4**CO2

*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) CO2/carbon dioxide taken in/used/used  
up (to form glucose or in photosynthesis)

**1**

**M3**    6 (mol/molecules) CO2/carbon dioxide given out due to  
**2** (mol/molecules) CO2/carbon dioxide from fermentation/  
Process 2 and **4** (mol/molecules) CO2/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) Breactants – (Σ) Bproducts = 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]**

**M24.**          (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 electron acceptor

***OR***

(readily) gains/accepts/receives electron(s)

*NOT an electron pair acceptor*

*Ignore removes/takes away/attracts electrons*

**1**

(ii)     Br2 ONLY

*Ignore “bromine”*

*Apply the list principle*

**1**

(iii)     H2SO4 + **2**H+ + **2**e–  SO2 + **2**H2O

***OR***

SO42– + 4H+ + **2**e–  SO2 + **2**H2O

*Ignore state symbols*

*Ignore absence of negative charge on electron*

*Or multiples of equations*

**1**

(c)     (i)      (acid) catalyst

***OR***

catalyses (the reaction)

***OR***

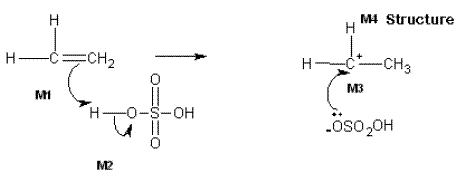
to speed up the reaction/increase the rate (of reaction)

*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 H2SO4 (or accept H2SO3 here)  
M1 could be to an H+ ion and M2 an independent  
O – H bond break on a compound with molecular  
formula for H2SO4 or H2SO3

**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 HSO4–*

*For M3, credit as shown or ―:OSO3H ONLY with the negative charge anywhere on this ion*

*OR correctly drawn out with the negative charge placed correctly on oxygen*

*Max 3 marks for wrong reactant*

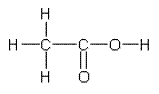
*Do not penalise the use of “sticks”*

**4**

(iii)     Primary ***OR*** 1° (alcohol)

**1**

(iv)    Displayed formula for ethanoic acid, CH3COOH



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

*Ignore bond angles.*

**1**

**[11]**

**M25.**          (a)     (i)      Hexan-1-ol1

*ONLY*

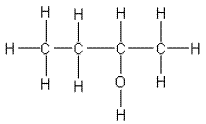
**1**

(ii)     Homologous (series)

*ONLY*

**1**

(iii)     Displayed formula for butan-2-ol



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

*Ignore bond angles*

**1**

(iv)    CH3CH2CH2CH2OH + [O]  CH3CH2CH2CHO + H2O

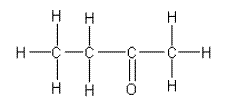
*Require this whole equation as written or formulae drawn out*

*Penalise “sticks”*

**1**

(v)     Displayed formula for butanone

(credit possible enols, ethers and cyclic structures for C4H8O)



*All bonds must be drawn out*

*Ignore bond angles*

**1**

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

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

**M3** 0.005 mol, therefore ΔH = **–1170** (kJ mol–1)

                          OR ΔH = **–1170.4** (kJ mol–1)

                         OR ΔH = **–1200** (kJ mol–1)

*Award full marks for correct answer*

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

*Ignore incorrect units in M2*

*Penalise M3 ONLY if correct answer but sign is incorrect OR value is in J mol–1*

*If m = 5 × 10–3 OR if ΔT = 281, CE and only allow one mark for correct mathematical formula for M1*

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

**3**

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

**M2** is burned completely in oxygen

OR burned in excess oxygen

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

OR

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

*For M3*

*Ignore reference to 1 atmosphere*

**3**

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

**M1**    Δ*H* =ΣΔ*H*f (**products**) – .ΣΔ*H*f (**reactants**)

OR a correct cycle of balanced equations

**M2**    = 4(–394) + 5(–286) – (–327)

          (This also scores M1)

**M3**    = **– 2679** (kJ mol–1) OR **–2680** (kJ mol–1)

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

*Correct answer to calculation gains full credit*

*Credit 1 mark if + 2679 (kJ mol–1)*

*For other incorrect or incomplete answers, proceed as follows*

*•    check for an arithmetic error (AE), which is either a  
     transposition error or an incorrect multiplication; this  
     would score 2 marks (M1 and M2)*

*•    If no AE, check for correct method; this requires either  
     a correct cycle with 4CO2 and 5H2O OR a clear  
     statement of M1 which could be in words and scores  
     only M1*

**3**

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

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

          increases by/has an extra CH2

OR

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

**M2    This is about the reaction and bond breaking/making**

          Combustion of each alcohol in the series breaks one

          more C-C and two more C-H compared with the previous one  
AND forms one more mol CO2 and one more mol H2O

OR

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

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

**2**

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

heat loss or heat absorbed by the apparatus

OR

incomplete combustion/not completely burned

OR

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

**2**

**[18]**

**M26.**          (a)     **M1** AgNO3 OR silver nitrate OR any soluble silver salt

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

**M3** white precipitate or white solid/white suspension

*An insoluble silver salt OR Tollens’ OR ammoniacal silver nitrate or HCl/AgNO3 is CE = 0 for the clip*

*For M1*

*Credit acidified (or HNO3) silver nitrate for M1 and mark on*

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

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

*For M2*

*Ignore “nothing”*

*Ignore “no observation”*

*Ignore “clear”*

*Ignore “dissolves”*

*For M3*

*Ignore “cloudy solution” OR “suspension”*

**3**

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

**M2** white precipitate or white solid/white suspension

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

***OR*** as an alternative

**M1** NaOH/KOH

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

**M3** white precipitate or white solid/white suspension

*An insoluble sulfate OR conc H2SO4 is CE = 0 for the clip*

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

*For the M1 soluble sulfate*

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

*For the M1 NaOH/KOH*

*If ammonia, then CE = 0*

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

*For no (observed) change in both alternatives*

*Ignore “nothing”*

*Ignore “no observation”*

*Ignore “clear”*

*Ignore “dissolves”*

*For the white precipitate in both alternatives*

*Ignore “cloudy solution” OR “suspension”*

**3**

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

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

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

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

OR as an alternative using conc sulfuric acid

**M1**    concentrated sulfuric acid OR c(onc) H2SO4

**M2** misty/white fumes/gas

OR remains white

OR no change (in colour)

**M3** turns black (solid)

OR purple fumes/gas

OR correct reference to H2S observation (e.g. bad egg smell)

*For M1*

*If incorrect formula or “ammonium”, penalise M1 but mark M2 and M3*

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

*For M3*

*Ignore “nothing”*

*Ignore “no observation”*

*For the alternative using sulfuric acid*

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

*If incorrect formula, penalise M1 but mark M2 and M3*

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

**3**

(d)     **M1** acidified potassium dichromate or K2Cr2O7/H2SO4

OR K2Cr2O7/H+ OR acidified K2Cr2O7

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

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

Alternative using KMnO4/H2SO4

**M1** acidified potassium manganate(VII) or KMnO4/H2SO4

OR KMnO4/H+ OR acidified KMnO4

**M2**    colourless solution OR goes colourless

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

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

*For M1*

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

*For M2 ignore dichromate described as “yellow” or “red”*

*For M3*

*Ignore “nothing”*

*Ignore “no observation”*

*For M1*

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

*Credit alkaline KMnO4 for possible full marks but M2 gives brown precipitate or solution goes green*

**3**

**[12]**

**M27.**          (a)     Pentan-2-one

*ONLY but ignore absence of hyphens*

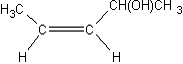
**1**

(b)     Functional group (isomerism)

*Both words needed*

**1**

(c)     (i)



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

*The group needs to be CHOHCH3 but do not penalise poor C–C bonds or absence of brackets around OH*

*Trigonal planar structure not essential*

**1**

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

OR

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

**1**

(d)

|  |  |
| --- | --- |
| **M1** Tollens’ (reagent)  *(Credit ammoniacal silver nitrate OR a description of making Tollens’)*  *(Do not credit Ag+, AgNO3 or [Ag(NH3)2+] or “the silver mirror test” on their own, but mark M2 and M3)* | **M1** Fehling’s (solution) / Benedict’s  *(Penalise Cu2+(aq) or CuSO4 but mark M2 and M3)* |
| **M2** silver mirror  OR black solid or black precipitate | **M2** Red solid/precipitate  *(Credit orange or brown solid)* |
| **M3** (stays) colourless  OR  no (observed) change / no reaction | **M3** (stays) blue  OR  no (observed) change / no reaction |

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

*Check the partial reagents listed and if M1 has a totally incorrect reagent, CE = 0 for the clip*

*Allow the following alternatives*

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

***M2*** *(turns) green*

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

*OR*

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

*mark on from incomplete formulae or incorrect oxidation state*

***M2*** *(turns) colourless*

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

*In all cases for* ***M3***

*Ignore “nothing (happens)”*

*Ignore “no observation”*

**3**

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

or named or correctly identified

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

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

**1**

(ii)     **If Isomer 1 is correctly identified, award any two from**

•        (Strong / broad) absorption / peak in the range  
**3230 to 3550** cm–1 or specified value in this range  
or **marked correctly** on spectrum  
**and**(characteristic absorption / peak for) OH group /**alcohol** group

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

•        Absorption / peak in the range **1620 to 1680** cm–1  
or specified value in this range or marked correctly  
on spectrum  
**and**

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

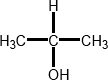
*If 6(e)(i) is incorrect or blank, CE=0*

*Allow the words “dip” OR “spike” OR “trough” OR “low transmittance” as alternatives for absorption.*

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

**2**

**[10]**

**M28.L**         

Allow (CH3)2CHOH     or      CH3CH(OH)CH3

*Allow name propan–2–ol*

*Penalise contradiction of name and structure*

**1**

**M**

Allow CH3CH=CH2

*Allow name propene*

*ignore -1- but penalise other numbers*

*Penalise contradiction of name and structure*

**1**

Step 1 NaBH4   or   LiAlH4

  Zn/HCl   or   Sn/HCl

  or H2/Ni   or  H2/Pt

*Ignore name if formula is correct*

*ignore solvent*

*ignore acid (for 2nd step) but penalise acidified NaBH4*

*Apply list principle for extra reagents and catalysts.*

M1

**1**

(nucleophilic) addition

Addition (not nucleophilic)

*Penalise electrophilic*

*Ignore reduction*

M2

**1**

Step 2   conc H2SO4   or   conc H3PO4   or   Al2O3

*Apply list principle for extra reagents and catalysts.*

M3

**1**

   elimination

*Independent from M3*

*penalise nucleophilic or electrophilic*

*ignore dehydration*

M4

**1**

Step  3  HBr

*Apply list principle for extra reagents and catalysts.*

M5

**1**

         electrophilic addition

*Independent from M5*

M6

**1**

**[8]**

**M29.**(a)    **M1**   C6H12O6      **2**CH3CH2OH   +   **2**CO2                                             (2C2H5OH)

*Mark independently*

*For M1 and M3 ignore state symbols and credit multiples*

*For M1 and M3 penalise C2H6O once only*

**M2**   fermentation

**M3**   CH3CH2OH   +   **3**O2      **2**CO2   +   **3**H2O  
 (C2H5OH)

**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 CO2

*For M5, “releases / increases carbon emissions” is insufficient as an alternative to releases CO2*

**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–*

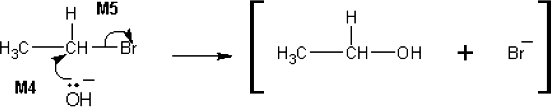
warm / heat / reflux and aqueous or (aq) or water

*For M2 ignore “dilute”*

*For M2 penalise T > 100 °C*

**M3** nucleophilic substitution

*Acidified KOH/NaOH or H2SO4 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 original molecule.

*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 SN1 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

         •   Bromoethane has to be manufactured / made first

         •   Bromoethane is expensive

*For M6 ignore references to other costs and expenses*

**6**

(c)     **M1** concentrated phosphoric acid / conc. H3PO4 ***OR*** concentrated sulfuric acid /conc. H2SO4

*Answers in any order*

*Ignore reference to support medium in M1*

**M2** hydration or (electrophilic) addition

**For M3 and M4 any two from**

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

     •   Excess ethene

***OR*** Excess steam / water / H2O

***OR*** remove the ethanol as it forms

***OR*** recycle the ethene

     •   Specified Pressure

         50 atm ≤ P ≤ 100 atm

***OR*** 5000 kPa ≤ P ≤ 10000 kPa

***OR*** 5 MPa ≤ P ≤ 10 MPa

     •   HighTemperature 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]**

**M30.**(a)     **For 2 marks at least one correct reference either to *Mr* or value to 5  
decimal places required**

***QoL*** *(associated with the bold statement here)*

**M1**  Compounds 1 and 3 (butanal and butanone) have the same *Mr* (to 5dp)  
        because **either**

*It may be possible to award 2 marks if there is a clear statement about oxygen having a different precise Ar in the context of the comparison*

•    they contain the same number of atoms of the same / each element

•    are both C4H8O

•    have the same molecular formula

*NB The word “similar” does not mean “the same”*

•    contain the same number of C, H and O atoms

**M2**  Compound 2 (pentane) has a different *Mr* (to 5dp) because **either**

•    it has different numbers of atoms of different elements

•    is C5H12 / only contains C and H

•    different molecular formula

•    does not contain oxygen (atom) / C=O

**2**

(b)     **WithTollens’ (reagent)**

**M1** silver mirror

***OR*** black solid/precipitate

(NOT silver (mirror) precipitate)

**M2** (stays) colourless

***OR*** no change / no reaction

***OR*** no silver mirror

**With Fehling’s (solution)**

**M1** Red solid/precipitate

(Credit orange or brown solid)

**M2** (stays) blue

***OR*** no change / no reaction

***OR*** no red solid

***OR*** no (red) precipitate

***N.B No mark is awarded for the reagent***

*If no reagent given allow 1 mark for a consistent statement of M1 and M2*

*For M2, ignore “nothing (happens)”*

*And ignore “no observation”*

**2**

**[4]**

**M31.**          (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 CO2 / CO2 from the factory / CO2 from the bioethanol (or  
biofuel) production

***OR***

reduces or limits the amount of CO2 released / given out (into the atmosphere)

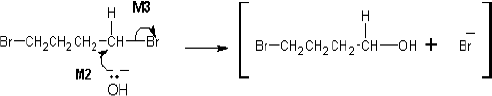
***OR***

Process 2 uses renewable glucose / renewable resource(s)

**2**

(b)     (i)      M1 nucleophilic substitution

*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 original molecule

*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 SN1 mechanism

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

*Penalise* ***M3*** *if an extra arrow is drawn from the Br of the C–Br bond to, for example, K+*

*Accept the correct use of “sticks*

**NB The arrows here are double-headed**

**3**

(ii)     **M1**   B

**M2**   C

**M3**   A

**3**

(c)     **M1** fermentation

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

**Three conditions in any order for M2 to M4**

*Penalise “bacteria” and “phosphoric acid” using the list principle*

**M2**    (enzymes from) yeast or zymase

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

*Ignore reference to “aqueous” or “water”, “closed container”, “pressure, “lack of oxygen”,*

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

**M4**    anaerobic / no oxygen / no air OR neutral pH

**4**

(d)     **M1**    primary OR 1° (alcohol)

*Mark independently*

**M2**    acidified potassium or sodium dichromate

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

***OR***    H2SO4 / K2Cr2O7 OR H+ / K2Cr2O7

*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**

HOCH2CH2CH2CH2OH + **4**[O]  HOOCCH2CH2COOH + **2**H2O

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

**3**

**[15]**

**M32.**          (a)     **2**Ca5F(PO4)3+ 9SiO2 +**15**C9CaSiO3 + CaF2 +**15**CO + **6**P

**1**

(b)     **M1** (P4 =) **0**

**M2** (H3PO4 =) **(+) 5**

*Accept Roman numeral V for* ***M2***

**2**

(c)     H2SO4

***Both numbers*** *required*

*Mr*      = 2(1.00794) + 32.06550 + 4(15.99491)  
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

*Calculations not required*

**and**

H3PO4

*Mr*      = 3(1.00794) + 30.97376 + 4(15.99491)  
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

**1**

(d)     (i)      A substance that speeds up a reaction OR alters / increases the rate of a  
reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas*** *needed*

*Ignore reference to activation energy or alternative route.*

**1**

(ii)     The addition of water (**QoL** ) to a molecule / compound

***QoL- for the underlined words***

**1**

(iii)     **M1** CH3CH=CH2 + H2O  CH3CH(OH)CH3

            (C3H6)

*For* ***M1*** *insist on correct structure for the alcohol but credit correct equations using either C3H6 or double bond not given.*

**M2** propan-2-ol

**2**

**[8]**

**M33.**         (a)      (i)     **M1   (could be scored by a correct mathematical expression which must have  
        all** ∆*H***symbols and the** ∑ or SUM)

**M1**      Δ*Hr* = ΣΔ*Hf* **(products)** - ΣΔ*Hf* **(reactants)**

***OR***     a correct cycle of balanced equations with 1C, 3H2 and 1O2

**M2**     Δ*Hr* = – 201 + (– 242) – (– 394)  
Δ*Hr* = – 201 – 242 + 394  
Δ*Hr* = – 443 + 394  
(This also scores M1)

**M3**    = – **49** (kJ mol–1)  
**(Award 1 mark ONLY for + 49)**

*Correct answer gains full marks*

*Credit 1 mark ONLY for + 49 (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  
         correct cycle of balanced equations with 1C, 3H2 and 1O2*

*OR a clear statement of* ***M1*** *which could be in words and  
         scores only* ***M1***

**3**

(ii)     It is an element / elemental

*Ignore reference to “standard state”*

**OR**

By definition

**1**

(b)     **M1** (The yield) increases / goes up / gets more

*If M1 is given as “decreases” / “no effect” / “no change” then CE= 0 for clip, but mark on only* ***M2*** *and* ***M3*** *from a blank M1*

**M2**   There are more moles / molecules (of gas) on the left / of reactants  
***OR***  fewer moles / molecules (of gas) on the right  
/ products   
***OR***  there are 4 moles /molecules (of gas) on the left and 2 moles / molecules on the right.  
***OR***  (equilibrium) shifts / moves to the side with less moles / molecules

*Ignore “volumes”, “particles” “atoms” and “species” for* ***M2***

**M3: Can only score M3 if M2 is correct**

The (position of) equilibrium shifts / moves (from left to right) to oppose the increase  
in pressure

*For* ***M3****, not simply “to oppose the change”*

*For* ***M3*** *credit the equilibrium shifts / moves (to right) to lower / decrease the pressure*

*(There must be a specific reference to the change that is opposed)*

**3**

(c)     **M1**  Yield increases goes up

**M2**   The (forward) reaction / to the right is endothermic OR takes in/ absorbs  
heat

***OR***

The reverse reaction / to the left is exothermic OR gives out / releases heat

*If M1 is given as “decrease” / “no effect” / “no change” then CE= 0 for clip, but mark on only* ***M2*** *and* ***M3*** *from a blank* ***M1***

**Can only score M3 if M2 is correct**

**M3** The (position of) equilibrium shifts / moves (from left to right) to oppose the increase  
in temperature **(QoL)**

*For* ***M3****, not simply “to oppose the change”*

*For* ***M3****, credit the (position of) equilibrium shifts / moves* ***(QoL)***

*to absorb the heat* ***OR***

*to cool the reaction* ***OR***

*to lower the temperature*

*(There must be a specific reference to the change that is opposed)*

**3**

(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 / level of carbon dioxide /CO2 carbon /greenhouse gas present in the atmosphere.

*The idea that the carbon /CO2 given out equals the carbon /CO2 that was taken in from the atmosphere*

**1**

(ii)     CH3OH    +    **1**½    O2        CO2     +     **2**H2O

*Ignore state symbols*

*Accept multiples*

**1**

(iii)     **3**H2    +     **1**½    O2          **3**H2O

*Ignore state symbols*

***OR***

*Accept multiples*

**2**H2     +     O2         **2**H2O

*Extra species must be crossed through*

**1**

(e)     **M1**    q = m c ∆T

*Award full marks for correct answer*

*Ignore the case for each letter*

***OR***    q = 140 × 4.18 × 7.5

**M2**    = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores M1)

**M3**    Using 0.0110 mol  
therefore ∆H = **– 399** (kJmol–1 )  
OR **– 400**

*Penalise* ***M3*** *ONLY if correct numerical answer but sign is incorrect; +399* ***gains 2 marks***

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

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

*If ∆T = 280.5; score q = m c ∆T only*

*If c = 4.81 (leads to 5050.5) penalise* ***M2*** *ONLY and mark on for* ***M3*** *= – 459*

**+399** **or +400 gains 2 marks**

*Ignore incorrect units*

**3**

**[16]**

**M34.**(a)    (i)      CH2O

*Atoms in any order*

*Accept a clear indication that C6H12O6 yields CH2O 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 C6H12O6  **2**CH3CH2OH + **2**CO2

*Penalise (C2H6O)*

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

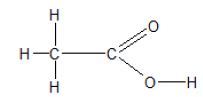
Either order  
M2 (enzymes from) yeast or zymase

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 CH3COOH



*All bonds must be drawn out, but ignore bond angles*

**1**

(ii)     O2 + 4H+ + 4e−  2H2O

*Ignore state symbols*

*Negative charge on electron not essential*

*Accept multiples*

*Accept electrons subtracted from RHS*

**1**

(iii)    CH3CH2OH + H2O   CH3COOH + 4H+ + 4e–

(C2H6O or C2H5OH)

*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*** H2SO4 / K2Cr2O7 OR H+ / K2Cr2O7 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) / H2SO4 +   
K2CrO4*

Possible alternative  
M1 (acidified) potassium manganate(VII) ***OR*** KMnO4 / H2SO4M2 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 / CO2 given out equals the carbon / CO2 that was taken in from the atmosphere / air*

***OR***

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

*Answer must refer to the atmosphere or air*

***OR***

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

**1**

(ii)     Renewable / sustainable ONLY

*Ignore references to global warming or greenhouse gases*

**1**

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

Subject to weather / climate

*Ignore “batch”*

***OR***

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

***OR***

Requires use of / uses more fossil fuels

***OR***

Not carbon-neutral OR CO2 produced during a named process (eg harvest, transport etc.)

***OR***

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

***OR***

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

**1**

**[13]**

**M35.**(a)    (i)      CH2O

*Atoms in any order*

*Accept a clear indication that C6H12O6 yields CH2O 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 C6H12O6  **2**CH3CH2OH + **2**CO2

*Penalise (C2H6O)*

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

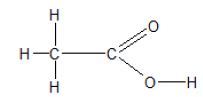
Either order  
M2 (enzymes from) yeast or zymase

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 CH3COOH



*All bonds must be drawn out, but ignore bond angles*

**1**

(ii)     O2 + 4H+ + 4e−  2H2O

*Ignore state symbols*

*Negative charge on electron not essential*

*Accept multiples*

*Accept electrons subtracted from RHS*

**1**

(iii)    CH3CH2OH + H2O   CH3COOH + 4H+ + 4e–

(C2H6O or C2H5OH)

*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*

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*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 / CO2 given out equals the carbon / CO2 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**

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**1**

**[13]**