**Q1.**          (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

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

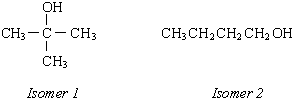
......................................................................................................................

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

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

**(3)**

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



(i)      What type of alcohol is Isomer 1? Suggest a reason why this type of alcohol is not easily oxidised.

*Type of alcohol* ...................................................................................

*Reason ..*.............................................................................................

(ii)     Draw the structural formulae of the two remaining alcohols of molecular formula C4H10O

*Isomer 3*                                             *Isomer 4*

**(4)**

(c)     Isomer 2 was oxidised by adding it dropwise to acidified potassium dichromate(VI) solution and immediately distilling off the product. When this product was treated with Fehling’s solution, a red precipitate was formed.

(i)      State the type of product distilled off during the oxidation by acidified potassium dichromate(VI) solution.

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

(ii)     Write an equation for the oxidation by potassium dichromate(VI), showing clearly the structure of the organic product. Use [O] to represent the oxidising agent.

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

(iii)     Name and draw a structure for the organic product formed by the reaction with Fehling’s solution.

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

*Structure* .............................................................................................

**(5)**

(d)     State **one** advantage and **one** disadvantage of the production of ethanol by the hydration of ethene compared to the fermentation of glucose.

*Advantage* ...................................................................................................

*Disadvantage .*..............................................................................................

**(2)**

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

**(4)**

**(Total 18 marks)**

**Q2.**          (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)**

**Q3.**          The alkanes form an homologous series of hydrocarbons.  The first four straight-chain alkanes are shown below.

methane                          CH4ethane                             CH3CH3propane                           CH3CH2CH3butane                             CH3CH2CH2CH3

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

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

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

(ii)     Give the general formula for the alkanes.

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

(iii)     Give the molecular formula for hexane, the sixth member of the series.

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

**(3)**

(b)     Each homologous series has its own general formula. State **two** other characteristics of an homologous series.

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

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

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

**(2)**

(c)     Branched-chain structural isomers are possible for alkanes which have more than three carbon atoms.

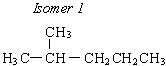
(i)      State what is meant by the term *structural isomers.*

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

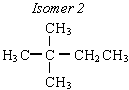
.............................................................................................................

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

(ii)     Name the **two** isomers of hexane shown below.



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



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

(iii)     Give the structures of **two** other branched-chain isomers of hexane.

*Isomer 3*                                             *Isomer 4*

**(6)**

(d)     A hydrocarbon, **W,** contains 92.3% carbon by mass.  The relative molecular mass of   
**W** is 78.0

(i)      Calculate the empirical formula of **W**.

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

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

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

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

(ii)     Calculate the molecular formula of **W**.

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

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

**(4)**

**(Total 15 marks)**

**Q4.**          Four isomers with the formula C4H9OH are given below.

|  |  |
| --- | --- |
| Isomer | Name |
| CH3CH2CH2CH2OH | butan-1-ol |
|  | 2-methylpropan-2-ol |
|  |  |
|  |  |

(i)      Complete the naming of the isomers in the table above.

(ii)      Name the type of isomerism shown by these four isomers.

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

**(Total 3 marks)**

**Q5.**          (a)     Compounds with double bonds between carbon atoms can exhibit geometrical isomerism.

(i)      Draw structures for the two geometrical isomers of 1,2-dichloroethene.

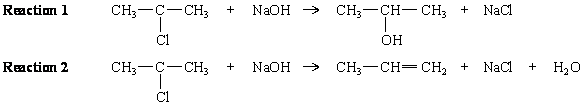
*Isomer 1*                       *Isomer 2*

(ii)     What feature of the double bond prevents isomer 1 from changing into isomer 2?

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

**(3)**

(b)     When 2-chloropropane reacts with sodium hydroxide, two different reactions occur.  
Each reaction produces a different organic product.



(i)      Outline a mechanism for **Reaction 1** and state the role of the hydroxide ion in this reaction.

*Mechanism*

*Role of the hydroxide ion* ....................................................................

(ii)     Outline a mechanism for **Reaction 2** and state the role of the hydroxide ion in this reaction.

*Mechanism*

*Role of the hydroxide ion* ....................................................................

**(7)**

**(Total 10 marks)**

**Q6.**          (a)     (i)      Give a suitable reagent and state the necessary conditions for the conversion of propan-2-ol into propanone. Name the type of reaction.

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

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

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

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

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

*Equation*

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

**(5)**

(b)     Propanal is an isomer of propanone.

(i)      Draw the structure of propanal.

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

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

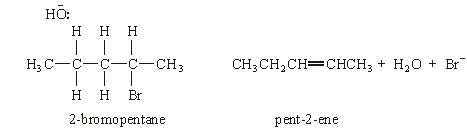
*Observation with propanone* ................................................................

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

**(4)**

**(Total 9 marks)**

**Q7.**          (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.

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

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

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

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

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

**(7)**

**(Total 12 marks)**

**Q8.**          Consider the following reaction schemes involving two alcohols, **A** and **B**, which are position isomers of each other.

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

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

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

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

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

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

**(2)**

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

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

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

**(2)**

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

(i)      State the type of reaction.

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

(ii)     Identify a suitable combination of reagents.

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

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

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

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

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

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

**(6)**

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

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

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

**(2)**

**(Total 12 marks)**

**Q9.**          (a)     (i)      Name the process used to separate petroleum into fractions.

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

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

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

.......................................................................…...............................

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

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

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

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

**(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.

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

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

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

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

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

**(2)**

**(Total 8 marks)**

**Q10.**Consider the following reaction in which an alkene is formed from a haloalkane.



(a)     Name the haloalkane used in this reaction.

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

**(1)**

(b)     Name and outline a mechanism for this reaction.

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

*Mechanism*

**(4)**

(c)     Another alkene, which is a structural isomer of but-2-ene, is also formed during this reaction.

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

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

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

(ii)     Draw the structure of this other alkene.

**(2)**

**(Total 7 marks)**

**Q11.**          Petroleum is separated into fractions by fractional distillation.  
The petrol fraction (C4 to C12) is burned in internal combustion engines and the naphtha  
fraction (C7 to C14) is cracked.

(a)     Petroleum is separated into fractions when it is heated and the vapour mixture is passed into a fractionating column.

(i)      Explain what is meant by the term *fraction* as applied to fractional distillation.

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

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

(ii)     State a property of the molecules in petroleum which allows the mixture to be separated into fractions.

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

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

(iii)     Describe the temperature gradient in the column.

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

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

**(3)**

(b)     The fractions from petroleum contain alkane hydrocarbons.

(i)      Write an equation for the incomplete combustion of the alkane C8H18 to produce carbon monoxide and water only.

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

(ii)     One isomer of C8H18 is 2,2,3-trimethylpentane. Draw the structure of this isomer.

**(2)**

(c)     State **one** economic reason for the cracking of petroleum fractions.

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

**(1)**

(d)     (i)      Give the type of reactive intermediate formed during catalytic cracking.

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

(ii)     Identify a catalyst used in catalytic cracking.

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

**(2)**

(e)     (i)      Give the type of reactive intermediate formed during thermal cracking.  
State how this reactive intermediate is formed.

*Reactive intermediate* ..........................................................................

*How intermediate is formed* .................................................................

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

(ii)     Identify the different type of hydrocarbon produced in a high percentage by the thermal cracking of alkanes.

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

**(3)**

**(Total 11 marks)**

**Q12.**          The fractions obtained from petroleum contain saturated hydrocarbons that belong to the homologous series of alkanes.

(a)     Any homologous series can be represented by a general formula.

(i)      State **two** other characteristics of homologous series.

*Characteristic 1 .*..................................................................................

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

*Characteristic 2 .*..................................................................................

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

(ii)     Name the process which is used to obtain the fractions from petroleum.

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

(iii)     State what is meant by the term *saturated*, as applied to hydrocarbons.

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

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

**(4)**

(b)     Decane has the molecular formula C10H22

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

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

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

(ii)     Give the molecular formula of the alkane which contains 14 carbon atoms.

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

(iii)     Write an equation for the incomplete combustion of decane, C10H22, to produce carbon and water only.

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

**(3)**

(c)     When petrol is burned in an internal combustion engine, some nitrogen monoxide, NO, is formed. This pollutant is removed from the exhaust gases by means of a reaction in a catalytic converter.

(i)      Write an equation for the reaction between nitrogen and oxygen to form nitrogen monoxide.

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

(ii)     Identify a catalyst used in a catalytic converter.

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

(iii)     Write an equation to show how nitrogen monoxide is removed from the exhaust gases as they pass through a catalytic converter.

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

**(3)**

**(Total 10 marks)**

**Q13.**         There are **seven** isomeric carbonyl compounds with the molecular formula C5H10O.  
The structures and names of some of these isomers are given below.

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

(a)     (i)      Complete the table.

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

*isomeric aldehyde*                           *isomeric ketone*

**(4)**

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

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

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

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

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

**(2)**

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

(i)      Identify this alcohol.

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

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

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

**(2)**

**(Total 8 marks)**

**Q14.**          The reaction of bromine with ethane is similar to that of chlorine with ethane. Three steps in the bromination of ethane are shown below.

Step **1**                          Br2  2Br•

Step **2**         Br• + CH3CH3  CH3CH2• + HBr

Step **3**         CH3CH2• + Br2CH3CH2Br + Br•

(a)     (i)      Name this type of mechanism.

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

(ii)     Suggest an essential condition for this reaction.

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

(iii)     Steps **2** and **3** are of the same type. Name this type of step.

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

(iv)    In this mechanism, another type of step occurs in which free-radicals combine. Name this type of step. Write an equation to illustrate this step.

*Type of step* .......................................................................................

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

**(5)**

(b)     Further substitution in the reaction of bromine with ethane produces a mixture of liquid organic compounds.

(i)      Name a technique which could be used to separate the different compounds in this mixture.

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

(ii)     Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C2Br6, by this substitution reaction.

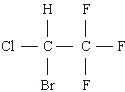
.............................................................................................................

**(2)**

(c)     The compound 1,2-dibromo-1,1,2,2-tetrafluoroethane is used in some fire extinguishers. Draw the structure of this compound.

**(1)**

(d)     Halothane is used as an anaesthetic and has the following structure.



(i)      Give the systematic name of *halothane*.

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

(ii)     Calculate the *M*r of halothane.

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

(iii)     Calculate the percentage by mass of fluorine in halothane.

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

**(3)**

**(Total 11 marks)**

**Q15.**         Petrol contains saturated hydrocarbons. Some of the molecules in petrol have the molecular formula C8H18 and are referred to as octanes. These octanes can be obtained from crude oil by fractional distillation and by cracking suitable heavier fractions.

Petrol burns completely in a plentiful supply of air but can undergo incomplete combustion in a car engine.

(a)     State the meaning of both the words *saturated* and *hydrocarbon* as applied to the term *saturated hydrocarbon*.

Name the homologous series to which C8H18 belongs.

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

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

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

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

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

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

**(3)**

(b)     Outline the essential features of the fractional distillation of crude oil that enable the crude oil to be separated into fractions.

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

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

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

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

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

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

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

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

**(4)**

(c)     C8H18 is obtained by the catalytic cracking of suitable heavy fractions.  
State what is meant by the term *cracking* and name the catalyst used in catalytic cracking.

Write an equation to show how one molecule of C14H30 is cracked to form one molecule of C8H18 and one molecule of another hydrocarbon.

Explain why oil companies need to crack ‘suitable heavy fractions’.

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

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

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

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

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

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

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

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

**(4)**

(d)     Write an equation for the incomplete combustion of C8H18 to form carbon monoxide and water only.

A catalytic converter is used to remove carbon monoxide from the exhaust gases in a car. Identify a catalyst used in the catalytic converter.

Write an equation to show how carbon monoxide is removed in a catalytic converter.

State why the water produced in the exhaust gases may contribute to global warming.

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

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

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

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

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

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

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

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

**(4)**

(e)     When some petrol was accidentally contaminated in 2007, the sensors in the affected cars caused a decrease in the supply of petrol to the engine.

Suggest the effect that the contaminated fuel would have on the performance of the cars.

State how the oil company might have recognised the problem before the petrol was sold.

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

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

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

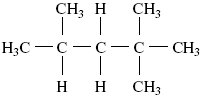
......................................................................................................................

**(2)**

(f)      The molecular formula C8H18 represents several structural isomers.

State what is meant by the term *structural isomers*.

Name the following structural isomer of C8H18



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

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

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

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

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

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

**(3)**

**(Total 20 marks)**

**Q16.**          The reaction of bromine with an alkene is used in a test to show that the alkene is unsaturated.

(a)     State what is meant by the term *unsaturated* as applied to an alkene.

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

**(1)**

(b)     Name and outline a mechanism for the reaction of bromine with but-2-ene.

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

Mechanism

**(5)**

(c)     But-2-ene can exist as a pair of stereoisomers.

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

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

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

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

**(2)**

(ii)     Draw the structure of (*E*)-but-2-ene.

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

**(1)**

**(Total 9 marks)**

**Q17.**          Hexane is a member of the homologous series of alkanes.

(a)     State **two** characteristics of a *homologous series*.

Characteristic 1 ............................................................................................

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

Characteristic 2 …….....................................................................................

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

**(2)**

(b)     (i)      Hexane can be converted into 2,2-dichlorohexane.

Draw the displayed formula of 2,2-dichlorohexane and deduce its empirical formula.

Displayed formula

Empirical formula ................................................................................

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

**(2)**

(ii)     Explain why 2,2-dichloro-3-methylpentane is a structural isomer of 2,2-dichlorohexane.

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

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

**(2)**

(c)     A reaction of hexane with chlorine is shown by the equation below.

C6H14  +  2Cl2  →  C6H12Cl2  +  2HCl

Calculate the percentage atom economy for the formation of C6H12Cl2 in this reaction.

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

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

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

**(2)**

(d)     The boiling points of some straight-chain alkanes are shown below.

|  |  |  |  |
| --- | --- | --- | --- |
| Alkane | C4H10 | C5H12 | C6H14 |
| Boiling point / °C | – 0.5 | 36.3 | 68.7 |

(i)      Explain the trend in these boiling points.

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

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

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

**(2)**

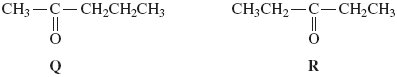
(ii)     Name a process which can be used to separate C5H12 from C6H14

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

**(1)**

**(Total 11 marks)**

**Q18.**          Two isomeric ketones are shown below.



(a)     Name and outline a mechanism for the reaction of compound **Q** with HCN and name the product formed.

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

Mechanism

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

**(6)**

(b)     Some students were asked to suggest methods to distinguish between isomers **Q** and **R**.

One student suggested testing the optical activity of the products formed when **Q** and **R** were reacted separately with HCN.

By considering the optical activity of these products formed from **Q** and **R**, explain why this method would **not** distinguish between **Q** and **R**.

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

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

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

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

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

**(3)**

(c)     Other students suggested using mass spectrometry and the fragmentation patterns of the molecular ions of the two isomers to distinguish between them.

They predicted that only one of the isomers would have a major peak at *m/z* = 57 in its mass spectrum so that this method would distinguish between **Q** and **R**.

(i)      Identify the isomer that has a major peak at *m/z* = 57 in its mass spectrum.

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

**(1)**

(ii)     Write an equation for the fragmentation of the molecular ion of this isomer to form the species that produces the peak at *m/z* = 57.

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

**(2)**

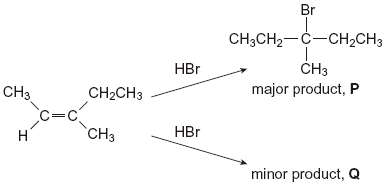
(iii)     Predict the *m/z* value of a major peak in the mass spectrum of the other isomer.

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

**(1)**

**(Total 13 marks)**

**Q19.**          The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



(a)     (i)      Name the major product **P**.

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

**(1)**

(ii)     Name the mechanism for these reactions.

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

**(1)**

(iii)     Draw the displayed formula for the minor product **Q** and state the type of structural isomerism shown by **P** and **Q**.

Displayed formula for **Q**

Type of structural isomerism ..............................................................

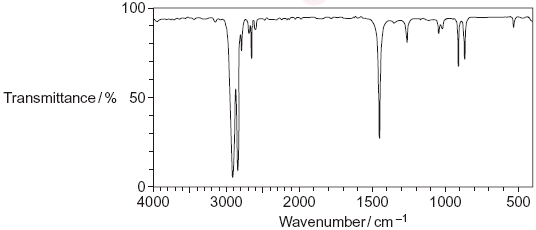
**(2)**

(iv)    Draw the structure of the (E)-stereoisomer of 3-methylpent-2-ene.

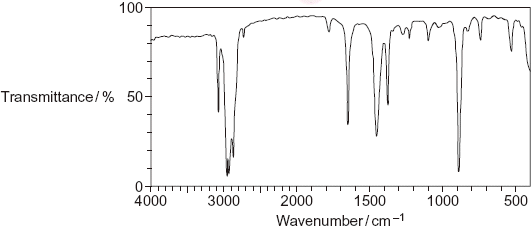
**(1)**

(b)     The infrared spectra of two compounds **R** and **S** are shown below. **R** and **S** have the molecular formula C6H12 and are structural isomers of 3-methylpent-2-ene. **R** is an unsaturated hydrocarbon and **S** is a saturated hydrocarbon.

Spectrum **1**

****

Spectrum **2**

****

(i)      Identify the infrared Spectrum **1** or **2** that represents compound **R**.  
Use information from the infrared spectra to give **one** reason for your answer.  
You may find it helpful to refer to **Table 1** on the Data Sheet.

**R** is represented by Spectrum ................

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

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

**(2)**

(ii)     State the type of structural isomerism shown by **R** and **S**.

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

**(1)**

(iii)     Name **one** possible compound which could be **S**.

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

**(1)**

**(Total 9 marks)**

**Q20.**          Octane is the eighth member of the alkane homologous series.

(a)     State **two** characteristics of a homologous series.

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

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

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

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

**(2)**

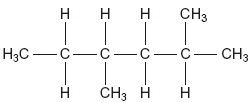
(b)     Name a process used to separate octane from a mixture containing several different alkanes.

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

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

**(1)**

(c)     The structure shown below is one of several structural isomers of octane.



Give the meaning of the term structural isomerism.  
Name this isomer and state its empirical formula.

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

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

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

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

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

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

**(4)**

(d)     Suggest why the branched chain isomer shown above has a lower boiling point than octane.

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

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

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

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

**(2)**

**(Total 9 marks)**

**Q21.**          The table below shows the structures of three isomers with the molecular formula C5H10O

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

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

**(1)**

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

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

**(1)**

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

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

**(1)**

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

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

**(1)**

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

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

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

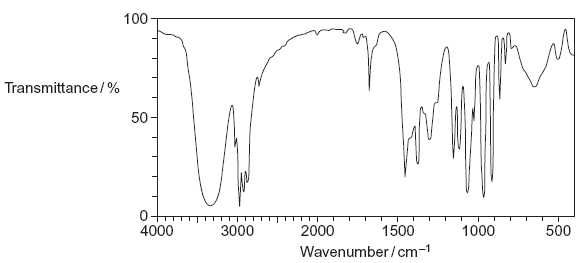
.....................................................................................................................

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

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

**(3)**

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



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

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

**(1)**

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

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

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

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

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

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

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

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

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

**(2)**

**(Total 10 marks)**

**Q22.**          (a)     Give the **formula** of a Group 2 metal hydroxide used in agriculture.

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

**(1)**

(b)     Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

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

**(1)**

(c)     Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.

Give the **formula** of **X**.

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

**(1)**

(d)     Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

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

**(1)**

(e)     Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.

Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product ......................................................

Formula of the oxidation product ................................................................

**(2)**

(f)      Draw the structure of each of the following organic compounds.

(i)      The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

**(1)**

(ii)     The alcohol that is a position isomer of butan-2-ol.

**(1)**

(iii)     The hydrocarbon that has a peak, due to its molecular ion, at *m/z* = 44 in its mass spectrum.

**(1)**

(iv)    The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

**(1)**

**(Total 10 marks)**

**Q23.**The following table shows the boiling points of some straight-chain alkanes.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | CH4 | C2H6 | C3H8 | C4H10 | C5H12 |
|  | Boiling point / °C | −162 | −88 | −42 | −1 | 36 |

(a)     State a process used to separate an alkane from a mixture of these alkanes.

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

**(1)**

(b)     Both C3H8 and C4H10 can be liquefied and used as fuels for camping stoves.

Suggest, with a reason, which of these two fuels is liquefied more easily.

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

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

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

**(1)**

(c)     Write an equation for the complete combustion of C4H10

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

**(1)**

(d)     Explain why the complete combustion of C4H10 may contribute to environmental problems.

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

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

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

**(1)**

(e)     Balance the following equation that shows how butane is used to make the compound called maleic anhydride.

..........CH3CH2CH2CH3 + .......... O2   ..........C2H2(CO)2O + .......... H2O

**(1)**

(f)     Ethanethiol (C2H5SH), a compound with an unpleasant smell, is added to gas to enable leaks from gas pipes to be more easily detected.

(i)      Write an equation for the combustion of ethanethiol to form carbon dioxide, water and sulfur dioxide.

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

**(1)**

(ii)     Identify a compound that is used to react with the sulfur dioxide in the products of combustion before they enter the atmosphere.

Give **one** reason why this compound reacts with sulfur dioxide.

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

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

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

**(2)**

(iii)    Ethanethiol and ethanol molecules have similar shapes.

Explain why ethanol has the higher boiling point.

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

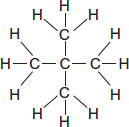
...............................................................................................................

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

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

**(2)**

(g)     The following compound **X** is an isomer of one of the alkanes in the table on above.



(i)      Give the IUPAC name of **X**.

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

**(1)**

(ii)     **X** has a boiling point of 9.5 °C.

Explain why the boiling point of **X** is lower than that of its straight-chain isomer.

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

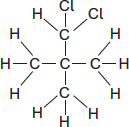
...............................................................................................................

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

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

**(2)**

(iii)    The following compound **Y** is produced when **X** reacts with chlorine.



Deduce how many **other** position isomers of **Y** can be formed.  
Write the number of **other** position isomers in this box.  
 

**(1)**

(h)     Cracking of one molecule of an alkane **Z** produces one molecule of ethane, one molecule of propene and two molecules of ethene.

(i)      Deduce the molecular formula of **Z**.

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

**(1)**

(ii)     State the type of cracking that produces a high proportion of ethene and propene.  
Give the **two** conditions for this cracking process.

Type of cracking ...................................................................................

Conditions .............................................................................................

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

**(2)**

**(Total 17 marks)**

**Q24.**(a)    The hydrocarbon but-1-ene (C4H8) is a member of the homologous series of alkenes. But-1-ene has structural isomers.

(i)      State the meaning of the term *structural isomers*.

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

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

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

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

**(2)**

(ii)     Give the IUPAC name of the **position** isomer of but-1-ene.

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

**(1)**

(iii)    Give the IUPAC name of the **chain** isomer of but-1-ene.

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

**(1)**

(iv)    Draw the displayed formula of a **functional group** isomer of but-1-ene.

**(1)**

(b)     But-1-ene burns in a limited supply of air to produce a solid and water only.

(i)      Write an equation for this reaction.

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

**(1)**

(ii)     State **one** hazard associated with the solid product in part (b)(i).

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

**(1)**

(c)     One mole of compound **Y** is cracked to produce two moles of ethene, one mole of but-1-ene and one mole of octane (C8H18) only.

(i)      Deduce the molecular formula of **Y**.

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

**(1)**

(ii)     Other than cracking, give **one** common use of **Y**.

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

**(1)**

(d)     In cars fitted with catalytic converters, unburned octane reacts with nitrogen monoxide to form carbon dioxide, water and nitrogen only.

(i)      Write an equation for this reaction.

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

**(1)**

(ii)     Identify a catalyst used in a catalytic converter.

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

**(1)**

**(Total 11 marks)**

**M1.**          (a)     % O = 21.6 % **(1)**

*If % O not calculated only M2 available*

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

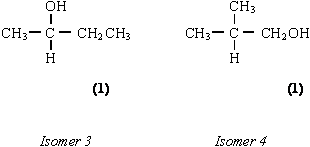
Ratio: 4 : 10: 1     ( C4H10O) **(1)**

*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*

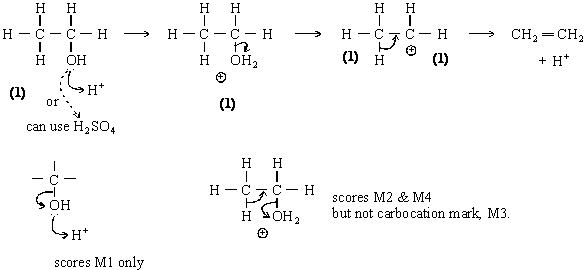
**5**

(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]**

**M2.**          (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)**

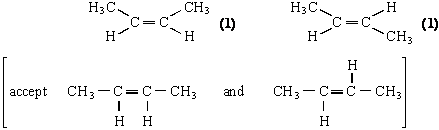
*NOT weak bonds  
NOT unstable  
Credit "stressed"*

(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]**

**M3.**         (a)     (i)      Molecule/compound/consists/composed/made up of hydrogen and  
carbon only **(1)**

(ii)     CnH2n+2 **(1)**

(iii)     C6H14 only **(1)***Do not credit structures alone or in addition.*

**3**

(b)     Chemically similar / react in same way / same chemistry  
Differ by CH2gradation in physical properties OR specified trend e.g. b.p.  
same functional group

*Any 2, 2 marks 1 + 1*

*Not same molecular formula*

**2**

(c)     (i)      Same molecular formula **(1)**

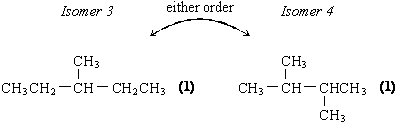
*NOT same Mr*

different structural formula / structures **(1)   
(or atoms arranged in different way)**

*NOT different spatial arrangements  
Only credit M2 if M1 correct*

(ii)     2-methylpentane **(1)**2,2-dimethylbutane **(1)**

(iii)



*OR correct condensed / structural formula*

*Penalise “sticks” once  
Penalise absence of vertical bonds once  
penalise badly drawn bonds once (vertical between H atoms)*

**6**

(d)     (i)      M1 % by mass of H = 7.7(0)% **(1)**M2          mol H = 7.70 / 1 = 7.70  
              mol C = 92.3 / 12 = 7.69 **(1)**

M3 (ratio 1:1 ) CH

*Credit variations for M2 e.g. 78 ×  = 6*

*and  = 6*

*Correct answer = 3 marks*

(ii)     (CH has empirical mass of 13 and  = 6 ) C6H6 **(1)**

*Correct answer 1 mark*

**4**

**[15]**

**M4.**         (i)

|  |  |  |
| --- | --- | --- |
| Isomer | Name |  |
| CH3CH2CH2CH2OH | butan-1-ol |  |
|  | 2-methylpropan-2-ol |  |
|  | *(2-)methyl propan-1-ol*  **(1)** | NOT prop-1-ol |
|  | *butan-2-ol*  **(1)** *OR 2-butanol* | NOT but-2-ol NOT hydroxy No RE |

*Allow e in the names*

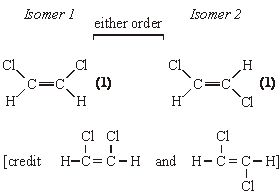
**2**

(ii)     Structural **(1)**OR chain and position(al)

**3**

**[3]**

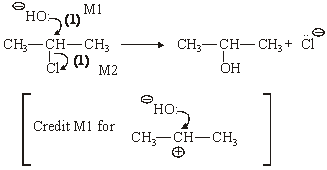
**M5.**          (a)     (i)



(ii)     restricted rotation OR no rotation OR cannot rotate **(1)**

**3**

(b)     (i)      *Mechanism*:



*M1 and M2 independent*

*Curly arrows must be from a bond or a lone pair*

*Do not penalise sticks*

*Penalise M1 if  precedes (penalise this once)*

*Penalise incorrect δ+ δ– for M2*

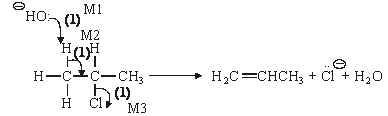
*Penalise + on C atom for M2*

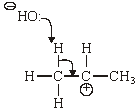
*Only allow M1 for incorrect haloalkane*

*Role of the hydroxide ion*: nucleophile **(1)**                                           electron pair donor  
                                           lone pair donor

*NOT nucleophilic substitution*

(ii)     *Mechanism*:





*Only allow M1 and M2 for incorrect haloalkane unless RE on (i)*

*+ charge on H on molecule, penalise M1*

*M3 independent  
M2 must be to correct C–C*

*M1 must be correct H atom*

*Credit M1 and M2 via carbocation mechanism*

*No marks after any attack of C  by OH–*

*Role of the hydroxide ion*: base **(1)**                                       proton acceptor  
                                       accepts H+

**7**

**[10]**

**M6.**          (a)     (i)      Potassium (OR sodium) dichromate(VI) OR correct formula  
OR potassium manganate(VII)

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

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

**1**

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

*(Ignore heat or reflux)*

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

**1**

         Oxidation or redox

**1**

(ii)     NaBH4 OR LiAlH4 OR H2/Ni

**1**

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

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

**1**

(b)     (i)      

*(Structure must show aldehyde structure)*

*(Credit C2H5 as alternative to CH3CH2)*

(ii)

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

         M2 stays colourless      stays blue                 stays orange

**1**

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

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

*(Credit other correct reagents and observation)*

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

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

**1**

**[9]**

**M7.**          (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]**

**M8.**          (a)     Compounds with the same molecular formula

**1**

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

**1**

(b)     Compound A is butan-1-ol only

**1**

Compound C is butanone or butan-2-one

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

**1**

(c)     (i)      oxidation or redox

**1**

(ii)     K2Cr2O7 or potassium dichromate(VI)

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

**1**

         acidified or H2SO4 (or other identified strong acid)

*(penalise H+)*

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

**1**

(iii)     (heat under) reflux

OR use excess oxidising agent

**1**

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

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

**1**

(v)     correctly drawn structure of methanoic acid

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

**1**

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

**1**

(ii)     correctly drawn structure of methylpropanal

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

**1**

**[12]**

**M9.**          (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]**

**M10.**(a)     2-bromobutane;

**1**

(b)     Elimination;

*(penalise “nucleophilic” OR “electrophilic” before the word “elimination”)*

**1**

M1: curly arrow from lone pair on oxygen of hydroxide ion to H atom  
on correct C-H adjacent to C-Br;

*(penalise M1 if KOH shown as covalent with an arrow breaking the bond)*

**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 unless arrows contradict)  
(Credit possible repeat error from 2(c)(iii) for M3)  
(If the wrong haloalkane is used OR but-1-ene is produced, award MAX. 2 marks for the mechanism)  
(If E1 mechanism is used, give full credit in which M1 and M2 are for correct curly arrows on the correct carbocation)*

(c)     (i)      (structural) isomers/hydrocarbons/compounds/they have the same  
molecular formula, but different structural formulas/different structures;  1

*(penalise statements which are not expressed in good English and which do not refer clearly to structural isomers i.e. plural)  
(penalise statements which refer to “different (spatial) arrangements”)  
(credit” different displayed formulas”)  
(Q of L mark)*

(ii)     Correct structure for but-1-ene;

**1**

**[7]**

**M11.**          (a)     (i)      compounds/mixtures/alkanes/hydrocarbons/molecules with a  
boiling point range/similar boiling point/similar number of  
carbon atoms/similar chain length;

*(insist on “similar” rather than “same”)  
(ignore references to size or Mr)  
(penalise references to bond breaking/cracking as contradictions)*

**1**

(ii)     molecules have different boiling points/intermolecular forces/sizes/chain  
lengths/Mr;

*(ignore references to melting points)  
(credit the idea that molecules condense at different temperatures)*

**1**

(iii)     the column has a higher temperature at the base *(Q of L mark)*

OR

         the column has a lower temperature at the top;

*(the statement needs to be expressed in good English and show a clear understanding of the correct temperature difference) (penalise “negative OR positive temperature gradient” without qualification to what the candidate means, otherwise ignore) (ignore references to the boiling points of the molecules) (credit correct statements which use specific temperatures with a maximum temperature of 500 °C at the base)*

**1**

(b)     (i)      C8H18 + 8½O2 →8CO + 9H2O;

*(or double this equation)*

**1**

(ii)     correctly drawn structure of 2,2,3-trimethylpentane

*(penalise the use of ‘sticks’ once on the paper, including the structures in the 2(a)(ii) and 2(c)(iii )mechanisms) (credit correctly condensed structures)*

**1**

(c)     cracking produces/makes ethene/propene/alkenes/motor fuels/petrol

OR

cracking makes more useful products/high(er) value products

OR

cracking satisfies the high demand for small(er) products;

*(ignore the idea that cracking makes or leads to plastics or polyethene) (high demand needs to be qualified)*

**1**

(d)     (i)      carbocation

OR

         carbonium ion;

*(do not credit examples or formulae, but otherwise ignore) (credit “carbon cation”)*

**1**

(ii)     zeolite

OR

aluminosilicate OR Al2O3;

**1**

(e)     (i)      M1: (free) radical;

*(credit alkyl radical)  
(do not credit examples or formulae, but otherwise ignore)  
(penalise “radical substitution” OR “hydrocarbon radical” as  
contradictions)*

**1**

M2: homolysis

OR

homolytic fission/splitting/cleavage

OR

C-C / C-H bonds break;

**1**

(ii)     alkene(s);

*(credit “small or short chain alkenes”)  
(penalise “cycloalkenes”)  
(penalise additional types of compounds (e.g. branched alkanes) as a  
contradiction)  
(do not credit examples or formulae, but ignore if these are correct and in addition to the word “alkene”)*

**1**

**[11]**

**M12.**          (a)     (i)      any two from:

show a gradation/trend/gradual change in physical properties/  
a specified property

differ by CH2

chemically similar or react in the same way

have the same functional group

*(penalise ‘same molecular formula’)*

*(penalise ‘same empirical formula’)*

**2**

(ii)     fractional distillation or fractionation

**1**

(iii)     contains only single bonds or has no double bonds

*(credit ‘every carbon is bonded to four other atoms’ provided it does not contradict by suggesting that this will always be H)*

**1**

(b)     (i)      the molecular formula gives the actual number of atoms of each

element/type in a molecule/hydrocarbon/compound/formula

*(penalise ‘amount of atoms’)*

*(penalise ‘ratio of atoms’)*

**1**

(ii)     C14H30 only

*(penalise as a contradiction if correct answer is  
accompanied by other structural formulae)*

**1**

(iii)     C10H22 + 5½O2 → 10C + 11H2O

*(or double this equation)*

**1**

(c)     (i)      ½N2 + ½O2 → NO

*(or double this equation)*

**1**

(ii)     Platinum or palladium or rhodium

**1**

(iii)     2CO + 2NO → 2CO2 + N2 or

2NO → N2 + O2 or

*(ignore extra O2 molecules provided the equation balances)*

C + 2NO → CO2 + N2

*(or half of each of these equations)*

C8H18 + 25NO → 8CO2 + 12½N2 + 9H2O

*(or double this equation)*

**1**

**[10]**

**M13.**          (a)     (i)      M1 pentan-3-one only

**1**

M2 CH3CH2CH2COCH3

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

*(penalise use of C3H7)*

**1**

(ii)     *aldehyde*         (CH3)2CHCH2CHO

**1**

*ketone*             (CH3)2CHCOCH3

**1**

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

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

*(ignore names)*

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

*(accept C4H9CHO going to C4H9COOH)*

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

**1**

(ii)     pentanoic acid

*(credit pentan–1–oic acid)*

**1**

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

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

**1**

(ii)     Primary

*(credit 1o or 1)*

**1**

**[8]**

**M14.**          (a)     (i)      (free–)radical substitution

*(both words required for the mark)*

**1**

(ii)     uv light OR sunlight OR high temperature OR 150 °C to 500 °C

**1**

(iii)     Propagation

*(ignore “chain”, “first”, “second” in front of the word propagation)*

**1**

(iv)    Termination

**1**

•CH2CH3 + Br•  CH3CH2Br   
OR 2•CH2CH3  C4H10

*(penalise if radical dot is obviously on CH3, but not otherwise)*

*(penalise C2H5•)*

*(credit 2Br• Br2)*

*(ignore “chain” in front of the word termination)*

**1**

(b)     (i)      Fractional distillation OR fractionation

*(credit gas–liquid chromatography, GLC)*

**1**

(ii)     CH3CH3 + 6Br2  C2Br6 + 6HBr

*(credit C2H6 for ethane)*

**1**

(c)     Correct structure for CF2BrCF2Br drawn out

*(penalise “Fl” for fluorine)*

**1**

(d)     (i)             2–bromo–2–chloro–1,1,1–trifluoroethane   
OR 1–bromo–1–chloro–2,2,2–trifluoroethane

*(insist on all numbers, but do not penalise failure to use alphabet)*

*(accept “flourine” and “cloro” in this instance)*

**1**

(ii)     197.4 only

*(ignore units)*

**1**

(iii)     (57/197.4 × 100) = 28.9% OR 28.88%

*(credit the correct answer independently in part (d)(iii), even if (d)(ii) is blank or incorrectly calculated, but mark consequential on part (d)(ii), if part (d)(ii) is incorrectly calculated, accepting answers to 3sf or 4sf only)*

*(penalise 29% if it appears alone, but not if it follows a correct answer)*

*(do not insist on the % sign being given)*

*(the percentage sign is not essential here, but penalise the use of units e.g. grams)*

**1**

**[11]**

**M15.**          (a)     Single bonds only /no double or multiple bonds;

**1**

          Contains carbon and hydrogen only;

*C and H only  
not C and H molecules*

**1**

          Alkanes;

**1**

(b)     (1) Fractions or hydrocarbons or compounds have different  
boiling points/ separation depends on bp;

*Ignore mp and vdw*

**1**

          (2) bp depends on size/ *M*r/ chain length;

*If refer to bond breaking/cracking/ blast furnace/oxygen/air 2 max*

**1**

(3) Temp gradient in tower or column / cooler at top of column  
or vice versa;

*QWC*

**1**

(4) Higher bp / larger or heavier molecules at bottom (of  
column) or vice versa;

*Not increasing size of fraction  
Not gases at top*

**1**

(c)     Large molecules or compounds or long chain hydrocarbons  
(broken) into smaller molecules or compounds or smaller  
chain hydrocarbons;

*QWC*

**1**

          Zeolite or aluminosilicate (catalyst);

**1**

          C14H30 → C8H18 + C6H12;

*Only*

**1**

Smaller chain molecules are in more demand or have higher  
value or vice versa;

*Insufficient to say more useful/have more uses*

**1**

(d)     C8H18 + 8½ O2 → 8CO + 9H2O;

*Allow multiples*

**1**

          Rh/ Pd/Pt/lr or in words;

*Penalise contradiction of name and symbol*

**1**

          2CO + 2NO → 2CO2 + N2 / 2CO + O2 → 2CO2;

*Allow multiples*

**1**

          Greenhouse gas/ absorbs infrared radiation;

**1**

(e)     car less powerful/ car stops/ reduced performance/ won’t run  
smoothly/ can’t accelerate;

*Not incomplete combustion or bad effect on engine*

*Not doesn’t go as far.*

**1**

          Test it (before sale) /Quality control etc;

**1**

(f)      (compounds with) same molecular formula / same no and type of atoms;

*Not atoms/elements with same molecular formula.  
If same chemical formula, can allow M2*

**1**

          And different structure/ structural formula;

*M2 consequential on M1  
Allow displayed formula for M2*

**1**

          2,2,4-trimethylpentane;

*Only (but allow numbers in any order)*

**1**

**[20]**

**M16.**          (a)     Contains a C=C ***OR***a double bond

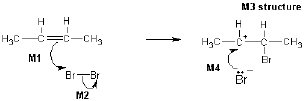
**1**

(b)     **Electrophilic addition**

*Both words needed*

**1**

          Mechanism:



*Ignore partial negative charge on the double bond.*

*M2 Penalise partial charges on bromine if wrong way and penalise formal charges*

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

**M1**    Must show an arrow from the double bond towards one  
of the Br atoms on a Br-Br molecule.

*Deduct 1 mark for sticks.*

**M2**    Must show the breaking of the Br-Br bond.

**M3**    Is for the structure of the secondary carbocation with Br substituent.

**M4**    Must show an arrow from the lone pair of electrons on a  
negatively charged bromide ion towards the positively  
charged carbon atom.

*Deduct 1 mark for wrong reactant, but mark consequentially.  
If HBr, mark the mechanism consequentially and deduct one mark  
If but-1-ene, mark the mechanism consequentially and deduct one mark.  
If both HBr and but-1-ene, mark the mechanism consequentially and deduct ONLY one mark.*

**4**

(c)     (i)      **M1**    Compounds with the same structural formula

*Penalise M1 if “same structure”  
Ignore references to “same molecular formula” or “same empirical formula”*

**1**

**M2**    With atoms/bonds/groups arranged differently in space  
*OR*atoms/bonds/groups have different spatial  
arrangements/ different orientation.

*Mark independently.*

**1**

(ii)  


*Award credit provided it is obvious that the candidate is drawing the trans isomer.*

*Do not penalise poor C–C bonds*

*Trigonal planar structure not essential*

**1**

**[9]**

**M17.**          (a)     General formula;

          Chemically similar;

          Same functional group;

          Trend in physical properties eg inc bp as *M*rincreases;

          Contains an additional CH2 group;

*Any two points.*

**2 max**

(b)     (i)  


*All bonds and atoms must be shown.*

**1**

         C3H6Cl;

*Allow any order of elements.  
Do not allow EF consequential on their wrong displayed formula.*

**1**

(ii)     Same Molecular formula/ both C6H12Cl2/ same number and type  
of atoms;

**1**

Different structural formula/ different structure/ different  
displayed formula;

*Not atoms or elements with same MF  
CE=O.*

*Allow different C skeleton.  
If same chemical formula can allow M2 only.  
M2 insufficient to say atoms arranged differently.  
M2 consequential on M1.*

**1**

(c)     *M*r =228 for total reactants;

**1**

 = 67.98%;

*Allow 67.98 or 68.0 or 68%.*

**1**

(d)     (i)      Bp increases with increasing (molecular) size/ increasing *M*r/  
increasing no of electrons/increasing chain length;

*Atoms CE =0.*

**1**

Increased VDW forces (between molecules) (when larger  
molecule)/ bigger IMFs;

*QWC  
Not dipole-dipole or hydrogen bonds.  
If VDW between atoms in M2 CE = 0.*

**1**

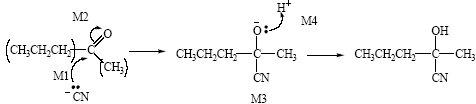
(ii)     Fractional distillation/ fractionation/ GLC/chromatography;

**1**

**[11]**

**M18.**          (a)     nucleophilic addition

**1**

****

*Attack by HCN loses M1 and M2  
M2 not allowed independent of M1, but*

*allow M1 for correct attack on C+  
+C=O loses M2  
M2 only allowed if correct carbon attacked  
allow minus charge on N i.e. :CN–*

**4**

**M3** for completely correct structure not including lp

*allow C3H7 in M3*

**M4** for lp and arrow

*allow without –*

**1**

2-hydroxy-2-methylpentan(e)nitrile

*allow 2-hydroxy-2-methylpentanonitrile*

(b)     Product from **Q** is a racemic mixture/equal amounts of enantiomers

*if no reference to products then no marks;*

**1**

racemic mixture is inactive or inactive explained

*not* ***Q*** *is optically active or has a chiral centre etc*

**1**

Product from **R** is inactive (molecule) or has no chiral centre

**1**

(c)     (i)      **mark the three sections of (c) separately**

**1**

**R** or CH3CH2COCH2CH3

(ii)     [CH3CH2COCH2CH3]+**. *OR*** [C5H10O]+**.**

**1**

→ [CH3CH2CO]+ + **.**CH2CH3***OR*** → [C3H5O]+ + **.**C2H5

**1**

*allow molecular formulae  
allow without brackets  
if brackets not shown, allow dot anywhere on radical or + anywhere on ion*

(iii)     m/z = 43 or 71

**1**

**[13]**

**M19.**          (a)     (i)      **3**-bromo-**3**-methylpentane ONLY

*Must be correct spelling but ignore hyphens and commas*

**1**

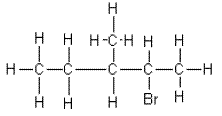
(ii)     Electrophilic addition (reaction)

*Both words needed*

*Accept phonetic spelling*

**1**

(iii)     **M1**    Displayed formula of 2-bromo-3-methylpentane



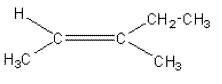
*All the bonds must be drawn out but ignore bond angles*

**M2** Position(al) (isomerism)

***Do not forget to award this mark***

**2**

(iv)    Structure of (E)-3-methylpent-2-ene



*The arrangement of groups around the double bond must be clear with the ethyl group attached in the correct order. Ignore bond angles.*

*Accept C2H5 for ethyl*

*Be lenient on C ─ C bonds. The main issue here is whether they have drawn an (E) isomer.*

*Accept “sticks” for C ─ H bonds and correct skeletal formula*

**1**

(b)     (i)      **M1** R is represented by **Spectrum 2**

**M2** Spectrum 2 shows an infrared absorption/spike/dip/  
trough/peak with any value(s)/range within the range 1620 to  
1680 (cm–1) OR this range quoted/identified and this  
is due to C=C   
OR this information could be a correctly labelled absorption  
on the spectrum

OR Spectrum 1 does not have an infrared absorption in range  
1620 to 1680 (cm–1) and does not contain C=C.

*Award M1 if it is obvious that they are referring to the second spectrum (or the bottom one)*

*M2 depends on a correct M1*

*Ignore other correctly labelled peaks*

*Ignore reference to “double bond” or “alkene”*

**2**

(ii)     Functional group (isomerism)

**1**

(iii)     Cyclohexane

***OR***

Methylcyclopentane etc.

*Named correctly*

*Ignore structures and ignore numbers on the methyl group of methylcyclopentane*

**1**

**[9]**

**M20.**          (a)     •        (Same) General formula/allow a named homologous series  
with its general formula

•        Chemically similar/same (chemical) reactions

•        Same functional group

•        Trend in physical properties/eg inc bp as *M*r increases

•        (Molecules) increase by CH2/*M*r = 14

*Any two points*

**2**

(b)     Fractional distillation/fractionation/chromatography

*Allow GLC*

**1**

(c)     (Molecules/compounds/substances) with the same molecular  
formula/same number and type of atoms

*Allow alkanes with same molecular formula*

*Allow same chemical formula in M1 = 0 but can allow M2*

**1**

but different structural formula/different displayed formula/different  
arrangement of atoms/different structures

*Not different positions in space*

**1**

2,4-dimethylhexane

*M2 dependent on M1*

**1**

C4H9

*Ignore the absence of dash and/or commas*

**1**

(d)     less surface contact/less surface area/less polarisable  
molecule

**1**

so fewer/weaker/less Van der Waals’/vdw forces

*Allow more spherical or fewer points of contact*

*Not smaller molecule/not more compact molecule/not shorter chain*

*Allow converse arguments*

*Must be comparative answer ie not just few VDW forces*

*QoL*

*Assume ‘it’ refers to the branched isomer*

**1**

**[9]**

**M21.**          (a)     Pentan-2-one

*ONLY but ignore absence of hyphens*

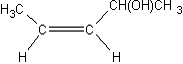
**1**

(b)     Functional group (isomerism)

*Both words needed*

**1**

(c)     (i)



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

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

*Trigonal planar structure not essential*

**1**

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

OR

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

**1**

(d)

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

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

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

*Allow the following alternatives*

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

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

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

*OR*

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

*mark on from incomplete formulae or incorrect oxidation state*

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

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

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

*Ignore “nothing (happens)”*

*Ignore “no observation”*

**3**

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

or named or correctly identified

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

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

**1**

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

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

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

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

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

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

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

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

**2**

**[10]**

**M22.**          (a)     Ca(OH)2 OR Mg(OH)2

*Ignore name*

*Could be ionic*

**1**

(b)     NaF or sodium fluoride

OR

NaCl or sodium chloride

*Either formula or name can score*

*Do not penalise the spelling “fluoride”*

*When both formula and name are written,*

*•    penalise contradictions*

*•    if the attempt at the correct* ***formula*** *is incorrect, ignore  
     it and credit* ***correct name*** *for the mark unless  
     contradictory*

*•    if the attempt at the correct name is incorrect, ignore it  
     and credit* ***correct formula*** *for the mark unless contradictory*

**1**

(c)     NaClO OR NaOCl

*Ignore name (even when incorrect)*

*The correct formula must be clearly identified if an equation is written*

**1**

(d)     **Br2** (ONLY)

*Only the correct formula scores;*

*penalise lower case “b”, penalise upper case “R”, penalise superscript*

*Ignore name*

*The correct formula must be clearly identified if an equation is written*

**1**

(e)     **M1** S OR S8 OR S2

**M2** I2 (ONLY)

*Ignore names*

*penalise lower case “i” for iodine,*

*penalise superscripted numbers*

*Mark independently*

*The correct formula must be clearly identified in each case if an equation is written*

**2**

(f)      (i)      CH3CH2CH=CH2

*Structure of but-1-ene. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(ii)     CH3CH2CH2CH2OH

*Structure of butan-1-ol. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(iii)     CH3CH2CH3

*Structure of propane. Ignore name*

*Ignore calculations and molecular formula*

*Credit “sticks” for C-H bonds*

*Ignore the molecular ion*

**1**

(iv)    CH3CH2Br OR C2H5Br

*Structure of bromoethane.*

*Ignore name and structure of nitrile*

*Credit “sticks” for C-H bonds*

**1**

**[10]**

**M23.**(a)     Fractional distillation / fractionation / GLC / gas liquid chromatography

**1**

(b)     C4H10

*Need C4H10* ***and*** *the reason for the mark*

Because it has a higher bp / has stronger IMF / larger molecule / longer chain / larger surface (area)

**1**

(c)     C4H10 + 6½ O2   4CO2 + 5H2O

*Accept multiples  
Ignore state symbols*

**1**

(d)     CO2 or H2O evolved is a greenhouse gas / CO2 or H2O evolved contribute to global warming / the products are greenhouse gases

*Ignore climate change*

**1**

(e)     CH3CH2CH2CH3 + 3.5O2  C2H2(CO)2O + 4H2O

*Accept multiples*

*Allow with or without a number 1 before the organic molecules*

**1**

(f)     (i)      C2H5SH + 4.5O2  2CO2 + 3H2O + SO2

*Accept multiples*

**1**

(ii)     Calcium oxide / calcium carbonate

*Allow any base or alkali  
Allow correct formulae*

**1**

Neutralises the SO2 / acid base reaction / it is a base

*Can only score M2 if base or alkali used in M1  
Allow M2 if blank in M1*

**1**

(iii)    Ethanol contains hydrogen bonding

*Breaking covalent bonds CE = 0 / 2*

Which is stronger than IMF (VDW / dipole-dipole forces) in ethanethiol / (H bonding) is the strongest IMF

*Only award M2 if M1 given, but allow IMF in ethanol are stronger than in ethanethiol for maximum 1 mark*

**1**

(g)     (i)      (2,2-)dimethylpropane

*Ignore punctuation*

**1**

(ii)     Because molecule is smaller / less polarisable / has less surface (area) / is more spherical / molecules can’t get as close to one another (to feel the vdW forces)

*Allow converse answers referring to straight chain isomers CE = 0 / 2 if breaking bonds*

**1**

vdW intermolecular forces or vdW force between molecules are weaker or fewer

*Need vdW rather than just IMF*

**1**

(iii)    1 or one

**1**

(h)    (i)      C9H20

*H20C9*

**1**

(ii)     Thermal (cracking)

*If not thermal cracking CE = 0 / 2*

**1**

High pressure AND high temperature

*If blank mark on*

*Allow high P and T*

**1**

***OR***

Pressure of ≥ 10 atm, ≥ 1 MPa ≥ 1000 kPa

AND temp of 400 °C ≤ T ≤ 1000 °C or 650 K ≤ T≤ 1300 K

*Do not allow high heat  
If no units for T, then range must be 650 − 1000*

**1**

**[17]**

**M24.**(a)     (i)      (Compounds with the) same molecular formula

*Allow same number and type of atom for M1*

*Ignore same general formula.*

**1**

But different structural formula / different displayed formula / different structures / different skeletal formula

*M2 dependent on M1*

*Not different positions of atoms / bonds in space.*

**1**

(ii)     But-2-ene

*Allow but-2-ene.*

*Allow but 2 ene.*

*Ignore punctuation.*

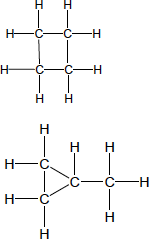
**1**

(iii)    (2)-methylprop-(1)-ene

*Do not allow 2-methyleprop-1-ene.*

**1**

(iv)



*Do not allow skeletal formulae.*

*Penalise missing H and missing C*

**1**

(b)     (i)      C4H8 + 2O2 → 4C + 4H2O

*Accept multiples.*

**1**

(ii)     Exacerbates asthma / breathing problems / damages lungs / smog / smoke / global dimming

*Ignore toxic / pollutant / soot / carcinogen.*

*Do not allow greenhouse effect / global warming / acid rain / ozone.*

**1**

(c)     (i)      C16H34

*Allow H34C16*

*C and H must be upper case.*

**1**

(ii)      Jet fuel / diesel / (motor) fuel / lubricant / petrochemicals / kerosene / paraffin / central heating fuel / fuel oil

*Ignore oil alone.*

*Not petrol / bitumen / wax / LPG / camping fuel.*

**1**

(d)     (i)       C8H18 + 25NO → 8CO2 + 12.5 N2 + 9H2O

*Accept multiples.*

**1**

(ii)      Ir / iridium

***OR***

Pt / platinum

***OR***

Pd / palladium

***OR***

Rh / rhodium

**1**

**[11]**