**Q1.**          Propene reacts with bromine by a mechanism known as electrophilic addition.

(a)     Explain what is meant by the term *electrophile* and by the term *addition*.

*Electrophile* ..................................................................................................

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

*Addition* ........................................................................................................

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

**(2)**

(b)     Explain why bromine, a non-polar molecule, is able to react with propene.

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**(2)**

(c)     Outline the mechanism for the electrophilic addition of bromine to propene. Give the name of the product formed.

*Mechanism*

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

**(5)**

(d)     The polymerisation of propene to form poly(propene) is an important industrial process.

Name the type of polymerisation involved.

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

**(1)**

**(Total 10 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* ...........................................................................................

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(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* .........................................................................

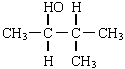
.............................................................................................................

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

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**(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.

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

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

*Alkene 1                                             Alkene 2*

**(5)**

**(Total 10 marks)**

**Q3.**          Epoxyethane is produced commercially by the oxidation of ethene.

State the reagent and the catalyst required for this process and identify two different types of hazard associated with the production of epoxyethane. Write an equation for the reaction of epoxyethane with water in a 1 : 1 mole ratio and give a use for the product obtained. Write an equation for the reaction of an excess of epoxyethane with ethanol and give a use for the product obtained.

**(Total 8 marks)**

**Q4.**          (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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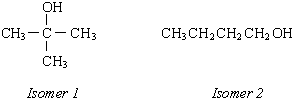
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**(3)**

(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.

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(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.

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(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 .*..............................................................................................

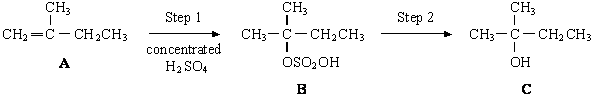
**(2)**

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

**(4)**

**(Total 18 marks)**

**Q5.**          The reaction scheme below shows the conversion of compound **A**, 2-methylbut-1-ene, into compound **B** and then into compound **C**.



(a)     The structure of **A** is shown below. Circle those carbon atoms which must lie in the same plane.



**(1)**

(b)     Outline a mechanism for the reaction in Step 1.

**(4)**

(c)     State the reagent and condition used in Step 2. Name compound **C**.

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

*Condition* .....................................................................................................

*Name of compound* ***C*** ..................................................................................

**(3)**

(d)     When compound **A** is converted into compound **C**, a second alcohol, **D**, is also formed.  
Alcohol **D** is isomeric with **C** but is formed as a minor product. Identify alcohol **D** and explain why it is formed as the minor product.

*Identity of alcohol* ***D .***.....................................................................................

*Explanation* …...............................................................................................

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**(3)**

**(Total 11 marks)**

**Q6.**          (a)     (i)      Write an equation for the formation of epoxyethane from ethene, showing the structure of the product.

(ii)     Explain why the epoxyethane molecule is highly reactive.

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

(iii)     Give the structure of the product formed by the reaction of one molecule of epoxyethane with one molecule of water. Give **one** use for this product.

*Structure*

*Use* ..............................................................................................................

**(5)**

(b)     But-2-ene can exist in two isomeric forms. Give the structures of these two isomers and name the type of isomerism.

*Structure 1*                                                       *Structure 2*

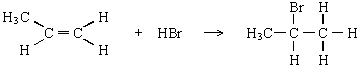
*Type of isomerism* ................................................................................................

**(3)**

**(Total 8 marks)**

**Q7.**          (a)     Propene reacts with hydrogen bromide by an electrophilic addition mechanism forming 2-bromopropane as the major product.

The equation for this reaction is shown below.



(i)      Outline the mechanism for this reaction, showing the structure of the intermediate carbocation formed.

(ii)     Give the structure of the alternative carbocation which could be formed in the reaction between propene and hydrogen bromide.

**(5)**

(b)     A substitution reaction occurs when 2-bromopropane reacts with aqueous sodium hydroxide.

(i)      Draw the structure of the organic product of this reaction and give its name.

*Structure*

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

(ii)     Name and outline the mechanism for this reaction.

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

*Mechanism*

**(5)**

(c)     Under different conditions, 2-bromopropane reacts with sodium hydroxide to produce propene.

(i)      Name the mechanism for this reaction.

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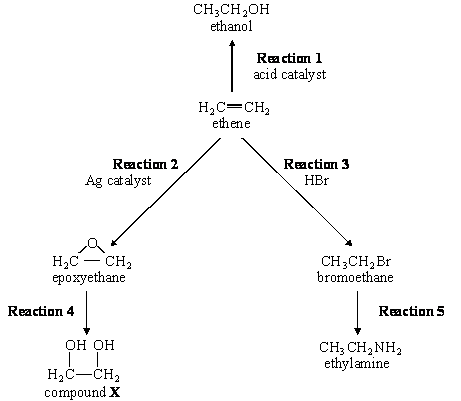
(ii)     State the role of sodium hydroxide in this reaction.

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

**(2)**

**(Total 12 marks)**

**Q8.**          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)**

**Q9.**          (a)     Crude oil is composed mainly of alkanes, which are saturated hydrocarbons.

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

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

(ii)     State what is meant by the term *saturated*, as applied to a hydrocarbon.

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

**(2)**

(b)     Crude oil can be separated into the fractions listed in the table below.

|  |  |
| --- | --- |
| Name of fraction | Number of carbon atoms |
| LPG (liquefied petroleum gas) | 1 – 4 |
| Petrol (gasoline) | 4 – 12 |
| Naphtha | 7 – 14 |
|  | 11 – 15 |
| Gas oil (diesel) | 15 – 19 |
| Mineral oil (lubricating oil) | 20 – 30 |
| Fuel oil | 30 – 40 |

(i)      Name the process used to obtain these fractions from crude oil.

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

(ii)     Complete the table by naming the missing fraction.

**(2)**

(c)     Some of the naphtha fraction is thermally cracked to produce more useful products.

(i)      Give the molecular formula of an alkane with ten carbon atoms.

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(ii)     Write an equation to illustrate the thermal cracking of one molecule of tetradecane, C14H30, in which the products are ethene and propene, in the ratio of 2:1, and one other product.

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(iii)     Name the mechanism involved in thermal cracking.

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**(4)**

**(Total 8 marks)**

**Q10.**          Butenedioic acid, HOOCCH=CHCOOH, occurs as two stereoisomers. One of the isomers readily forms the acid anhydride C4H2O3 when warmed.

(a)     Draw the structures of the two isomers of butenedioic acid and name the type of isomerism shown.  
Use the structures of the two isomeric acids to suggest why only one of them readily forms an acid anhydride when warmed. Draw the structure of the acid anhydride formed.

**(6)**

(b)     Identify one electrophile which will react with butenedioic acid and outline a mechanism for this reaction.

**(4)**

(c)     Write an equation for a reaction which occurs when butenedioic acid is treated with an excess of aqueous sodium hydroxide.

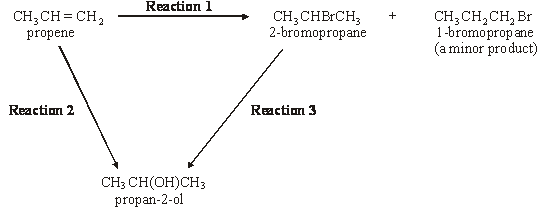
**(2)**

(d)     Describe and explain the appearance of the proton n.m.r. spectrum of butenedioic acid.

**(3)**

**(Total 15 marks)**

**Q11.**          Consider the following reaction scheme.



(a)     (i)      Name the mechanism for **Reaction 1**.

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(ii)     Explain why 1-bromopropane is only a minor product in **Reaction 1**.

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**(3)**

(b)     Give a suitable reagent and state the essential conditions required for **Reaction 3**.

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

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

**(2)**

(c)     The reagent used for **Reaction 3** can also be used to convert 2-bromopropane into propene. State the different conditions needed for this reaction.

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**(1)**

(d)     **Reaction 2** proceeds in two stages.

*Stage 1*      CH3CH=CH2 + H2SO4  →  CH3CH(OSO2OH)CH3

*Stage 2*      CH3CH(OSO2OH)CH3 + H2O  →  CH3CH(OH)CH3 + H2SO4

(i)      Name the class of alcohols to which propan-2-ol belongs.

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

(ii)     Outline a mechanism for Stage 1 of **Reaction 2**, using concentrated sulphuric acid.

(iii)     State the overall role of the sulphuric acid in **Reaction 2**.

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**(6)**

**(Total 12 marks)**

**Q12.**          (a)     Ethanol, C2H5OH, can be made from glucose, C6H12O6

(i)      Write an equation to represent this reaction.

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

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**(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.

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

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(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.

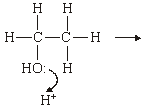
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**(3)**

(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)**

**Q13.**         (a)     Addition reactions to both alkenes and carbonyl compounds can result in the formation of isomeric compounds.

(i)      Choose an alkene with molecular formula C4H8 which reacts with HBr to form two structural isomers. Give the structures of these two isomers and name the type of structural isomerism shown.

Outline a mechanism for the formation of the major product.

(ii)     Using HCN and a suitable carbonyl compound with molecular formula C3H6O, outline a mechanism for an addition reaction in which two isomers are produced.  
Give the structures of the two isomers formed and state the type of isomerism shown.

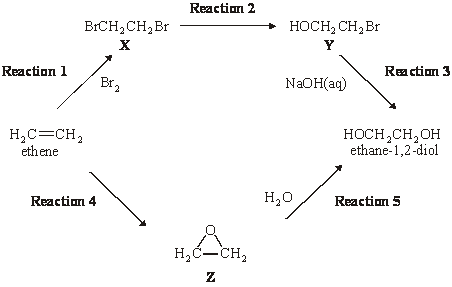
**(14)**

(b)     Explain why ethanoyl chloride reacts readily with nucleophiles.  
Write an equation for one nucleophilic addition–elimination reaction of ethanoyl chloride.   
(A mechanism is not required.)

**(4)**

**(Total 18 marks)**

**Q14.**          Consider the following scheme of reactions for making ethane-1,2-diol from ethene by two different routes.



(a)     Name compound **X** and name a mechanism for **Reaction 1**. Explain why ethene is able to react with bromine in this reaction, given that bromine molecules are non-polar.

**(4)**

(b)     Name and outline a mechanism for **Reaction 3**. Explain why compound **Y** is susceptible to attack by hydroxide ions.

**(4)**

(c)     Identify a reagent and a suitable catalyst for **Reaction 4**. Name compound **Z** and explain why compound **Z** reacts readily with water in **Reaction 5**.

**(4)**

(d)     Give a use for ethane-1,2-diol. For **each** route from ethene to ethane-1,2-diol, identify **one** hazard.

**(3)**

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**(Total 15 marks)**

**Q15.**          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.

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

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**(2)**

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

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

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**(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.

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**(1)**

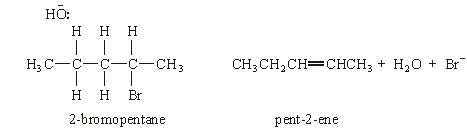
(e)     Name the type of polymerisation which occurs when ethene is converted into poly(ethene).

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**(1)**

**(Total 8 marks)**

**Q16.**          (a)     Complete the mechanism below by drawing appropriate curly arrows.



**(3)**

(b)     Draw and name the geometrical isomers of pent-2-ene.

*Isomer 1*                                                                  *Isomer 2*

*Name* ............................…....................         *Name* .............…...........................

**(2)**

(c)     Pent-1-ene reacts with hydrogen bromide to produce 2-bromopentane as the major product.

(i)      Outline the mechanism for this reaction.

(ii)     Identify the minor product formed in this reaction.

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(iii)     Explain why 2-bromopentane is the major product of this reaction.

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**(7)**

**(Total 12 marks)**

**Q17.**          (a)     (i)      Name the process used to separate petroleum into fractions.

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(ii)     Give the molecular formula for an alkane with nine carbon atoms.

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(iii)     Write an equation for the complete combustion of the alkane C11H24

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(iv)    Write an equation for the incomplete combustion of C11H24 to produce carbon and water only.

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**(4)**

(b)     Alkenes can be produced by cracking the naphtha fraction obtained from petroleum.

(i)      Write an equation for the thermal cracking of one molecule of C10 H22 to give one molecule of propene and one molecule of an alkane only.

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(ii)     Draw the structure of the chain isomer of but-1-ene.

**(2)**

(c)     The alkanes and the alkenes are examples of homologous series of compounds.   
One feature of an homologous series is the gradual change in physical properties as the relative molecular mass increases. State **two** other general features of an homologous series of compounds.

*Feature 1* ......................................................................................................

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*Feature 2* ......................................................................................................

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**(2)**

**(Total 8 marks)**

**Q18.**          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.

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(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* …...........................................................................................

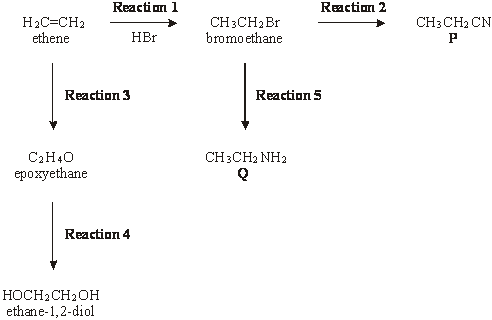
*Observation with oleic acid ……..........................................................*.

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**(5)**

**(Total 10 marks)**

**Q19.**          Consider the following scheme of reactions.



(a)     In **Reaction 1**, ethene undergoes electrophilic addition with hydrogen bromide.

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

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

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(ii)     Outline a mechanism for this reaction.

**(5)**

(b)     Epoxyethane is formed from ethene in **Reaction 3**.

(i)      Identify a reagent and a catalyst for this reaction.

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

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

(ii)     Draw the structure of epoxyethane.

(iii)     Identify a reagent which will react with epoxyethane to form ethane-1,2-diol in **Reaction 4**.

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**(4)**

(c)     In **Reactions 2** and **5**, bromoethane undergoes nucleophilic substitution.

(i)      Identify a reagent for **Reaction 2**. Name the organic product, **P**.

*Reagent for* ***Reaction 2*** ......................................................................

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

(ii)     Identify a reagent for **Reaction 5**. Name the organic product, **Q**.

*Reagent for* ***Reaction 5*** ......................................................................

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

(iii)     Outline a mechanism for **Reaction 5**.

**(8)**

**(Total 17 marks)**

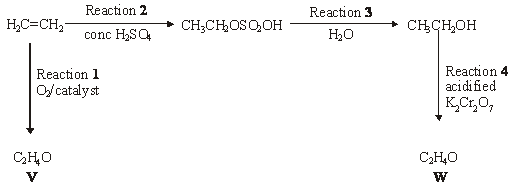
**Q20.**          The table below gives some of the names and structures of isomers having the molecular formula C4H9Br

|  |  |
| --- | --- |
| **Structure** | **Name** |
| CH3CH2CH2CH2Br |  |
|  | 2-bromo - 2-methypropane |
|  | 1-bromo - 2-methypropane |
|  | 2-methypropane |

Complete the table.

**(Total 2 marks)**

**Q21.**         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)**

**Q22.**          (a)     Bromoethane, CH3CH2Br, reacts with sodium hydroxide in an elimination reaction to form ethene.

(i)      Outline a mechanism for this elimination reaction.

(ii)     Suggest **one** reason why this method for making ethene is not used in industry.

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**(4)**

(b)     Ethene is used to make epoxyethane.

(i)      State why epoxyethane is very reactive.

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(ii)     Identify the product formed when one molecule of epoxyethane reacts with one molecule of water. Give a use for this product.

*Product*...............................................................................................

*Use* .....................................................................................................

**(3)**

**(Total 7 marks)**

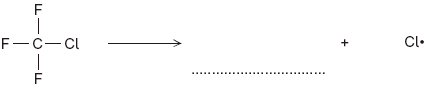
**Q23.**          Oxygen and ozone (O3) both occur as gases in the upper atmosphere.  
Chlorine atoms catalyse the decomposition of ozone and contribute to the formation of a hole in the ozone layer.  
These chlorine atoms are formed from chlorofluorocarbons (CFCs) such as CF3Cl

(a)     (i)      Give the IUPAC name of CF3Cl

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

**(1)**

(ii)     Complete the following equation that shows the formation of a chlorine atom from a molecule of CF3Cl



**(1)**

(iii)     State what the • represents in Cl•

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

**(1)**

(b)     Write two equations that show how chlorine atoms catalyse the decomposition of ozone into oxygen.

Equation 1 ....................................................................................................

Equation 2 ....................................................................................................

**(2)**

(c)     An equilibrium is established between oxygen and ozone molecules as shown below.

3O2(g) 2O3(g)                Δ*H* = +284 kJ mol–1

(i)      State Le Chatelier’s principle.

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**(1)**

(ii)     Use Le Chatelier’s principle to explain how an increase in temperature causes an increase in the equilibrium yield of ozone.

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**(2)**

(d)     Chemists supported the legislation to ban the use of CFCs. Modern refrigerators use pentane rather than CFCs as refrigerants.  
With reference to its formula, state why pentane is a more environmentally acceptable refrigerant.

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**(1)**

**(Total 9 marks)**

**Q24.**          Cetane (C16H34) is a major component of diesel fuel.

(a)     Write an equation to show the complete combustion of cetane.

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

**(1)**

(b)     Cetane has a melting point of 18 °C and a boiling point of 287 °C.  
In polar regions vehicles that use diesel fuel may have ignition problems.  
Suggest **one** possible cause of this problem with the diesel fuel.

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

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**(1)**

(c)     The pollutant gases NO and NO2 are sometimes present in the exhaust gases of vehicles that use petrol fuel.

(i)      Write an equation to show how NO is formed and give a condition needed for its formation.

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

Condition .............................................................................................

**(2)**

(ii)     Write an equation to show how NO is removed from the exhaust gases in a catalytic converter. Identify a catalyst used in the converter.

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

Catalyst ...............................................................................................

**(2)**

(iii)     Deduce an equation to show how NO2 reacts with water and oxygen to form nitric acid (HNO3).

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

**(1)**

(d)     Cetane (C16H34) can be cracked to produce hexane, butene and ethene.

(i)      State **one** condition that is used in this cracking reaction.

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

**(1)**

(ii)     Write an equation to show how one molecule of cetane can be cracked to form hexane, butene and ethene.

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

**(1)**

(iii)     State **one** type of useful solid material that could be formed from alkenes.

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

**(1)**

**(Total 10 marks)**

**Q25.**It is possible to convert but-1-ene into its structural isomer but-2-ene.

(a)     State the type of structural isomerism shown by but-1-ene and but-2-ene.

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

**(1)**

(b)     The first stage in this conversion involves the reaction of hydrogen bromide with but-1-ene.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| CH3CH2CH=CH2 | + | HBr |  | CH3CH2CHBrCH3 |

Outline a mechanism for this reaction.

**(4)**

(c)     The second stage is to convert 2-bromobutane into but-2-ene.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CH3CH2CHBrCHCH3 | + | KOH |  | CH3CH=CHCH3 | + | KBr | + | H2O |

Outline a mechanism for this reaction.

**(3)**

**(Total 8 marks)**

**Q26.**Alkanes are used as fuels. A student burned some octane (C8H18) in air and found that the combustion was incomplete.

(a)     (i)      Write an equation for the incomplete combustion of octane to produce carbon monoxide as the only carbon-containing product.

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

**(1)**

(ii)     Suggest **one** reason why the combustion was incomplete.

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

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

**(1)**

(b)     Catalytic converters are used to remove the toxic gases NO and CO that are produced when alkane fuels are burned in petrol engines.

(i)      Write an equation for a reaction between these two toxic gases that occurs in a catalytic converter when these gases are removed.

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

**(1)**

(ii)     Identify a metal used as a catalyst in a catalytic converter.  
Suggest **one** reason, other than cost, why the catalyst is coated on a ceramic honeycomb.

Metal .....................................................................................................

Reason .................................................................................................

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

**(2)**

(c)     If a sample of fuel for a power station is contaminated with an organic sulfur compound, a toxic gas is formed by complete combustion of this sulfur compound.

(i)      State **one** environmental problem that can be caused by the release of this gas.

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

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**(1)**

(ii)     Identify **one** substance that could be used to remove this gas.  
Suggest **one** reason, other than cost, why this substance is used.

Substance ............................................................................................

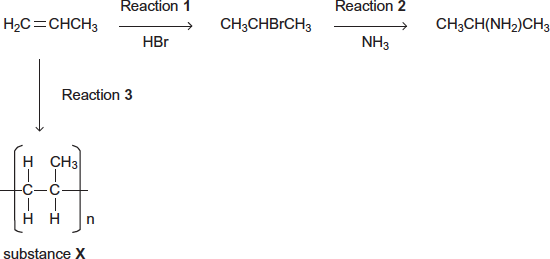
Reason why used ................................................................................

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

**(2)**

**(Total 8 marks)**

**Q27.**Consider the following reactions.



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

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

Mechanism

**(5)**

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

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

Mechanism

**(5)**

(c)     State the type of reaction in Reaction **3**.  
Give the name of substance **X**.

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

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

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

**(2)**

(d)     The haloalkane produced in Reaction **1** can be converted back into propene in an elimination reaction using ethanolic potassium hydroxide.

CH3CHBrCH3   H2C=CHCH3

Outline a mechanism for this conversion.

**(3)**

**(Total 15 marks)**

**Q28.**Ethanol is an important industrial compound.

(a)     Ethanol can be produced by the hydration of ethene.  
The equation for the equilibrium that is established is

H2C=CH2(g)   +   H2O(g)       CH3CH2OH(g) Δ*H* = −42 kJ mol−1

The operating conditions for the process are a temperature of 300 oC and a pressure of 7 MPa.  
Under these conditions, the conversion of ethene into ethanol is 5%.

(i)      Identify the catalyst used in this process.  
Deduce how an overall yield of 95% is achieved in this process without changing the operating conditions.

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**(2)**

(ii)     Use your knowledge of equilibrium reactions to explain why a manufacturer might consider using an excess of steam in this process, under the same operating conditions.

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**(3)**

(iii)    At pressures higher than 7 MPa, some of the ethene reacts to form a solid with a relative molecular mass greater than 5000.

Deduce the identity of this solid.

Give **one** other reason for **not** operating this process at pressures higher than 7 MPa.  
Do **not** include safety reasons.

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**(2)**

(b)     Write an equation for the reaction that has an enthalpy change that is the standard enthalpy of formation of ethanol.

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

**(2)**

(c)     When ethanol is used as a fuel, it undergoes combustion.

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

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**(3)**

(ii)     Consider these bond enthalpy data.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | C–H | C–C | C–O | O=O | C=O | O–H |
|  | **Bond enthalpy / kJ mol−1** | 412 | 348 | 360 | 496 | 805 | 463 |

Use these data and the equation to calculate a value for the enthalpy of combustion of gaseous ethanol.

CH3CH2OH(g)   +   3O2(g)        2CO2(g)   +   3H2O(g)

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

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**(3)**

(d)     Gaseous ethanol can be used to convert hot copper(II) oxide into copper.

(i)      Deduce the role of ethanol in this reaction.

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

**(1)**

(ii)     Draw the structure of the organic compound with *M*r = 60 that is produced in this reaction.

**(1)**

**(Total 17 marks)**

**Q29.**The alkene *(E)*-but-2-enenitrile is used to make acrylic plastics.  
The structure of *(E)*-but-2-enenitrile is



(a)    (i)      Draw the structure of *(Z)*-but-2-enenitrile.

**(1)**

(ii)     Identify the feature of the double bond in the E and Z isomers that causes them to be stereoisomers.

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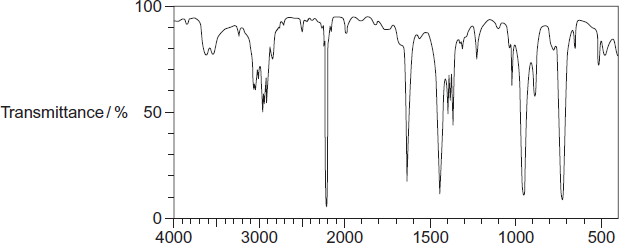
...............................................................................................................

**(1)**

(b)     Draw the repeating unit of the polyalkene formed by addition polymerisation of *(E)*-but-2-enenitrile.

**(1)**

(c)     Consider the infrared spectrum of *(E)*-but-2-enenitrile.



Wavenumber / cm−1

Identify **two** features of the infrared spectrum that support the fact that this is the infrared spectrum for but-2-enenitrile.  
You may find it helpful to refer to **Table 1** on the Data Sheet.

Feature 1 .......................................................................................................

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

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

Feature 2 .......................................................................................................

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

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**(2)**

**(Total 5 marks)**

**Q30.**In each of the following questions, you should draw the structure of the compound in the space provided.

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

**(1)**

(b)     Draw the structure of the alcohol with molecular formula C4H10O that is resistant to oxidation by acidified potassium dichromate(VI).

**(1)**

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

**(1)**

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

**(1)**

**(Total 4 marks)**

**Q31.**The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.  
Describe what you would observe in each case.

(a)     AgBr(s) and AgI(s)

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

Observation with AgBr(s)...............................................................................

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

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

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

**(3)**

(b)     HCl(aq) and HNO3(aq)

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

Observation with HCl(aq) ...............................................................................

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

Observation with HNO3(aq) ..........................................................................

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

**(3)**

(c)     Cyclohexane and cyclohexene

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

Observation with cyclohexane .......................................................................

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

Observation with cyclohexene ......................................................................

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

**(3)**

(d)     Butanal and butanone

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

Observation with butanal ...............................................................................

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

Observation with butanone ............................................................................

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

**(3)**

**(Total 12 marks)**

**Q32.**Sulfuric acid is manufactured by the Contact Process.

(a)     In this process, sulfur dioxide reacts with oxygen.  
The equation for the equilibrium that is established is

SO2(g) + O2(g)       SO3(g) *ΔH* = −98 kJ mol−1

(i)      State and explain the effect of a **decrease** in temperature on the equilibrium yield of SO3.

Effect of a decrease in temperature on yield .......................................

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

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

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

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

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

**(3)**

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

Feature 1 ...............................................................................................

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Feature 2 ..............................................................................................

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

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**(2)**

(b)     Write an equation for the reaction of concentrated sulfuric acid with potassium bromide to form potassium hydrogensulfate and hydrogen bromide.

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

**(1)**

(c)     Bromine is one of the products formed when concentrated sulfuric acid reacts with hydrogen bromide.

Write an equation for this reaction.  
State the role of sulfuric acid in this reaction.

Equation

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

Role of sulfuric acid .......................................................................................

**(3)**

(d)     Concentrated sulfuric acid is used in a two-stage process to convert 2-methylpropene into 2-methylpropan-2-ol.

Stage **1** (CH3)2C=CH2 + H2SO4         (CH3)2C(OSO2OH)CH3

Stage **2**  (CH3)2C(OSO2OH)CH3 + H2O        (CH3)2C(OH)CH3 + H2SO4

(i)      Name and outline a mechanism for Stage **1** of this conversion.

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

Mechanism

**(5)**

(ii)     Deduce the type of reaction in Stage **2** of this conversion.

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

**(1)**

(iii)    State the overall role of sulfuric acid in this conversion.

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

**(1)**

**(Total 16 marks)**

**M1.**          (a)     *Electrophile*: e– pair / lone pair acceptor or e– deficient species or e–seeking species **(1)**

*For ‘species’ accept atom, molecule, ion  
NOT ‘+’ ion  
NOT ‘attracted to ‘‑’ charge’*

*Addition:* reaction which increases number of substituents or  
convert double bond to single bond or where two molecules  
form one molecule **(1)**

**2**

(b)     (High) e– dense or e– rich C=C or e– rich π bond or 4 e– between the C’s **(1)**

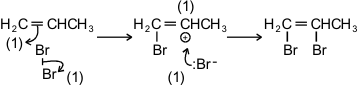
*NOT just ‘C=C’*

          causes induced dipole in Br2 **(1)**

*Ignore refs to ‘temporary’  
can score M2 from δ+ / δ– on Br2 in (c) unless a contradicting error in (b)*

**2**

(c)     *Mechanism:*

**

*If incorrect alkene, lose M3 (wrong cation)  
Mark M4 conseq on M3*

**

*Name of product:* 1,2-dibromopropane **(1)**

**5**

(d)     addition **(1)**

*Not additional*

**1**

**[10]**

**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.**          Oxygen or air **(1)** *Can score from the equation*Silver catalyst **(1)**

Linked to process: e.g. Consequence of leaks etc. **(1)**Hazard 1 = flammable **or** explosive **(1)**Hazard 2: = toxic **or** causes respiratory failure or neurological effects **(1)**

(CH2CH2)O +H2O → HOCH2CH2OH (1) Not (CH2CH2)2O, CH2CH2O,  
C2H4O, but only penalise once  
Uses include antifreeze or polyester formation / terylene (1), Not plastics,  
polymers, surfactants

n(CH2CH2)O + CH3CH2OH → CH3CH2O(CH2CH2O)nH **(1)**Uses include brake fluids or plasticisers **(1)** **OR surfactant or detergent**

*CH3CH2(OCH2CH2)nOH and H(CH2CH2O)n+1OH are OK in  
last equation*

**[8]**

**M4.**          (a)     % O = 21.6 % **(1)**

*If % O not calculated only M2 available*

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

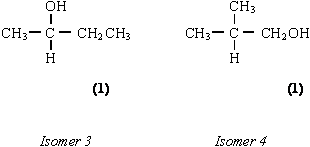
Ratio: 4 : 10: 1     ( C4H10O) **(1)**

*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*

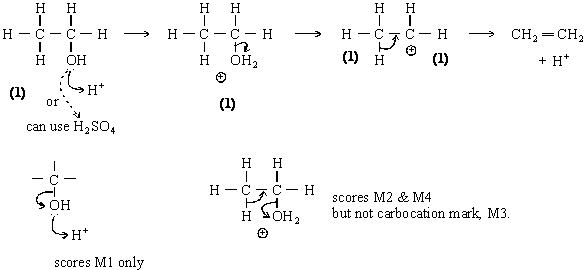
**5**

(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*

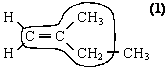
**2**

(e)



**4**

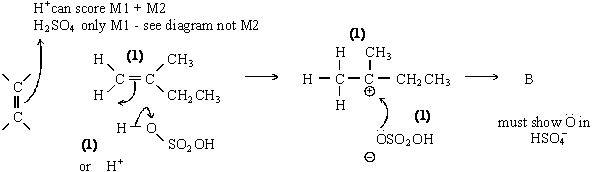
**[18]**

**M5.**          (a)     

*May circle 4 C’s separately*

**1**

(b)



*Ignore δ+ and δ- unless wrong*

**4**

(c)     *Reagent*: H2O or water **OR steam, Or dilute sulphuric acid (1)***Condition*: heat, or warm, or boil or reflux [50-100°C] **(1)***Name of compound* ***C***: 2-methylbutan-2-ol **(1)**

*Allow 2-methylbutane-2-ol  
Penalise hydroxy-2-methylbutane and 2-methylbut-2-ol once only in the paper*

**3**

(d)     *Identity of alcohol D*: 2-methylbutan-1-ol **(1),***OR its structure, could describe  
                                 structure*

*Explanation:* C formed via t-carbocation; D via p-carbocation, **(1)**                     tertiary more stable than primary **(1)**

*If have wrong carbocation can still score stability mark*

**3**

**[11]**

**M6.**          (a)     (i)      H2C=CH2 + ½O2 →  (**OR 2×)**

Product **(1)** M1  
Correct balanced equation **(1)** M2

*OR C2H4OR CH2=CH2OR CH2CH2*

*NOT [O]  
For M2, allow credit when C2H4O OR CH2CH2O are used*

(ii)     strained (ring) **(1)**

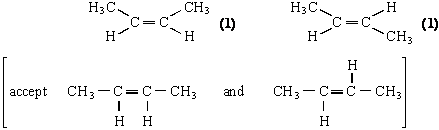
*NOT weak bonds  
NOT unstable  
Credit "stressed"*

(iii)     *Structure*:  **(1)**

*Use*:  antifreeze **(1)**or production of Terylene  
or feedstock for polyester or PET

*NOT plasticiser  
NOT solvent  
NOT de-icer  
NOT alcohol*

**5**

(b)     

*Credit 1 mark for a correct formula for but-2-ene  
Credit 1 mark for any pair of cis / trans isomers*

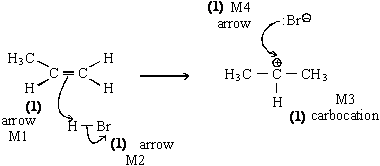
         Geometric(al)  
Or cis-trans  
Or diastereoisomerism

*NOT stereoisomerism*

**3**

**[8]**

**M7.**          (a)     (i)



*If wrong carbocation, lose structure mark  
If wrong alkene, lose structure mark   
Can still score ¾ i.e. penalise M3  
Penalise M2 if      polarity included incorrectly  
     no bond between H and Br  
     bond is shown as  or *

(ii)     

*credit secondary carbocation here if primary carbocation has been used in (i)*

*Ignore attack on this carbocation by *

**5**

(b)     (i)      *Structure*:



*No credit for propan-1-ol even when named correctly*

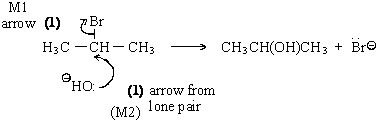
*Credit propane-2-ol*

*Name*: propan-2-ol **(1)**

*Not 2-hydroxypropane*

(ii)     *Name of mechanism*: nucleophilic substitution **(1)** **(both words)  
(NOT SN1 orSN2)**

*Mechanism*:



*penalise incorrect polarity on C‑Br (M1)  
Credit the arrows even if incorrect haloalkane  
If SN1, both marks possible*

**

**5**

(c)     (i)      elimination **(1)***Ignore nucleophylic elimination  
Penalise electrophilic elimination*

(ii)     base **(1)**

*OR proton acceptor  
NOT nucleophile (base)*

**2**

**[12]**

**M8.**          (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*

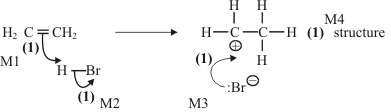
Reaction 4      H2O **(1)**

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]**

**M9.**          (a)     (i)      A molecule / compound / Consists / composed of hydrogen  
and carbon only **(1)**

*or clearly implied*

(ii)     only single bonds (or clearly implied) **(1)**OR has no double bond

*NOT has maximum number of hydrogen atoms*

**2**

(b)     (i)      Fractional distillation OR fraction **(1)**

(ii)

|  |  |
| --- | --- |
| Name of fraction | Number of carbon atoms |
| LPG (liquefied petroleum gas) | 1 – 4 |
| Petrol (gasoline) | 4 – 12 |
| Naphtha | 7 – 14 |
| *Kerosine or Kerosene or Paraffin* **(1)** *(Ignore uses)* | 11 – 15 |
| Gas oil (diesel) | 15 – 19 |
| Mineral oil (lubricating oil) | 20 – 30 |
| Fuel oil | 30 – 40 |

**2**

(c)     (i)      C10H22 only **(1)**

*NOT CH3CH2CH2CH2CH2CH2CH2CH2CH2CH3*

(ii)     C14H30 → 2C2H4 + C3H6 + C7H16

OR C14H30 → 4C2H4 + 2C3H6 + H2

***(1)*** *alkene formula* ***(1)*** *balanced*

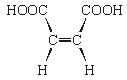
(iii)     (free) radical OR homolysis OR homolytic fission **(1)**

*NOT radical substitution  
NOT thermal decomposition*

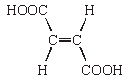
**4**

**[8]**

**M10.**          (a)



**1**

****

**1**

*NB     The bonds shown in the structure must be correct*

         Isomerism: Geometric or cis-trans

*If written answer is correct, ignore incorrect labelling of structures.  
If no written answer, allow correctly labelled structures.*

**1**

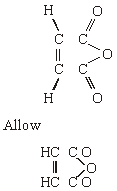
         Both COOH groups must be on the same side/ close together/ cis

**1**

         No rotation about C=C axis

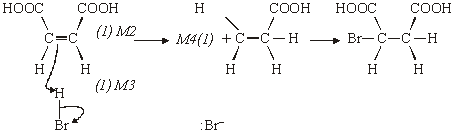
**1**

          Structure



**1**

(b)     Br2 / HBr / H2SO4 / H+ / Br+ / NO2+ (*Mark M1*)



*NB If electrophile H+ / Br+ / NO2+ allow M1, M2 and M4  
     If the acid is incorrect, M2 and M3 can still be scored  
     Allow M4 consequentially if repeat error from part (a)*

**4**

(c)     e.g. 2NaOH + HO2CCHCHCO2H → NaO2CCHCHCO2Na + 2H2O

          Both H replaced

**1**

Balanced for atoms and charges

**1**

*NB Allow ionic equations and      2NaOH + C4H4O4 → C4H2O4Na2+ 2H2O*

*Allow one if structure incorrect but molecular formula  
     correct*

*Allow one for a correct equation showing one H replaced*

(d)     *M1*    Two peaks

**1**

*M2*    No splitting or singlets

**1**

*M3*    (Two) non-equivalent protons or two proton environments

**1**

*M4*    No adjacent protons

**1**

*M5*    Same area under the two peaks or same relative intensity

**1**

*NB Doublet could score M1 and M3 or M5 (Max 2)*

*More than two peaks CE = 0*

*Apply the “list principle” to incorrect answers if more  
     than 3 given*

**Max 3**

**[15]**

**M11.**          (a)     (i)      Electrophilic addition

*(Both words required)*

**1**

(ii)     M1 the reaction to form 1-bromopropane goes *via* the primary  
carbocation OR 1o carbocation

         OR *via* 

M2 primary carbocations are less stable than secondary carbocations

*(Credit converse arguments for M1 and M2 i.e. the reaction to form 2-bromopropane goes via the secondary carbocation , M1, and secondary carbocations are more stable than primary carbocations, M2)*

*(Accept the use of “carbonium ions” as an alternative to carbocation)*

**1**

(b)     M1 NaOH OR KOH OR correct name

**1**

M2 aqueous or solution in water *(ignore heat, reflux etc.)*

*(Penalise M1 for hydroxide ion alone, but mark on and credit M2)  
(Credit M2 ONLY for H2O as reagent and heat / warm / T=50 to 100oC)  
(NaOH(aq) scores M1 and M2 provided it is not contradicted)  
(Penalise M2 if NaOH(aq) followed by concentrated or ethanol)  
(Penalise M1 and M2 if followed by acid)*

**1**

(c)     Ethanolic OR alcoholic OR CH3CH2OH / CH3OH solvent OR  
aqueous ethanol/alcohol  
OR higher temperature *(must be comparative)*

*(Ignore heat or heat under reflux)*

*(Credit part (c) independently from part (b))*

*(Penalise “ethanoic”)*

**1**

(d)     (i)      Secondary OR 2o

**1**

(ii)     

         M1 arrow from double bond to H of H – O bond  
M2 arrow from bond to oxygen atom to show H – O bond breakage  
M4 arrow from lone pair of electrons to carbon atom of carbocation

*(Penalise M1 if arrow goes to H2SO4 or to formal positive charge on H, but ignore partial charges on sulphuric acid unless wrong)*

*(Credit M2 for H+ ion)*

*(For M4, accept negative charge anywhere on the ion)*

**4**

(iii)     Catalyst ONLY

*(Ignore homogeneous, heterogeneous)*

**1**

**[12]**

**M12.**          (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)*

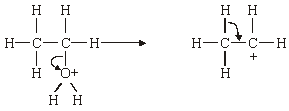
**1**

(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]**

**M13.**          (a)     (i)      An appropriate alkene; CH3CH2CHCH2 or (CH3)2CCH2

**1**

Isomer 1

**1**

Isomer 2

**1**

Position isomerism

**1**

Mechanism

electrophilic attack and electron shift to Br (Unless H+ used)

**1**

carbocation

**1**

reaction with carbocation

*[Allow mechanism marks for the alkene CH3CHCHCH3]  
[Allow one mark if mechanism for minor product given]*

**1**

(ii)     An appropriate carbonyl; CH3CH2CHO

**1**

Mechanism nucleophilic attack and electron shift to O

**1**

anion intermediate

**1**

reaction with anion

*[Allow mechanism marks for the carbonyl (CH3)2CO]*

**1**

         Isomer 1

**1**

Isomer 2

**1**

Optical isomerism

*NB     Isomer structures must be tetrahedral*

*NB     Penalise “stick” structures once in part (a)*

**1**

(b)     QoL  
Large charge on carbonyl carbon atom due to bonding  
to O and Cl

**1**

Nucleophiles have electron pairs which can be donated

**1**

Equation Species

**1**

Balanced

**1**

**[18]**

**M14.**          (a)     M1 X is 1,2-dibromoethane only

**1**

M2 electrophilic addition

*(both words needed)*

**1**

          M3 the double bond is a centre of electron density  
OR electron-rich  
OR nucleophilic  
OR a source of an electron pair  
OR a pi cloud/bond of electrons

**1**

M4 a dipole or polarity is induced/created/formed in the  
Br-Br bond/molecule -  
award this mark only if the quality of language justifies the award.

**1**

(b)     nucleophilic substitution

*(both words needed)*

**1**

Mechanism M1 curly arrow from lone pair on oxygen of hydroxide  
ion to C atom of C-Br

**1**

Mechanism M2 curly arrow from C-Br bond to side of Br atom

*(a possible repeat error here from Question 4a)  
(award a maximum of one mark for the wrong haloalkane)  
(credit an SNl mechanism in which Ml will be a curly arrow from the lone pair on oxygen of the hydroxide ion to the correct positive carbon atom)*

**1**

Y is susceptible to attack by hydroxide ions for one of the following  
reasons

o       the C-Br bond is polar

o       the carbon atom is partially positive (or shown as such)

o       the carbon atom is electron deficient

**1**

(c)     M1 oxygen

*(ignore “air”)*

**1**

M2 silver or silver-based

*(penalise silver nitrate)*

**1**

M3 Z is epoxyethane

**1**

M4 epoxyethane

o       has a strained ring structure

o       has a bond angle of 60°

o       has a bond angle significantly less than tetrahedral

*(ignore “unstable”, “has strained bonds”, “is stressed”)*

**1**

(d)     Ethane-1,2-diol is used in antifreeze  
OR in the manufacture of PET/Terylene/polyester

*(penalise “solvent” or “plasticiser”)*

**1**

          Hazard in Route *via* X/Y

o       bromine is toxic or corrosive

o       sodium hydroxide is corrosive or caustic

**1**

Hazard in Route *via* epoxyethane

o       risk of explosion in reaction 4

o       epoxyethane is toxic

o       epoxyethane is a respiratory irritant

o       epoxyethane causes neurological damage

**1**

**[15]**

**M15.**          (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]**

**M16.**          (a)     M1 curly arrow from lone pair on oxygen of hydroxide ion to  
H atom on C-H adjacent to C-Br

**1**

M2 curly arrow from single bond of adjacent C-H  
to adjacent single bond C-C

*(only credit M2 if M1 is being attempted to correct H atom)*

**1**

M3 curly arrow from C-Br bond to side of Br atom

*(credit M3 independently)*

**1**

(b)     Ml credit a correct structure for either geometrical isomer and its  
designation as either *cis* or *trans.*OR credit two correct geometrical isomer structures  
(ignore the names)  
OR credit two correct names for *cis* pent-2-ene and *trans*pent-2-ene (ignore the structures)

**1**

M2 credit a second mark if all four parts of the required structures and  
names are correct.

*(credit “linear” structures)  
(insist on the alkyl groups being attached clearly by C-C bonds)*

**1**

(c)     (i)      Ml curly arrow from middle of C = C bond to H atom on H-Br

*(penalise M1 if partial negative charge or formal positive   
charge on H)  
(penalise Ml if pent-2-ene is used)*

**1**

         M2 curly arrow from H-Br bond to side of Br atom

**1**

M3 correct structure for correct secondary carbocation

**1**

M4 curly arrow from lone pair on bromide ion to the positive  
carbon of carbocation, ensuring that bromide ion has a  
negative charge.

*(with the exception of pent-2-ene, if the wrong alkene is used, only penalise the structure M3)  
(penalise the use of two dots in addition to a covalent bond, once only)*

**1**

(ii)     1-bromopentane

**1**

(iii)     Ml 2-bromopentane is formed *via* the secondary (or 2°)  
carbocation

**1**

OR 1-bromopentane is formed *via* the primary (or 1°)  
carbocation  
M2 a secondary carbocation is more stable than a primary  
carbocation -  
award this mark only if the quality of language justifies  
the award.

*(the argument must involve clear statements about carbocations)*

**1**

**[12]**

**M17.**          (a)     (i)      fractional distillation or fractionation

**1**

(ii)     C9H20 only

**1**

(iii)     C11H24 + 17O2 → 11CO2 + 12H2O

**1**

(iv)    C11H24 + 6O2 → 11C + 12H2O

**1**

(b)     (i)     C10H22 → C3H6  + C7H16

**1**

(ii)     correctly drawn structure of methylpropene

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

**1**

(c)     Any two from

o     chemically similar or chemically the same or react in  
the same way

o     same functional group

o     same general formula

o     differ by CH2

*(penalise same molecular formula or same empirical formula)*

**2**

**[8]**

**M18.**          (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]**

**M19.**          (a)     (i)      Electron pair/ lone pair acceptor OR seeking/bonds  
with an electron pair

*(insist on reference to a pair of electrons)*

**1**

(ii)     M1 curly arrow from middle of C=C bond of the alkene towards/  
alongside the H atom of the H-Br;

*(penalise arrows which go towards one of the carbon atoms) (ignore a partial negative charge on the C=C)*

**1**

         M2 curly arrow from H-Br bond to side of Br atom;

*(penalise M2 if there are formal charges on HBr or if there are partial charges which are the wrong)  
(penalise M2 if the single bond has two dots in addition to the line)*

**1**

         M3 correct structure for carbocation;

*(penalise M3 if the positive charge is placed on the end of a bond) (penalise M3 if any alkene other than ethene is used - all other marks can score)*

**1**

M4 curly arrow from lone pair on bromide ion to the positive carbon  
of carbocation, ensuring that bromide ion has a negative charge;

(b)     (i)      M1 Oxygen *OR* O2*;*

*(do not credit “air” alone, but otherwise ignore)*

         M2 silver *OR* Ag OR silver-based

*(penalise silver nitrate)*

**1**

(ii)     correct structure for epoxyethane;

*(penalise poorly presented C-O bonds)*

**1**

(iii)     water

         OR

         H2O;

*(credit steam OR H2SO4 (aqueous OR dilute) OR NaOH(aq) OR HCl(aq),  
OR H3PO4(aq), but insist that (aq) is included)  
(do not credit HCl or H2SO4 (concentrated or without water present))*

**1**

(c)     (i)      M1: potassium cyanide OR KCN OR sodium Cyanide OR NaCN;

*(ignore conditions - dissolved in (aq) or (alc) or KOH(aq) all work) (penalise HCN)*

**1**

M2: propanenitrile;

*(credit propan-1-nitrile OR propan nitrile, but not propanitrile)*

**1**

(ii)     M1: ammonia OR NH3;

*(If formula is written, insist that it is correct)  
(ignore conditions, but penalise acidic)*

**1**

M2: ethylamine;

*(credit aminoethane)*

**1**

(iii)     M1: curly arrow from lone pair on nitrogen of (correct formula for)  
ammonia towards/alongside C atom of C-Br;

*(penalise M1 if formula of ammonia is wrong or has a negative charge or has no lone pair or arrow is from negative charge)*

**1**

         M2: curly arrow from C-Br bond towards/alongside side Br atom;

*(credit M2 independently)  
(penalise M2 if formal positive charge on C atom of C-Br)*

**1**

         M3: correct structure of the ethylammonium ion;

*(credit the structure drawn out with all four bonds around the nitrogen atom OR written as C2H5NH3+ OR CH3CH2NH3+)*

**1**

M4: curly arrow from the middle of one of the H-N bonds towards the  
positive *N atom*;

*(possible to credit M4 on an incorrect ethylammonium ion with no positive charge)  
(ignore use of ammonia or bromide ion etc. to remove proton from ethylammonium ion)  
(If the wrong haloalkane is used, award MAX. 3 marks for the mechanism) (If SN1 mechanism is used, give full credit in which M1 is for a curly arrow from the lone pair of the N atom of (correct formula for) ammonia towards/alongside the positive carbon atom of CH3CH2+)*

**[17]**

**M20.**          1(-)bromobutane

**1**

          correct structure for 1-bromo-2-methylpropane

*(C–C bonds must be clear where drawn)*

**1**

**[2]**

**M21.**          (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]**

**M22.**          (a)     (i)      M1 curly arrow from lone pair of electrons on oxygen of hydroxide ion

*(insist on a lone pair of electrons on the oxygen atom and a negative charge, but only credit this mark if the attack is to a correct H atom)*

**1**

M2 curly arrow from the middle of the C–H bond to the middle of   
the C–C bond.

*(only credit this mark if the arrow originates from the correct  
C–H bond and if an attempt has been made at M1)*

**1**

M3 curly arrow from the middle of the C–Br bond towards/alongside   
the Br atom.

*(credit M3 independently unless the bond breaking is   
contradicted by an additional arrow)*

*(penalise M3 curly arrow if the C–Br has a formal positive charge)*

*(ignore partial charges on the C–Br bond, but penalise if incorrect)*

*(credit full marks for an E1 mechanism, with M2 awarded for a correct curly arrow on the correct carbocation)*

*(award a maximum of two marks for an incorrect haloalkane)*

*(ignore products)*

**1**

(ii)     Haloalkane/C2H5Br is made from ethane  
OR haloalkane is not (readily) available  
OR haloalkane is expensive   
OR it is (too) expensive/costly  
OR (reaction) yield is too low/poor  
OR it is too slow  
OR a valid reference to nucleophilic substitution/alcohol formation  
occurring as an alternative reaction.

*(ignore references to temperature or to energy consumption)*

*(do not credit statements which refer to the idea that this route  
is not chosen, because industry chooses another route e.g. cracking)*

**1**

(b)     (i)      Strained ring/ bonds/ structure/molecule  
OR three–membered ring  
OR 60o bond angle  
OR bond angle much less than tetrahedral

*(penalise “stressed ring”)*

*(ignore “weak bonds”, ignore “unstable”)*

**1**

(ii)     ethane–1,2–diol OR correct structure

*(penalise ethylene glycol OR 1,2–dihydroxyethane if these appear alone)*

*(credit ethan–1,2–diol)*

*(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**

(used in) antifreeze  
OR   
for OR in the manufacture/making/formation of terylene, polyester,  
PET only

*(ignore reference to terylene etc. if they accompany “antifreeze”*

*(penalise “de–icer”, “solvent”, “surfactant”, “plasticizer”)*

*(If the candidate indicates that the product is antifreeze ,then this can gain credit, but not if contradicted in its use e.g. as de–icer)*

**1**

**[7]**

**M23.**          (a)     (i)      chlorotrifluoromethane

*Spelling must be correct but do not penalise “flouro”*

*Ignore use of 1–*

**1**

(ii)     CF3•

*May be drawn out with dot on C*

*OR if as shown dot may be anywhere*

**1**

(iii)     An unpaired/non-bonded/unbonded/free/a single/one/lone  
electron

*NOT “bonded electron” and NOT “paired electron”*

*NOT “pair of electrons”*

*NOT “electrons”*

*Ignore “(free) radical”*

**1**

(b)     **M1**   Cl• + O3 → ClO• + O2

**M2**    ClO• + O3 → **2**O2 + Cl•

*Mark independently*

*Equations could gain credit in either position*

*The dot can be anywhere on either radical*

*Penalise the absence of a dot on the first occasion that it is seen and then mark on. Do not make the same penalty in the next equation, but penalise the absence of a dot on the other radical.*

*Apply the list principle for additional equations*

**2**

(c)     (i)      (If any factor is changed which affects an equilibrium),  
the (position of) equilibrium will shift/move so as to oppose  
the change.

***OR***

(When a system/reaction in equilibrium is disturbed),  
the equilibrium shifts/moves in a direction which tends to  
reduce the disturbance

*Must refer to equilibrium*

*Ignore reference to “system” alone*

*A variety of wording will be seen here and the key part is the last phrase.*

*An alternative to shift/move would be the idea of changing/altering the position of equilibrium*

**1**

(ii)     **M1** The (forward) reaction/to the right is endothermic or  
takes in heat

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

**M2** The equilibrium moves/shifts to oppose the increase in  
temperature

*M2 depends on a correct statement for M1*

*For M2 accept*

*The equilibrium moves/shifts*

*•    to take in heat/lower the temperature*

*•    to promote the endothermic reaction and take in heat/   lower the temperature*

*•    to oppose the change and take in heat/lower the             temperature*

*(leading to the formation of more ozone)*

**2**

(d)     Any one of

•        Pentane does not contain chlorine OR C–Cl (bond)

•        Pentane is chlorine-free

•        Pentane does not release chlorine (atoms/radicals)

*Ignore reference to F OR C–F OR halogen*

*Ignore “Pentane is not a CFC”*

*Ignore “Pentane is a hydrocarbon”*

*Ignore “Pentane only contains C and H”*

*Ignore “Pentane is C5H12”*

**1**

**[9]**

**M24.**          (a)     C16H34 + 24.5O2 → 16CO2 + 17H2O

*Allow multiples*

*Ignore state symbols in equation*

**1**

(b)     Solidifies/freezes/goes viscous/waxing occurs

*Allow does not vapourise/less volatile*

*Lack of Oxygen = 0*

*Apply list principle*

**1**

(c)     (i)      N2 + O2 → 2NO

*Allow multiples/Ignore state symbols in equation*

**1**

Spark/(very) high temp/2500 °C – 4000 °C

*Ignore pressure/catalyst/low % of oxygen*

*Not just heat/hot*

*Apply list principle eg if high temp 150 °C = 0*

**1**

(ii)     2CO + 2NO → 2CO2 + N2

*Allow multiples/Ignore state symbols in equation*

***OR***

C8H18 + 25NO → 8CO2 + 12.5 N2 + 9H2O

*Allow other alkane reacting with NO in correctly balanced equation*

***OR***

C + 2NO → CO2 + N2

***OR***

2NO → N2 + O2

**1**

Pt/Pd/Rh/Ir

*Penalise contradiction of name and symbol*

**1**

(iii)     4NO2 + 2H2O + O2 → 4HNO3

*Allow multiples/Ignore state symbols in equation*

**1**

(d)     (i)      High temp/

anywhere in range 400 °C – 900 °C/

anywhere in range 670-1200K/high pressure/anywhere  
in range 5000 kPa up to 8000 kPa/

*Not catalyst/heat*

**1**

(ii)           C16H34 → C6H14 + 2C4H8 + C2H4

Or C16H34 → C6H14 + C4H8 + 3C2H4

*Do not allow multiples*

*Ignore state symbols in equation*

**1**

(iii)     Polymers/plastics/named polymer

*Allow polyesters or polyamides*

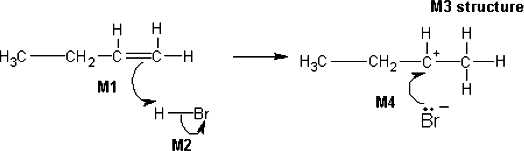
*Ignore object made from polymer*

**1**

**[10]**

**M25.**(a)    Position(al) (isomerism)

**1**

(b)

*Penalise one mark from their total if half-headed arrows are used*

**M1** must show an arrow from the double bond towards the H atom of the H–Br  
      molecule

*M1 Ignore partial negative charge on the double bond.*

**M2** must show the breaking of the H–Br bond.

*M2 Penalise partial charges on H–Br bond if wrong way and penalise formal charges*

**M3** is for the structure of the secondary carbocation.

*Penalise M3 if there is a bond drawn to the positive charge*

**M4** must show an arrow from the lone pair of electrons on the negatively charged  
      bromide ion towards the positively charged carbon atom of either a primary or       secondary carbocation.

*Penalise once only in any part of the mechanism for a line and two dots to show a bond*

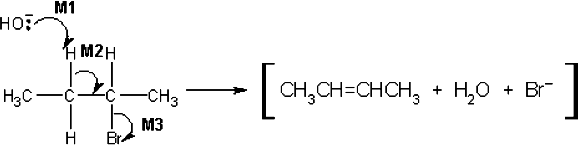
*Maximum any 3 of 4 marks for wrong reactant or primary carbocation.*

*If Br2 is used, maximum 2 marks for their mechanism*

*Do not penalise the use of “sticks”*

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

**4**

(c)

*Penalise one mark from their total if half-headed arrows are used*

**M1** must show an arrow from the lone pair on oxygen of a negatively charged  
      hydroxide ion to a correct H atom

*Penalise M1 if covalent KOH*

**M2** must show an arrow from a C–H bond adjacent to the C–Br bond towards      the appropriate C–C bond. Only award if an arrow is shown attacking the      H atom of an adjacent C–H (in M1)

**M3** is independent provided it is from their original molecule.

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

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

*Ignore other partial charges*

*Penalise once only in any part of the mechanism for a line and two dots to show a bond.*

*Maximum any 2 of 3 marks for wrong reactant or wrong product(if shown) or a mechanism that leads to but-1-ene*

*Accept the correct use of “sticks” for the molecule except for the C–H being attacked*

*Award full marks for an E1 mechanism in which M2 is on the correct carbocation.*

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

***3***

***[8]***

***M26.****(a)      (i)     C8H18 + 8 O2 → 8CO + 9H2O*

*Accept multiples*

***1***

*(ii)     Not enough oxygen or air (available for complete combustion) /lack of oxygen or air / too much octane*

*Ignore poor ventilation, low temp, poor mixing, incomplete combustion*

***1***

*(b)     (i)     2CO + 2NO → 2CO2 + N2*

*Allow multiples*

***1***

*(ii)     Pt / Pd / Rh / Ir or names*

*Apply list principle*

***1***

*Big(ger) surface area / increased reaction rate / removes more of the gases /ensures complete reaction*

*Allow (ceramic) withstands high temperatures*

***1***

*(c)     (i)     Acid rain*

*Allow consequence of acid rain*

*Ignore greenhouse gas / global warming / ozone*

***1***

*(ii)     CaO/ lime / CaCO3 /limestone*

*Allow chemical names*

***1***

*Neutralises the gas or words to that effect/it is basic/ SO2 is acidic*

*Allow ‘reacts with it’ or ‘it is alkaline’*

*Ignore ‘absorb’*

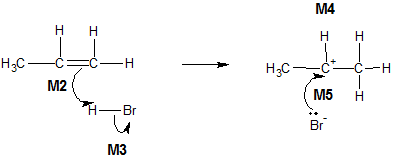
***1***

***[8]***

***M27.****(a)****M1 electrophilic addition***

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

*Accept phonetic spelling*

**

***For the mechanism***

***M2*** *Ignore partial negative charge on the double bond*

*M2 must show an arrow from the double bond towards the H atom of the H–Br molecule*

***M3*** *Penalise partial charges on H–Br bond if wrong way and penalise formal charges*

*M3 must show the breaking of the H–Br bond*

*Penalise once only in any part of the mechanism for a line and two dots to show a bond*

*M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom*

***Maximum any 3 of 4 marks for the mechanism*** *for wrong (organic) reactant* ***OR*** *wrong organic product (if shown)* ***OR*** *primary carbocation*

*Accept the correct use of sticks*

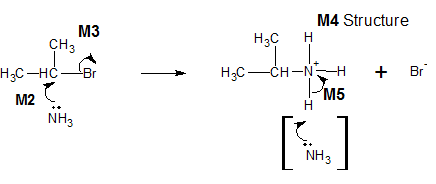
***NB These are double-headed arrows***

***5***

*(b)****M1******Nucleophilic substitution***

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

*Accept phonetic spelling*

**

***For the mechanism***

*Penalise* ***M2*** *if NH3 is negatively charged*

*M2 must show an arrow from the lone pair of electrons* ***on the nitrogen atom*** *of an ammonia molecule to the correct C atom*

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

*Penalise* ***M3*** *for an additional arrow from the Br to something else*

*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 their original molecule*

*The second mole of ammonia is not essential for* ***M5****; therefore ignore any species here*

*M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge* ***must*** *be shown on / or close to, the N atom*

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

*M5 is for an arrow from the N–H bond to the N atom*

***Maximum any 3 of 4 marks for the mechanism*** *for   
wrong organic reactant* ***OR*** *wrong organic product if shown*

*Award full marks for an SN1 mechanism in which* ***M2*** *is the attack of the ammonia on the intermediate carbocation*

*Accept the correct use of “sticks”*

***NB These are double-headed arrows***

***5***

*(c)     M1 (addition) polymerisation OR poly-addition*

*Ignore “additional”*

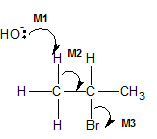
*Credit polyprop-1-ene and polypropylene*

*M2 poly(propene) / polypropene*

*Penalise “condensation polymerisation”*

***2***

*(d)*

**

*Penalise* ***M1*** *if covalent KOH*

*M1 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom*

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

*M2 must show an arrow from a correct C–H bond adjacent to the C–Br bond to the appropriate C–C bond. Only award if an arrow is shown attacking the H atom of a correct C−H bond in* ***M1***

*Ignore other partial charges*

*Penalise once only in any part of the mechanism for a line and two dots to show a bond*

*M3 is independent provided it is from their original molecule, but* ***CE=0 if nucleophilic substitution***

***Maximum any 2 of 3 marks*** *for wrong organic reactant*

*Award full marks for an E1 mechanism in which* ***M3*** *is on the correct carbocation.*

*Accept the correct use of “sticks” for the molecule except for the C–H being attacked*

***NB These are double-headed arrows***

***3***

***[15]***

***M28.****(a)     (i)      M1 c(oncentrated) phosphoric acid / c(onc.) H3PO4****OR*** *c(oncentrated) sulfuric acid / c(onc.) H2SO4*

*In* ***M1****, the acid must be concentrated.  
Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.*

*M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants****OR*** *pass the gases over the catalyst several / many times*

*In* ***M2****, ignore “remove the ethanol”.  
Credit “re-use”.*

***2***

*(ii)     M1   
(By Le Chatelier’s principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction*

***M2 depends on a correct statement of M1****The equilibrium moves / shifts to*

*•        oppose the addition of / increased concentration of / increased moles / increased amount of water / steam*

*•        to decrease the amount of steam / water*

***Mark M3 independently****M3 Yield of product / conversion increase* ***OR*** *ethanol increases / goes up / gets more*

***3***

*(iii)    M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE*

***M2 At higher pressures****More / higher cost of electrical energy to pump / pumping cost****OR****Cost of higher pressure equipment / valves / gaskets / piping etc.****OR*** *expensive equipment*

*Credit all converse arguments for* ***M2***

***2***

*(b)     M1 for balanced equation*

*M2 for state symbols in a correctly balanced equation*

*2C(s / graphite) + 3H2(g) + ½O2(g)   CH3CH2OH(l)  
(C2H5OH)*

*Not multiples but credit correct state symbols in a correctly balanced equation.*

*Penalise C2H6O but credit correct state symbols in a correctly balanced equation.*

***2***

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

*If standard enthalpy of formation* ***CE=0***

*M2 is burned / combusts / reacts completely in oxygen****OR*** *burned / combusted / reacted in excess oxygen*

*M3 with (all) reactants and products / (all) substances in standard / specified states****OR*** *(all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K*

*For* ***M3****Ignore reference to 1 atmosphere*

***3***

*(ii)     M1*

*Correct answer gains full marks*

*ΣB(****reactants****) − ΣB(****products****) = ΔH*

*Credit 1 mark for (+) 1279 (kJ mol−1)*

*OR  
Sum of bonds broken − Sum of bonds formed = ΔH  
OR  
B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS)  
− 4B(C=O) − 6B(O−H) (RHS) = ΔH*

*M2 (also scores* ***M1****)  
348+360+463+5(412)+3(496) [LHS =* ***4719****]  
                         (2060)   (1488)  
− 4(805) − 6(463) [RHS = −* ***5998****] = ΔH  
(3220)     (2778)  
OR using only bonds broken and formed (****4256 − 5535****)*

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

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

*•        If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of* ***M1*** *which could be in words and scores* ***only M1***

*M3  
ΔH=* ***− 1279*** *(kJ mol−1)*

*Allow a maximum of one mark if the only scoring point is LHS = 4719* ***OR*** *RHS = 5998*

*Award 1 mark for +1279*

***Candidates may use a cycle and gain full marks***

***3***

*(d)    (i)      Reducing agent* ***OR*** *reductant* ***OR*** *electron donor****OR*** *to reduce the copper oxide*

*Not “reduction”.*

*Not “oxidation”.*

*Not “electron pair donor”.*

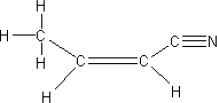
***1***

*(ii)     CH3COOH*

***1***

***[17]***

***M29.****(a)     (i)      Structure of (Z)-but-2-enenitrile with or without either or both of the CH3 and the CN groups displayed*

**

*Penalise C−NC*

*Do not penalise C−H3C*

*Ignore bond angles.*

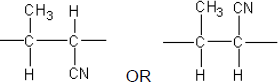
***1***

*(ii)     Restricted rotation / no (free) rotation about the double bond / about the C=C* ***OR*** *does not rotate (about the double bond)*

*Must use the word rotate / rotation.*

***1***

*(b)     Repeating unit of polyalkene*

**

*All the bonds relevant to the unit must be drawn out including those on either side of the unit. There is no need to expand either the CH3 or the CN*

*Penalise C−NC*

*Penalise “sticks”.*

*Ignore brackets.*

*Penalise “n”*

***1***

*(c)****Feature 1****Absorption / peak in the range* ***2220 to 2260*** *cm−1 or specified value in this range or marked correctly on spectrum****and****(characteristic absorption / peak for)* ***C≡N*** */* ***CN*** *group /* ***nitrile*** */* ***cyanide*** *group*

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

*Allow a peak at 2200 cm−1 to 2220 cm−1* ***in this case****.*

***Feature 2****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***

*Ignore reference to other absorptions eg C-H*

*Either order.*

***2***

***[5]***

***M30.****(a)    Structure for 3-methylbut-1-ene*

*H2C=CHCH(CH3)2*

*Any correct structural representation.*

*Credit “sticks” and require the double bond.*

***1***

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

*(CH3)3COH*

*Any correct structural representation.*

*Credit “sticks”.*

***1***

*(c)     Structure for propene*

*H2C=CHCH3*

*Any correct structural representation.*

*Credit “sticks” and require the double bond.*

***1***

*(d)     Structure for 2-aminobutane*

*CH3CH2CH(NH2)CH 3*

*Any correct structural representation.*

*Credit “sticks”.*

***1***

***[4]***

***M31.****(a)     M1 concentrated sulfuric acid OR c(onc) H2SO 4*

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

*M2 (cream solid) turns orange****OR*** *orange / red / brown fumes / gas / vapour*

*If dilute sulfuric acid* ***OR*** *“aq” (alone)* ***CE=0***

*M3 (yellow solid) turns black****OR*** *purple fumes / gas / vapour****OR*** *correct reference to H2S observation (eg bad egg smell)*

*If H2SO4 / sulfuric acid given but not stated whether dilute or concentrated, penalise* ***M1*** *and mark on for* ***M2*** *and* ***M3****If incorrect formula for the acid, penalise* ***M1*** *but mark* ***M2*** *and* ***M3***

***OR as an alternative***

*M1 concentrated ammonia* ***OR*** *c(onc) NH3*

*If NH3 / ammonia / aq ammonia given, but not stated as concentrated* ***OR*** *if dilute ammonia given, penalise* ***M1*** *but mark on for* ***M2*** *and* ***M3****Ignore “partially” and ignore “clear” in* ***M2***

*M2 (cream solid) dissolves / solution formed*

*M3 precipitate remains / does not dissolve / insoluble****OR*** *no reaction / no change / (yellow solid) turns to white solid*

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

*In* ***M3*** *for ammonia.  
ignore “nothing (happens)”.  
ignore “no observation”.*

***3***

*(b)     M1 AgNO3* ***OR*** *silver nitrate* ***OR*** *any soluble silver salt*

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

*M2 white precipitate or white solid / white suspension*

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

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

*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***

*Credit alternative test for nitrate ions*

*For* ***M2****Ignore “cloudy solution”* ***OR*** *“suspension”.*

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

***3***

*(c)     M1 Br2* ***OR*** *bromine (water)* ***OR*** *bromine (in CCl4 / organic solvent)*

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

***Either Order***

*M2     (stays) Orange / red / yellow / brown / the same****OR*** *no reaction* ***OR*** *no (observed) change****OR*** *reference to colour going to cyclohexane layer*

*No credit for combustion observations;* ***CE=0****For* ***M2 in every case****.  
Ignore “nothing (happens)”.  
Ignore “no observation”.  
Ignore “clear”.*

*M3 decolourised / goes colourless / loses its colour*

***With bromine (water)  
For M1****, it must be a whole reagent and / or correct formula.  
If oxidation state given in name, it must be correct.****For M1*** *penalise incorrect formula, but mark* ***M2*** *and* ***M3***

***OR as an alternative***

***Use KMnO4/H2SO4****M1 acidified potassium manganate(VII) or KMnO4/H2SO4****OR****KMnO4/ H+* ***OR*** *acidified KMnO4M2 (stays) purple or no reaction or no (observed) change*

***With potassium manganate(VII)  
For M1***

M3 purple to colourless solution ***OR*** goes colourless

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

Credit alternative test using **iodine** (for **M1**)  
M2 (brown) to purple or accept no change, M3 colourless  
Credit alternative test using concentrated H2 SO4M2 no change, M3 brown

*Credit alkaline / neutral KMnO4 for possible full marks but* ***M3*** *gives brown precipitate or solution goes green.*

**3**

(d)     M1 Tollens’ (reagent) OR 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 (Ignore silver precipitate)  
M3 (stays) colourless or no reaction or no (observed) change

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

***For M3 in every case****Ignore “nothing (happens)”.  
Ignore “no observation”.*

Alternative using Fehling’s (solution)  
M1 Fehling’s (solution) or Benedict’s solution  
(Ignore Cu2+(aq) or CuSO4 on their own, but mark M2 and M3)  
M2 Red solid / precipitate (Credit Orange or brown solid)  
M3 (stays) blue or no reaction or no (observed) change

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

Alternative using K2Cr2O7/H2 SO4M1 acidified potassium dichromate or K2Cr2O7/H2SO4***OR*** K2Cr2O7/H+ ***OR*** acidified K2Cr2O7M2 (Orange to) green solution OR goes green  
M3 (stays) Orange or no reaction or no (observed) change

*For* ***M3****Ignore dichromate described as “yellow” or “red”.*

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

Alternative using KMnO4 /H2 SO4M1 acidified potassium manganate(VII) or KMnO4 /H2 SO 4***OR*** KMnO 4 /H + ***OR*** acidified KMnO 4M2 purple to colourless solution OR goes colourless  
M3 (stays) purple or no reaction or no (observed) change

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

**3**

**[12]**

**M32.**(a)     (i)      M1 (Yield) increases / goes up / gets more

*If* ***M1*** *is blank, mark on and seek to* ***credit the correct information in the explanation.****If* ***M1*** *is incorrect CE=0 for the clip.*

M2  
The (forward) reaction / to the right is exothermic or gives out / releases heat   
***OR*** The reverse reaction / to the left is endothermic or takes in / absorbs heat

***M3*** *depends on a correct statement for* ***M2***

**M3 depends on correct M2 and must refer to temperature / heat**The (position of ) equilibrium shifts / moves left to right to oppose the  
decrease in temperature

*For* ***M3****, the equilibrium shifts / moves  
to release heat* ***OR****to raise the temperature* ***OR****to heat up the reaction.*

**3**

(ii)     M1    *Concentration(s)* (of reactants and products) remain or stay constant /  
         the same

*For* ***M1*** *credit [ ] for concentration.*

M2    Forward rate = reverse / backward rate

*Not “equal concentrations”.  
Not “concentrations is / are the same”.  
Not “amount”.*

*Ignore “dynamic” and ignore “speed”.*

*Ignore “closed system”.*

*It is possible to score both marks under the heading of a single feature.*

**2**

(b)     KBr + H2SO4   KHSO4 + HBr

*Credit this equation in its ionic form.*

*Ignore state symbols.*

*Credit multiples.*

**1**

(c)     M1 SO2 identified

**M2 correctly balanced equation (would also gain M1)**

*Credit* ***M2*** *equation in its ionic form.*

*Ignore state symbols.*

**2**HBr + H2SO4   Br2 + SO2 + **2**H2O

*Credit multiples.*

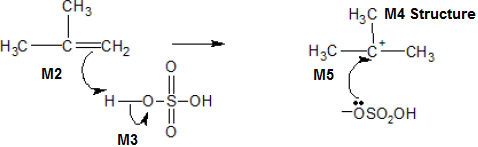
*Not H2SO3 on the right-hand side.*

**Mark M3 independently**M3 Oxidising agent ***OR*** electron acceptor ***OR*** oxidant  
***OR*** to oxidise the bromide (ion) / HBr

***M3*** *Not “electron pair acceptor”.*

**3**

(d)    (i)      **M1 Electrophilic addition**



***M1*** *both words required.*

***For the mechanism  
M3*** *Penalise incorrect partial charges on O − H bond and penalise formal charges  
Ignore partial negative charge on the double bond.*

***M5*** *Not HSO4 –*

*For* ***M5****, 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.*

M2 must show an arrow from the double bond towards the H atom of the H − O bond / HO on a compound with molecular formula for H2SO4M2 could be to an H+ ion and M3 an independent O − H bond break on a compound with molecular formula for H2SO4

*Max any 3 of 4 marks* ***for a correct mechanism*** *using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation.*

M3 must show the breaking of the O − H bond on H2SO4

*Penalise once only in any part of the mechanism for a line and two dots to show a bond.*

M5 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 on their carbocation

*Credit the correct use of “sticks”.*

*For* ***M5****, credit attack on a partially positively charged carbocation structure, but penalise* ***M4***

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

**5**

(ii)     Hydrolysis

*Credit “(nucleophilic) substitution” but do not accept any other prefix.*

*Credit phonetic spelling.*

**1**

(iii)    Catalyst

**1**

**[16]**