**Q1.**          (a)     Gas oil (diesel), kerosine (paraffin), mineral oil (lubricating oil) and petrol (gasoline) are four of the five fractions obtained by the fractional distillation of crude oil within the temperature range 40–400 °C.

Identify the missing fraction and state the order in which the five fractions are removed as the fractionating column is ascended. Give **two** reasons why the fractions collect at different levels in the fractionating column.

**(4)**

(b)     Thermal cracking of large hydrocarbon molecules is used to produce alkenes. State the type of mechanism involved in this process. Write an equation for the thermal cracking of C21H44 in which ethene and propene are produced in a 3:2 molar ratio together with one other product.

**(3)**

(c)     Write equations, where appropriate, to illustrate your answers to the questions below.

(i)      Explain why it is desirable that none of the sulphur-containing impurities naturally found in crude oil are present in petroleum fractions.

(ii)     The pollutant gas NO is found in the exhaust gases from petrol engines. Explain why NO is formed in petrol engines but is not readily formed when petrol burns in the open air.

(iii)     The pollutant gas CO is also found in the exhaust gases from petrol engines. Explain how CO and NO are removed from the exhaust gases and why the removal of each of them is desirable.

**(10)**

**(Total 17 marks)**

**Q2.**          The equation below represents a reaction between methane and chlorine.

CH4(g)   +   Cl2(g)   →   CH3Cl(g)   +   HCl(g)

(a)     State an essential condition required for this reaction to occur. Explain why this condition is essential.

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

*Explanation* ..................................................................................................

**(2)**

(b)     (i)      State the type of mechanism involved in the above reaction.

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(ii)     Name the three types of step involved in this mechanism.

*Step 1* .................................................................................................

*Step 2* .................................................................................................

*Step 3* .................................................................................................

**(4)**

(c)     In addition to CH3Cl, compounds such as CH2Cl2 and CH3CH2Cl may also be formed when chlorine reacts with methane.

(i)      Write equations for the two steps in the mechanism by which CH2Cl2 is formed from CH3Cl

*Equation 1* .........................................................................................

*Equation 2* ..........................................................................................

(ii)     Write an equation to represent a step in the mechanism in which CH3CH2Cl is formed.

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**(3)**

**(Total 9 marks)**

**Q3.**          Many hydrocarbon compounds burn readily in air.

(i)      Write an equation to show the complete combustion of C15H32

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(ii)      One of the gaseous products of the incomplete combustion of methane in gas fires is known to be poisonous. Identify this product and write an equation for the reaction in which it is formed from methane.

*Identity of product* ........................................................................................

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

**(Total 4 marks)**

**Q4.**          In the presence of ultraviolet light, methane and chlorine react to form a number of chlorine-containing products, including CH2Cl2 and CHCl3

(i)      Write an equation for the initiation step in the mechanism for this reaction.

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(ii)      Write the overall equation for the formation of CHCl3 from CH2Cl2 and Cl2

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(iii)     Write equations for the two propagation steps by which CH2Cl2 is converted into CHCl3

*Equation 1* ...................................................................................................

*Equation 2 .*...................................................................................................

(iv)     Suggest what effect increasing the intensity of the ultraviolet light would have on the rate of the reaction between methane and chlorine. Explain your answer.

*Effect on rate* ...............................................................................................

*Explanation* ..................................................................................................

**(Total 6 marks)**

**Q5.**          (a)     Crude oil is separated into fractions by fractional distillation. Outline how different fractions are obtained by this process.

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**(3)**

(b)     The table below gives details of the supply of, and demand for, some crude oil fractions.

|  |  |
| --- | --- |
| **Fractions** | **Approximate %** |
| **Typical supply from crude oil** | **Globaldemand** |
| Gases | 2 | 4 |
| Petrol and naphtha | 16 | 27 |
| Kerosine | 13 | 8 |
| Gas oil | 19 | 23 |
| Fuel oil and bitumen | 50 | 38 |

(i)      Use the data given above to explain why catalytic cracking of crude oil fractions is commercially important.

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(ii)     Give the two main types of product obtained by catalytic cracking.

*Type 1* .................................................................................................

*Type 2* .................................................................................................

**(4)**

(c)     Name a catalyst used in catalytic cracking. State the type of mechanism involved and outline the industrial conditions used in the process.

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

*Type of mechanism/…*................................................................................

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

**(4)**

**(Total 11 marks)**

**Q6.**          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.*

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(ii)     Give the general formula for the alkanes.

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

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**(3)**

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

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**(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.*

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(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**.

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

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**(4)**

**(Total 15 marks)**

**Q7.**          When chlorine reacts with trichloromethane, tetrachloromethane, CCl4, is formed.

(a)     (i)      Write the overall equation for this reaction.

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(ii)     State **one** essential condition for this reaction.

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**(2)**

(b)     The mechanism for the chlorination of trichloromethane is free-radical substitution, which proceeds by a series of steps. Write equations for the steps named below in this chlorination.

*Initiation step*

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*First propagation step*

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*Second propagation step*

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

*A termination step*

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

**(4)**

**(Total 6 marks)**

**Q8.**          (a)     Butane, C4H10, is a hydrocarbon which is used as a fuel.

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

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(ii)     Explain what is meant by the term *fuel*.

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(iii)     Write an equation for the complete combustion of butane.

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

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(v)     Under what conditions would you expect incomplete combustion to occur?

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**(5)**

(b)     Three different carbocations are formed by breaking C – C bonds in separate molecules of butane during catalytic cracking. One of these structures is shown below. Give the structures of the other two carbocations.

*Structure 1*               *Structure 2*               *Structure 3*

       

**(2)**

(c)     Ethane can be cracked in the presence of a catalyst to produce ethene and hydrogen.

(i)      Write an equation for this reaction.

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(ii)     Give a suitable catalyst for this reaction.

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(iii)     State **one** reason why cracking is important.

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**(3)**

**(Total 10 marks)**

**Q9.**          (a)     Chloromethane can be made by the reaction of chlorine with methane.

(i)      Give **one** essential condition for this reaction.

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(ii)     Name the mechanism for this reaction.

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(iii)     Further substitution can occur during this reaction. Identify the main organic product when a large excess of chlorine is used in this reaction.

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**(3)**

(b)     Ethanenitrile can be made by reacting chloromethane with potassium cyanide.

(i)      Write an equation for this reaction.

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(ii)     Name the mechanism for this reaction.

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(iii)     Explain, in terms of bond enthalpies, why bromomethane reacts faster than chloromethane with potassium cyanide.

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**(3)**

(c)     Ethanenitrile can be hydrolysed to a carboxylic acid by heating it under reflux with a dilute acid. Identify the carboxylic acid formed in this reaction.

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**(1)**

(d)     Chloromethane can react with ammonia to produce a primary amine.

(i)      What feature of the chloromethane molecule makes it susceptible to attack by an ammonia molecule?

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(ii)     Name the amine produced in this reaction.

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(iii)     Outline a mechanism for this reaction.

**(6)**

**(Total 13 marks)**

**Q10.**          The burning of fossil fuels can produce atmospheric pollutants.

(a)     The combustion of petrol in an internal combustion engine can lead to the formation of carbon monoxide, CO, and nitrogen monoxide, NO.

(i)      Write an equation for the incomplete combustion of octane, C8H18, to produce CO and water only.

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(ii)     State **one** essential condition for the formation of NO in an engine. Write an equation for the reaction in which NO is formed.

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

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

**(3)**

(b)     All new petrol-engined cars must be fitted with a catalytic converter.

(i)      Name **one** of the metals used as a catalyst in a catalytic converter.

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

(ii)     Write an equation to show how CO and NO react with each other in a catalytic converter.

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**(2)**

(c)     State why sulphur dioxide gas is sometimes found in the exhaust gases of petrol-engined cars. Give **one** adverse effect of sulphur dioxide on the environment.

*Reason for SO2 in exhaust gases* .................................................................

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*Environmental effect of SO2* ..........................................................................

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**(2)**

**(Total 7 marks)**

**Q11.**          (a)     Crude oil is composed mainly of alkanes, which are saturated hydrocarbons.

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

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

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

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

**(2)**

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

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

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

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

**(2)**

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

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

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

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(iii)     Name the mechanism involved in thermal cracking.

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**(4)**

**(Total 8 marks)**

**Q12.**          (a)     Bromomethane, CH3Br, can be formed by a reaction between bromine and methane.

The mechanism for this reaction is similar to the mechanism for the chlorination
of methane.

(i)      Name the mechanism for this reaction.

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(ii)     Give the name of, and state an essential condition for, the first step in the mechanism for this reaction.

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

*Essential condition* ..............................................................................

(iii)     Write an equation for a termination step in the mechanism for this reaction which gives ethane as a product.

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(iv)    Bromomethane can undergo further substitution. Write an overall equation for the reaction between bromomethane and bromine in which dibromomethane is formed.

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**(5)**

(b)     Bromomethane reacts with the nucleophile ammonia according to the following equation.

CH3Br + 2NH3  →  CH3NH2 + NH4Br

(i)      Explain what is meant by the term *nucleophile*.

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(ii)     Name the organic product of this reaction.

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(iii)     Outline a mechanism for this reaction.

**(6)**

**(Total 11 marks)**

**Q13.**          Glucose can be used as a source of ethanol. Ethanol can be burned as a fuel or can be converted into ethene.

C6H12O6   →   CH3CH2OH   →   H2C=CH2

glucose            ethanol            ethene

(a)     Name the types of reaction illustrated by the two reactions above.

*Glucose to ethanol* .......................................................................................

*Ethanol to ethene .*........................................................................................

**(2)**

(b)     (i)      State what must be added to an aqueous solution of glucose so that ethanol is formed.

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

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**(2)**

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

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

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**(2)**

(d)     Most of the ethene used by industry is produced when ethane is heated to 900°C in the absence of air. Write an equation for this reaction.

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**(1)**

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

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**(1)**

**(Total 8 marks)**

**Q14.**          The mechanism for the reaction of methane with fluorine is a free-radical substitution similar to the chlorination of methane.

(a)     Outline the following steps in the mechanism for the reaction of methane with fluorine to form fluoromethane, CH3F

*Initiation step*

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*First propagation step*

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

*Second propagation step*

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

*A termination step*

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

**(4)**

(b)     Write an overall equation for the reaction of fluorine with fluoromethane to form tetrafluoromethane.

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**(1)**

**(Total 5 marks)**

**Q15.**          (a)     (i)      Name the process used to separate petroleum into fractions.

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

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

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

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**(4)**

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

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

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

**(2)**

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

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

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

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**(2)**

**(Total 8 marks)**

**Q16.**          Chlorination of ethane follows a free-radical substitution mechanism. This mechanism is similar to that which occurs when methane is chlorinated. The overall equation for the reaction of ethane to form chloroethane is given below.

C2H6 + Cl2  C2H5Cl + HCl

State the conditions and outline a mechanism for this reaction. Show how butane can be formed in this reaction.

**(Total 5 marks)**

**Q17.**          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.

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

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(iii)     Describe the temperature gradient in the column.

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**(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.

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(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.

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**(1)**

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

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(ii)     Identify a catalyst used in catalytic cracking.

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

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

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**(3)**

**(Total 11 marks)**

**Q18.**          Glucose, C6H12O6, can be converted into ethanol. Ethanol can be used as a fuel or can be converted into ethene by acid-catalysed dehydration. Most of the ethene used by industry is formed by the thermal cracking of alkanes.

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

**(7)**

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

**(3)**

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

**(5)**

**(Total 15 marks)**

**Q19.**          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 .*..................................................................................

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

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

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**(4)**

(b)     Decane has the molecular formula C10H22

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

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

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

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**(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.

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

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

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**(3)**

**(Total 10 marks)**

**Q20.**          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.

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(ii)     Suggest an essential condition for this reaction.

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

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(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.

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

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**(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.

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

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**(3)**

**(Total 11 marks)**

**Q21.**          (a)     Hexane (C6H14) is a hydrocarbon which is a component of LPG (liquid petroleum gas), used as a fuel for heating. When burning fuels in boilers it is important to ensure complete combustion.

(i)      Give two reasons why boilers are designed to ensure complete combustion.

Reason 1 ............................................................................................

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Reason 2 ............................................................................................

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(ii)     Write an equation for the incomplete combustion of hexane.

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(iii)     Suggest how an engineer or a chemist could demonstrate that the combustion of hexane in a faulty boiler was incomplete.

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**(5)**

(b)     Branched chain alkanes are often preferred as fuels. Draw the structure of two branched chain isomers of hexane and name the first isomer.

                                        Isomer 1                                           Isomer 2

*Name of isomer 1 .*.......................................................................................

**(3)**

(c)     Hexane can be cracked in the presence of a catalyst to produce another hydrocarbon, Z, and methane.

(i)      Draw a possible structure for Z.

(ii)     Give a suitable catalyst for this reaction.

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(iii)     Suggest why the product Z has more commercial value than hexane.

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**(3)**

(d)     The overall equation for the production of dichloromethane from methane and chlorine is shown below.

CH4 + 2Cl2 → CH2Cl2 + 2HCl

(i)      Calculate the % atom economy for the formation of CH2Cl2 in this reaction.

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(ii)     Give one reason why this atom economy of less than 100% is an important consideration for the commercial success of this process and predict how a chemical company would maximise profits from this process.

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**(3)**

**(Total 14 marks)**

**Q22.**         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.

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**(3)**

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

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**(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’.

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**(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.

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**(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.

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**(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



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**(3)**

**(Total 20 marks)**

**Q23.**          Hexane is a member of the homologous series of alkanes.

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

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

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

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

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**(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.

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**(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.

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**(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.

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**(2)**

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

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**(1)**

**(Total 11 marks)**

**Q24.**          (a)     Two organic compounds with similar relative molecular masses are shown below.



Ethanol                                      Propane

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

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

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

**(2)**

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

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

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

**(2)**

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



**(3)**

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

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

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

**(1)**

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

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**(1)**

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

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**(1)**

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

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

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

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

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

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**(2)**

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

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**(1)**

**(Total 13 marks)**

**Q25.**          Alkanes are saturated hydrocarbons which can be obtained from crude oil.
Pentane is an example of an alkane. A molecule of pentane contains five carbon atoms.

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

Saturated ............................................................................................

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

Hydrocarbon .......................................................................................

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

**(2)**

(ii)     Give the general formula for the alkanes.

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

**(1)**

(b)     Pentane burns completely in oxygen.

(i)      Write an equation for this reaction.

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**(1)**

(ii)     State how the products of this reaction may affect the environment.

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**(1)**

(c)     Give the name of a solid pollutant which may form when pentane burns incompletely in air.

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**(1)**

(d)     One molecule of C9H20 can be cracked to form one molecule of pentane and one other product.

(i)      Write an equation for this cracking reaction.

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**(1)**

(ii)     Suggest a type of compound that can be manufactured from the other product of this cracking reaction.

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**(1)**

(iii)     State why a high temperature is needed for cracking reactions to occur.

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**(1)**

(e)     Pentane can react to form the following haloalkane **Q**.



(i)      Name **Q**.

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**(1)**

(ii)     State the type of structural isomerism shown by **Q** and the haloalkane shown below.



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

**(1)**

**(Total 11 marks)**

**Q26.**          Pent-1-ene is a member of the alkene homologous series.

(a)     Pent-1-ene can be separated from other alkenes.

State the physical property of alkenes that allows them to be separated from a mixture by fractional distillation.

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**(1)**

(b)     (i)      State the meaning of the term *structural isomerism*.

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**(2)**

(ii)     Name the branched chain isomer of pent-1-ene shown below.



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**(1)**

(iii)     Draw the structure of a functional group isomer of pent-1-ene.

**(1)**

(c)     The cracking of one molecule of compound **X** produces pent-1-ene, ethene and butane in a 1:2:1 mol ratio.
Deduce the molecular formula of **X** and state a use for the ethene formed.

Molecular formula of **X** .................................................................................

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

Use of ethene ...............................................................................................

**(2)**

**(Total 7 marks)**

**Q27.**          The alkane butane is used as a fuel.

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

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**(1)**

(ii)     State a condition which may cause carbon to be formed as a product in the combustion of butane.

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

**(1)**

(b)Butane obtained from crude oil may contain trace amounts of an impurity.
When this impurity burns it produces a toxic gas that can be removed by reacting it with calcium oxide coated on a mesh.

(i)      Suggest the identity of the toxic gas.

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**(1)**

(ii)     Suggest why calcium oxide reacts with the toxic gas.

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**(1)**

(iii)     Suggest why the calcium oxide is coated on a mesh.

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**(1)**

**(Total 5 marks)**

**Q28.**          There are several oxides of nitrogen.

(a)     An oxide of nitrogen contains 25.9% by mass of nitrogen. Determine the empirical formula of this oxide.

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**(3)**

(b)     Give **one** reason why the oxide NO is a pollutant gas.

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**(1)**

(c)The oxide NO reacts with oxygen to form nitrogen dioxide. Write an equation for this reaction.

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**(1)**

(d)     Explain how NO is produced in the engine of a motor vehicle.

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**(2)**

(e)     Write an equation to show how NO is removed from the exhaust gases in motor vehicles using a catalytic converter.

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**(1)**

**(Total 8 marks)**

**Q29.**          The initiatives to decrease the carbon dioxide in the atmosphere include the use of carbon-neutral fuels and the development of carbon capture.
The mineral serpentine, Mg3Si2O5(OH)4, has been proposed as a solid for the capture of carbon dioxide gas.

(i)      Give the meaning of the term *carbon-neutral*, as applied to a fuel.

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**(1)**

(ii)      Balance the following equation for the reaction of serpentine with carbon dioxide.

Mg3Si2O5(OH)4 + ..........CO2 → ..........MgCO3 + ..........SiO2 + ..........H2O

**(1)**

**(Total 2 marks)**

**Q30.**          Pentane is a member of the alkane homologous series.

(a)     Give the general formula for the homologous series of alkanes.

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

**(1)**

(b)     One of the structural isomers of pentane is 2,2-dimethylpropane.

Draw the displayed formula of 2,2-dimethylpropane.

State the type of structural isomerism shown.

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**(2)**

(c)     A molecule of hydrocarbon **Y** can be thermally cracked to form one molecule of pentane and two molecules of ethene only.

Deduce the molecular formula of **Y**.

State why high temperatures are necessary for cracking reactions to occur.

Give **one** reason why thermal cracking reactions are carried out in industry.

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

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**(3)**

(d)     Write an equation for the incomplete combustion of pentane to form a solid pollutant.

Suggest why this solid pollutant is an environmental problem.

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

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**(2)**

(e)     Pentane can react with chlorine as shown in the following equation.

C5H12 + Cl2 → C5H11Cl + HCl

Calculate the percentage atom economy for the formation of C5H11Cl

Deduce how many straight-chain isomers of C5H11Cl could be formed.

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

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**(3)**

(f)      Consider the following compound.



Name this compound.

Deduce the empirical formula of this compound.

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**(2)**

**(Total 13 marks)**

**Q31.**          (a)     There is a risk of gas explosions in coal mines. This risk is mainly due to the presence of methane. If the percentage of coal-mine methane (CMM) in the air in the mine is greater than 15%, the explosion risk is much lower. CMM slowly escapes from the mine into the atmosphere.

Write an equation to show the complete combustion of methane.

Suggest **one** reason why there is a much lower risk of an explosion if the percentage of CMM is greater than 15%.

State why it is beneficial to the environment to collect the CMM rather than allowing it to escape into the atmosphere.

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

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**(3)**

(b)     Methane can be obtained from crude oil. Some of this crude oil contains an impurity called methanethiol (CH3SH). This impurity causes environmental problems when burned.

Write an equation to show the complete combustion of methanethiol.

State why calcium oxide can be used to remove the sulfur-containing product of this combustion reaction.

State **one** pollution problem that is caused by the release of this sulfur-containing product into the atmosphere.

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

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**(3)**

**(Total 6 marks)**

**Q32.**Hexane (C6H14) is a member of the homologous series of alkanes.

(a)     (i)      Name the raw material from which hexane is obtained.

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

**(1)**

(ii)     Name the process used to obtain hexane from this raw material.

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

**(1)**

(b)     C6H14 has structural isomers.

(i)      Deduce the number of structural isomers with molecular formula C6H14

|  |  |
| --- | --- |
| Write the number in this box. |  |

*(Space for working)*

**(1)**

(ii)     State **one** type of structural isomerism shown by the isomers of C6H14

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

**(1)**

(c)     One molecule of an alkane **X** can be cracked to form one molecule of hexane and two molecules of propene.

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

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

**(1)**

(ii)     State the type of cracking that produces a high percentage of alkenes. State the conditions needed for this type of cracking.

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

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

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**(2)**

(iii)    Explain the main economic reason why alkanes are cracked.

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**(1)**

(d)     Hexane can react with chlorine under certain conditions as shown in the following equation.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| C6H14 | + | Cl2  |  | C6H13Cl | + | HCl |

(i)      Both the products are hazardous. The organic product would be labelled ‘flammable’.
Suggest the most suitable hazard warning for the other product.

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**(1)**

(ii)    Calculate the percentage atom economy for the formation of C6H13Cl (*M*r = 120.5) in this reaction.

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**(1)**

(e)     A different chlorinated compound is shown below. Name this compound and state its empirical formula.



Name ............................................................................................................

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

**(2)**

**(Total 12 marks)**

**Q33.**Compound **X** is shown below. It is a member of a homologous series of hydrocarbons.



(a)     (i)      Deduce the general formula of the homologous series that contains **X**.

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

**(1)**

(ii)     Name a process used to obtain a sample of **X** from a mixture containing other members of the same homologous series.

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**(1)**

(b)     There are several isomers of **X**.

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

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**(1)**

(ii)     Draw the structure of a functional group isomer of **X**.

**(1)**

(c)     At high temperatures, one molecule of C15H32 can be converted into two molecules of **X** and one molecule of another compound.

(i)      Write an equation for this reaction.

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**(1)**

(ii)     State the name of the process used to obtain a high yield of **X** from C15H32
Give **one** reason why this process is used in industry.

Name ....................................................................................................

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

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**(2)**

(iii)    State why high temperatures are needed for this process.

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**(1)**

(d)     Compound **X** can be converted into compound **Y**.
Compound **Y** is shown below.



(i)      Suggest the formula of a reagent that could be added to **X** in order to convert it into**Y**.

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**(1)**

(ii)     Give **one** use of **Y**.

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

**(1)**

(iii)    Write an equation to show the reaction of **Y** in a limited supply of air to produce a solid and water only.

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

**(1)**

(iv)    When a sample of **Y**, contaminated with CH3SH, is burned completely in air, a toxic gas is formed.
Identify this toxic gas and suggest a compound that could be used to remove the toxic gas from the products of combustion.

Toxic gas ..............................................................................................

Compound used to remove toxic gas ..................................................

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

**(2)**

(v)      Suggest the name of the process that occurs when the toxic gas in part (d)(iv) is removed.

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**(1)**

(e)     Explain why the boiling points of **X** and **Y** are similar.

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

**(2)**

**(Total 16 marks)**

**Q34.**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.

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**(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.

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

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

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

**(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.

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**(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)**

**M1.**(a)     Missing fraction = naphtha *(allow naphtha from list if not quoted
separately***) (1)** Order = mineral oil (lubricating oil), gas oil (diesel),

kerosene (paraffin),
          naphtha, petrol (gasoline) **(1)**

*Mark order consequential on M1 (if no missing fraction
given, M2 = 0) Accept correct reversed order*

Negative temperature gradient on the column**or** temperature of column decreases upwards **(1)**

Larger molecules **or** heavier fractions condense at higher
temperatures **or** lower down the column **or** reference to
different boiling points

*(ignore mp)* ***(1)***

**4**

(b)     Type of mechanism = (free) radical / homolytic
fission - **used in complete sentence/phrase (1)**

C21H44 → 3 C2H4 + 2 C3H6 + C9H20 *correct alkenes* **(1)** *Accept CH2CH2 & CH2CHCH3**all correct* **(1)**

**3**

(c)     (i)      Sulphur (containing impurities) burn to form **or** forms SO2 **or**oxides of sulphur *(if oxide identified, must be correct)***(1)
OR** equation: e.g. S + O2 → SO2 **or** H2S + 1½O2 → SO2 + H2O

Leading to acid rain (*must have specified oxides of S* ***or burning***)**or** toxic product **or** respiratory problems **(1)**

(ii)     NO formed by reaction between N2 and O2 from the air **(1)
OR** N2 +O2 → 2NO
High combustion temperature **or** spark in engine **(1)**provides EA **or** sufficient heat / energy to break NN **(1)**

(iii)     Need to remove NO as forms acid rain **or** toxic product **or** causes
respiratory problems **(1)**2NO + O2 → 2NO2 **(1)**4NO2 + O2 + 2H2O → 4HNO3 **(1)**

Need to remove CO as it is poisonous **(1)**

Catalytic converter **(1)**uses Pt / Rh / Pd / Ir (*wrong answer cancels a correct one*) **(1)**Provides active sites / reduces EA **(1)**Forms N2 + CO2 **(1)**2NO + 2CO → N2 + 2CO2 (*correct equation worth last 2 marks*) **(1)**

**Max 10**

**[17]**

**M2.**(a) *Condition:* U.V. light or sunlight or 450°C or high temp **(1)***Explanation:* U.V. light etc. provides energy to break(Cl‑Cl) bond **(1)**

*Do not accept reference to Ea or wrong bond or ‘to make Cl radicals’*

**2**

(b)     (i)      (Free) radical substitution **(1)**

(ii) *Step 1:* initiation **(1)***Step 2:* propagation **(1)***Step 3:* termination **(1)**

*Any order
Don’t be too harsh on spelling*

**4**

(c)     (i) *Equation 1:* CH3 + Cl• → CH2Cl• + HCl **(1)***Equation 2*: CH2Cl• + Cl2 → CH2Cl2 + Cl• **(1)**

*or  CH2Cl• + Cl• → CH2Cl2
Mark equ independently
any order*

(ii)     CH2Cl• + CH3•→ CH3CH2Cl **(1)
or** CH3CH2• + Cl2→ CH3CH2Cl + Cl•**or** CH3CH2• + Cl•→ CH3CH2Cl

*Equ must have CH3CH2Cl as product
Accept C2H5Cl
Penalise absence of • once only*

**3**

**[9]**

**M3.**(i)      C15H32 + 23 O2 → 15 CO2 +16 H2O

*Products (1)
Balance (1)
If wrong reactant C.E*

(ii)      Identity of product: CO or carbon monoxide **(1)**

Equation: CH4 + O2 → CO +2 H2O **(1)**

*Any balanced equation using CH4, producing CO
could also make C + CO2*

**[4]**

**M4.****Penalise missing • once only**

(i)      Cl2 → 2 Cl• **(1)**

(ii)      CH2Cl2 + Cl2 → CHCl3 +HCl **(1)**

(iii)     CH2Cl2 + Cl• → CHCl2• +HCl **(1)**CHCl2• +Cl2 → CHCl3 + Cl• **(1)**

*Can reverse order*

(iv)     Effect on rate: increases **(1) If decrease given C.E zero marks**Explanation: more Cl• radicals formed **(1)**

*More Cl atoms, more Cl—Cl or Cl2 bonds broken, more Cl2 have*

*EA, increased rate of Cl****•*** *production*

**[6]**

**M5.**(a)     Crude oil is heated to vaporise it / **oil vaporised (1)**(Vapour passed into fractionating) tower / column **(1)**Top of tower cooler than bottom
or **negative temperature gradient (1)**fractions separated by b.p**OR condensed at different temperatures OR levels
OR low boiling fractions at the top
OR at the top small molecules or light components (1)**

**max 3**

(b)     (i)      Identify shortfall in supply - e.g. petrol / small molecules **(1)**Higher value products **OR more useful products (1)**

*OR cracking produces more of material (problem solving)*

(ii)     Motor fuels
Aromatic hydrocarbons
Branched alkanes / hydrocarbons
Cycloalkanes

*Any two (2)
Ignore specific fractions, alkanes, shorter alkanes, penalise alkenes, and hydrogen*

**4**

(c) *Catalyst*: Zeolite / aluminosilicate **(1)***Type of mechanism*: Carbocation / heterolytic fission **(1)***Conditions:* High temp OR around 450 °C [300 – 600] °C **NOT heat / warm (1)**Slight pressure [> 1 atm  10 atm **OR 1 megaPa, 1000 kPa] (1)**

*NOT high pressure*

**4**

**[11]**

**M6.**(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 CH2
gradation 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]**

**M7.**(a)     (i)      CHCl3 + Cl2 → CCl4 + HCl **(1)**

(ii)     UV light / sunlight OR high T OR T ≥ 500°C **(1)**

*maxT = 1000°C
NOT heat / light*

*Ignore pressure*

**2**

(b) *Initial step*: Cl2 → 2Cl· **(1)**

*Condition could be on first equation arrow*

*First propagation step*: CHCl3 + Cl· →  + HCl **(1)**

*Second propagation step*:  + Cl2 → CCl4 + Cl· **(1)**

*A termination step*:  + Cl· → CCl4 **(1)**OR *2**→ C2Cl6*

*Not 2Cl·→ Cl2*

*Ignore additional termination steps*

**4**

**[6]**

**M8.**(a)     (i)      A molecule/compound/it consists/it is composed/it is made up of
hydrogen/H and carbon/C only **(1)**

*QoL*

(ii)     release (heat) energy (when burned) **(1)**OR provides a (useable form of) energy
OR is a source of energy

*Accept heat  energy
NOT is energy / is heat
NOT burns exothermically*

(iii)     C4H10 + 6½O2 → 4CO2 + 5H2O **(1)**OR 2C4H10 + 13 O2 → 8CO2 + 10H2O

*ignore state symbols*

(iv)    C4H10 + 4½O2 → 4CO + 5H2O **(1)**OR 2C4H10 + 9O2 → 8CO + 10H2O

*ignore state symbols*

*(iii) and (iv) if not C4H10 = CE*

(v)     Limited or reduced supply of air / oxygen **(1)**OR low temperature OR poor mixing
OR insufficient oxygen / air OR shortage of O2

*NOT no oxygen / lack of oxygen / not in excess*

**5**

(b) *Structure 1**Structure 2**Structure 3*

**

*allow credit for positive charge around C atom
no alternative carbocations allowed*

**2**

(c)     (i)      C2H6 / CH3CH3 → CH2=CH2 / H2C=CH2 / C2H4 + H2 / CH2CH2

*NOT CH2.CH2*

(ii)     Al2O3 OR Zeoli(y)te OR aluminosilicate **(1)**

*NOT bauxite*

*ignore SiO2*

*NOT Aluminium Silicate*

*NOT porous pot*

*NOT SiO2 alone*

(iii)     More useful / needed fuels / products OR implied

*OR more valuable products*

*OR qualified demand exeeds supply*

*OR to produce motor fuels OR petrol OR cycloalkanes OR aromatic hydrocarbons OR balanced alkanes OR smaller molecules OR alkenes*

**3**

**[10]**

**M9.**(a)     (i)      UV light OR sunlight OR T  450°C **(1)**

*NOT high T*

(ii)     (free) radical substitution **(1)**

(iii)     CCl4 **(1)** OR named

**3**

(b)     (i)      CH3Cl + KCN → CH3CN + KCl **(1)**CN–                       Cl–

(ii)     nucleophilic substitution **(1)**

(iii)     C–Br bond is weaker (than C–Cl bond)
OR C–Br bond enthalpy is less than C–Cl **(1)**

*Ignore electronegativity*

**3**

(c)     CH3COOH OR ethanoic acid **(1)**

**1**

(d)     (i)       OR C–Cl is polar **(1)** OR C atom is electron deficient / δ+

(ii)     methylamine **(1)** only

(iii)     SN1 scores full marks



**6**

**[13]**

**M10.**          (a)     (i)      C8H18 + 8½O2 → 8CO + 9H2O **(1)**

*OR double this equation*

(ii)     *Condition*: Spark OR high T OR T = 2500 – 4000 °C **(1)**

*Equation*: N2 + O2 → 2NO **(1)**

*OR half this equation*

**3**

(b)     (i)      platinum OR rhodium OR palladium **(1)**

(ii)     2CO + 2NO → N2 + 2CO2 **(1)**

*OR half this equation*

**2**

(c)     *Reason for SO2 in exhaust gases*: fraction / petrol / fuels contain sulphur
or sulphur-containing impurities (which burn to give SO2) **(1)**

*Environmental effect SO2*: acid rain OR a specific effect **(1)**

*NOT greenhouse effect
NOT damages ozone layer*

**2**

**[7]**

**M11.**          (a)     (i)      A molecule / compound / Consists / composed of hydrogen
and carbon only **(1)**

*or clearly implied*

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

*NOT has maximum number of hydrogen atoms*

**2**

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

(ii)

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

**2**

(c)     (i)      C10H22 only **(1)**

*NOT CH3CH2CH2CH2CH2CH2CH2CH2CH2CH3*

(ii)     C14H30 → 2C2H4 + C3H6 + C7H16

OR C14H30 → 4C2H4 + 2C3H6 + H2

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

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

*NOT radical substitution
NOT thermal decomposition*

**4**

**[8]**

**M12.**          (a)     (i)      (Free) radical substitution

*(Both words needed)*

**1**

(ii)     M1 initiation ONLY

**1**

M2 ultra-violet light OR sunlight OR 1000°C  T  450 °C

*(Ignore reference to temperature if included with uv light)*

*(Penalise “high temperature” for M2)*

**1**

(iii)      → C2H6

*(OR CH3CH3  as alternative to C2H6)*

**1**

(iv)    CH3Br + Br2 → CH2Br2 + HBr

**1**

(b)     (i)      Electron pair donor
OR species with an electron pair able to form a covalent bond.

**1**

(ii)     Methylamine

*(Credit “aminomethane”)*

**1**

(iii)



**1**

         M1 arrow to show breakage of C – Br bond

**1**

M2 arrow from lone pair on N of NH3 to form bond with C

**1**

         M4 arrow from bond of N – H to N atom of CH33

*(Ignore partial charges on haloalkane but penalise if incorrect)*

*(Accept  for M3)*

*(Full credit for carbocation mechanism; M1 for C – Br bond breakage and M2 for lone pair attack on carbocation)*

*(Second mole of ammonia not essential to mechanism for full credit)*

**1**

**[11]**

**M13.**          (a)     M1     fermentation

**1**

M2     dehydration or elimination

**1**

(b)     (i)      yeast OR zymase OR an enzyme

**1**

(ii)     concentrated sulphuric or phosphoric acid

*(penalise aqueous or dilute as a contradiction)*

**1**

(c)     (i)      primary or 1°

**1**

(ii)     sugar or glucose or ethanol is renewable
OR ethanol does not contain sulphur-containing impurities
OR ethanol produces less pollution or is less smoky or less CO/C

*(the objective is a positive statement about ethanol)
(penalise the idea that ethanol is an infinite source or vague statements that ethanol has less impurities) (penalise the idea that ethanol produces no pollution)*

**1**

(d)     C2H6 →C2H4 + H2

**1**

(e)     Addition

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

**1**

**[8]**

**M14.**          (a)     F2 → 2F•

**1**

CH4 + F• → •CH3 + HF

**1**

•CH3 + F2 → CH3F + F•

**1**

•CH3 + F• → CH3F

**1**

OR 2•CH3 → C2H6

*(allow credit on this occasion for 2F•→ F2)*

*(penalise incorrect symbol Fl, once only)
(penalise absence of radical dot once only)*

(b)     CH3F + 3F2  → CF4 + 3HF

**1**

**[5]**

**M15.**          (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]**

**M16.**          M1:    uv light/sunlight

OR

T = 450 °C to 1000 °C;

*(do not credit “high temperature”)
(ignore references to pressure or catalyst)
(penalise M1 if aqueous chlorine OR chlorine water)
(credit M1 if the condition appears over the arrow of the initiation step)*

**1**

M2:    Cl2 → 2Cl.;

*(credit correct half arrows, but penalise (once in the question) the use of double headed arrows)*

**1**

M3:    C2H6 + Cl. →CH3CH2. + HCl;

*(credit CH3CH3 for ethane and C2H5- for the ethyl radical)*

**1**

M4:    CH3CH2. + Cl2  →C2H5Cl + Cl.;

**1**

M5:    CH3CH2. + CH3CH2. → C4H10;

*(penalise the absence of dots once only in this question)
(penalise subsequent ionic reactions as contradictions for each reaction contradicted)
(if neither M3 nor M4 scored, allow CH3CH2. + Cl. → C2H5Cl for one mark)*

**1**

**[5]**

**M17.**          (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]**

**M18.**          (a)     **M1**: aqueous or solution in water or (aq) in the equation

**1**

**M2**: yeast or zymase

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

**1**

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

**1**

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

*(ignore references to pressure)*

*(ignore uv light)*

**1**

**M5**: fermentation

**1**

**M6**: C6H12O6 → 2CH3CH2OH + 2CO2

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

**1**

**M7**: CH3CH2OH + 3O2 → 2CO2 + 3H2O

*(credit use of C2H5OH)*

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

**1**

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

*(do not credit ‘from a ‘substance’)*

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

**1**

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

**1**

**M3**: CH3CH2OH → H2C=CH2 + H2O

*(credit use of C2H5OH)*

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

*Possible credit as repeat error)*

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

*CH2, CH2:CH2)*

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

**1**

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

**1**

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

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

**1**

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

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

**1**

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

*(ignore ‘pressure’)*

**1**

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

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

**1**

**[15]**

**M19.**          (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]**

**M20.**          (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]**

**M21.**          (a)     (i)      Prevents release of toxic CO
More energy efficient (releases more energy on combustion)

**1**

(ii)     C6H14 + 6.5O2 → 6CO + 7H2O

**1**

         Suitable product eg CO or C

**1**

         Balanced equation

**1**

(iii)     Detect CO gas or C (soot or particles) in exhaust gases

**1**

(b)     CH3CH2CH2CH(CH3)2

**1**

          2-methylpentane

**1**

          CH3CH2CH(CH3)CH2CH3 etc

**1**

(c)     (i)      CH3CH2CH2CH=CH2

**1**

(ii)     Alumino silicate etc

**1**

(iii)     Can be made into polymers (or alcohols etc)

**1**

(d)     (i)      % atom economy = mass CH2Cl2/total mass
reactants = 85 × 100/158

**1**

= 53.8%

**1**

(ii)     Because expensive chlorine is not incorperated into
desired product Raise money by selling HCl

**1**

**[14]**

**M22.**          (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]**

**M23.**          (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]**

**M24.**          (a)     (i)      Covalent;

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

**1**

         Shared pair of electrons (one from each atom);

*Not shared electrons.*

**1**

(ii)     Hydrogen bonds / H bonds;

*Not just hydrogen.*

**1**

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

**1**

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

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

**1**

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

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

**1**

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

**1**

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

*Accept multiples.
Allow C2H6O.*

**1**

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

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

**1**

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

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

**1**

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

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

**1**

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

*Accept incomplete reaction.*

**1**

(ii)     Occupies a (much) smaller volume;

*Not easier to store or transport.*

**1**

**[13]**

**M25.**          (a)     (i)      single (C-C) bonds only/no double (C=C) bonds

**1**

*Allow all carbon atoms bonded to four other atoms
Single C-H bonds only = 0
C=H CE*

C and H (atoms) only/purely/solely/entirely

*Not consists or comprises
Not completely filled with hydrogen
CH molecules = CE
Element containing C and H = CE*

**1**

(ii)     CnH2n+2

*Formula only
CxH2x+2*

**1**

(b)     (i)      C5H12 + 8O2 → 5CO2 + 6H2O

*Accept multiples
Ignore state symbols*

**1**

(ii)     gases produced are greenhouse gases/contribute to Global
warming/effect of global warming/climate change

*Allow CO2 or water is greenhouse gas/causes global warming
Acid rain/ozone CE = 0*

**1**

(c)     carbon

*Allow C
Allow soot*

**1**

(d)     (i)      C9H20 → C5H12 + C4H8

***OR***

C9H20 → C5H12 + 2C2H4

*Accept multiples*

**1**

(ii)     Plastics, polymers

*Accept any polyalkene/haloalkanes/alcohols*

**1**

(iii)     so the bonds break ***OR*** because the bonds are strong

*IMF mentioned = 0*

**1**

(e)     (i)      1,4-dibromo-1-chloropentane/1-chloro-1,4-dibromopentane

*Ignore punctuation*

**1**

(ii)     Chain/position/positional

*Not structural or branched alone*

**1**

**[11]**

**M26.**          (a)     (Different) boiling points

*Ignore mp’s, references to imf, different volatilities*

**1**

(b)     (i)      Compound which have the same molecular formula

*Accept same no and type of atom for M1
But If same (chemical) formula M1 = 0 but allow M2
If empirical formula CE = 0/2*

**1**

but different structures/different structural
formulae/different displayed formulae

*M2 dependent on M1*

**1**

(ii)     3-methylbut-1-ene

*only
ignore commas and hyphens*

**1**

(iii)



*Allow any correct structure with a cyclic alkane*

**1**

*Do not allow*

**

*i.e with an H missing on one C*

(c)     C13H28

*only*

**1**

Making plastics/used to make polymers or polythene/used
to make antifreeze/make ethanol/ripening fruit/any named
additional polymer

*not used* ***as*** *a plastic/polymer/antifreeze
not just ‘polymers’ – we need to see that they are being made*

**1**

**[6]**

**M27.**          (a)     (i)      C4H10 + 6O2 → 4CO2 + 5H2O

*Allow multiples*

**1**

(ii)     insufficient oxygen/low temperature/poor mixing of
butane and air

*Allow insufficient air
Allow lack or oxygen/air
Do not allow no oxygen
Not incomplete combustion*

**1**

(b)     (i)      Sulfur dioxide/SO2

*Allow sulfur trioxide/SO3*

*(allow spelling of sulphur to be sulphur)*

**1**

(ii)     It is basic/the gas (SO2) is acidic

*Idea of neutralisation
It = calcium oxide*

**1**

(iii)     bigger surface area to react

*Do not allow cheaper*

**1**

**[5]**

**M28.**          (a)     O = 74.1%

**1**

****

*If atomic numbers or molecular masses are used lose M2*

**1**

1.85       4.63
1            2.5
N2O5

**1**

*This ratio alone will not score the final mark. (It would get 2)
Allow 3 marks for N2O5*

(b)     Toxic/poisonous/forms an acidic gas/forms NO2 which is acidic/
respiratory irritant/forms HNO3 when NO reacts with water and oxygen/
triggers asthma attacks/greenhouse gas/photochemical smog/
contributes to global warming/formation of acid rain

*ignore NO is an acidic gas or NO is acidic in water
Not references to ozone layer*

**1**

(c)     2NO + O2 → 2NO2

*Accept multiples or fractions of equation
Ignore wrong state symbols*

**1**

(d)     Nitrogen/N2 and oxygen/O2 combine/react

*QWC (not N and O combine)
Not nitrogen in fuel
Allow N2 + O2 → 2NO for M1 only*

**1**

spark/high temperature/2500-4000 °C

**1**

(e)     2NO + 2CO → N2 + 2CO2

***OR***

2NO → N2 + O2

*Accept multiples or fractions of equation
Ignore wrong state symbols*

*Allow C8H18 + 25NO → 8CO2 + 12.5N2 + 9H2O*

**1**

**[8]**

**M29.**          (i)      An activity which has no net/overall (annual) carbon emissions
to the atmosphere/air

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

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

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

*Answer must refer to the atmosphere or air*

**1**

(ii)      Mg3Si2O5(OH)4 + **3**CO2  **3**MgCO3 + **2**SiO2 + **2**H2O

*Allow multiples*

**1**

**[2]**

**M30.**          (a)     Cn H2n+2

*Allow x in place of n*

**1**

(b)



Chain

*Must show every bond*

*Allow branched chain*

**2**

(c)     C9H20

*Only*

**1**

To break the (C-C and/or C-H) bonds

*M2=0 if break C=C*

**1**

To make products which are in greater demand / higher
value / make alkenes

*Not more useful products*

*Allow specific answers relating to question*

**1**

(d)     C5H12 + 3O2 → 5C + 6H2O

*Allow other balanced equations which give C and CO/CO2*

**1**

Causes global dimming / exacerbates asthma / causes
breathing problems / makes visibility poor / smog

*Apply list principle*

*Ignore causes cancer / toxic*

**1**

(e)      (x 100)

**1**

74.48%

*Allow 74.5%*

**1**

3

*Only*

**1**

(f)      2,3-dichloro-3-methylpentane

*Ignore punctuation*

**1**

C3H6Cl

*Only*

**1**

**[13]**

**M31.**          (a)     CH4 + 2O2 → CO2 + 2H2O

*Accept multiples*

*Ignore state symbols even if incorrect*

**1**

Not enough oxygen / air

**1**

CMM / methane is a greenhouse gas / contributes
to global warming

*Do not allow formation of CO2 / CO2 is a greenhouse gas*

*Apply list principle, eg*

*CH4 is a greenhouse gas and toxic = 0*

*CH4 is a greenhouse gas and damages ozone = 0*

*Allow CH4 and CO2 are greenhouses gases*

*Allow collect to use as a fuel so fossil fuels do not run out (as quickly)*

**1**

(b)     CH3SH + 3O2 → CO2 + 2H2O + SO2

*Accept multiples*

*Ignore state symbols even if incorrect*

**1**

Calcium oxide is basic (and SO2 is acidic) /

CaO neutralises SO2 /

CaO reacts with SO2 to form gypsum / salt / solid /
CaSO4 / CaSO3

Allow CaO + SO2 → CaSO3

***M2 and M3 can only be scored if SO2 seen somewhere in the answer***

**1**

Acid rain

*Allow consequence of acid rain eg increased rusting of iron / fish in lakes die / problems for asthmatics*

*Apply list principle*

*Ignore air pollution*

**1**

**[6]**

**M32.**(a)      (i)      Crude oil / oil / petroleum

*Do not allow ‘petrol’*

**1**

(ii)     Fractional distillation / fractionation / fractionating

*Not distillation alone*

**1**

(b)     (i)     5

*Allow five / V*

**1**

(ii)     Chain (isomerism)

*Allow branched chain / chain branched / side chain (isomerism)*

*Ignore position (isomerism)*

*Do not allow straight chain / geometric / branched / function*

**1**

(c)     (i)     C12H26 / H26C12

*Only*

**1**

(ii)     Thermal cracking

*If not thermal cracking, CE = 0/2*

*If blank mark on*

**1**

High temperature

*Allow ‘high heat’ for ‘high temperature’*

(400°C < T < 900°C) or (650 K < T < 1200 K)

*Not ‘heat’ alone*

*If no T, units must be 650 – 900*

**and**

High pressure (> 10 atm, > 1 MPa, >1000 kPa)

**1**

(iii)    To produce substances which are (more) in demand / produce products with a
high value / products worth more

*Ignore ‘to make more useful substances’*

**1**

(d)     (i)     Corrosive or diagram to show this hazard symbol

*Ignore irritant, acidic, toxic, harmful*

**1**

(ii)     (  120.5     × 100)(86 + 71             )

=76.75(%) or 76.8(%)

*Allow answers > 3 sig figs*

**1**

(e)     2,2-dichloro-3–methylpentane

*Ignore punctuation*

*Any order*

**1**

C3H6Cl

**1**

**[12]**

**M33.**         (a)      (i)     CnH2n / CxH2x

**1**

(ii)     Fractional distillation / GLC / gas liquid chromatography / fractionation

*Do* ***not*** *allow cracking / distillation*

**1**

(b)     (i)     But-1-ene / but1ene

*Ignore hyphens and commas*

*Do* ***not*** *allow butene-1 / but-2-ene / butane / butane /alkene / C4H8 / propene / straight-chain alkene*

**1**

(ii)     A structure of cyclobutane or
methyl-cyclopropane

*Allow skeletal formula.*

**1**

(c)     (i)     C15H32 → 2C4H8 + C7H16

*Do not accept multiples.*

**1**

(ii)     Thermal cracking

*Not catalytic cracking or cracking.*

**1**

To produce products that are in greater demand / more valuable / more
expensive / more profitable

*The (unsaturated) alkene or the (unsaturated) molecule or X produced can be polymerised or can be made into plastics.*

*Ignore more useful products.*

**1**

(iii)     Break (C–C or C–H) bonds

*Allow to overcome the activation energy.*

*Allow to break the carbon chain.*

*Penalise breaking wrong bonds.*

**1**

(d)     (i)     H2

*Only.*

**1**

(ii)     Fuel / LPG

*Allow camping gas, lighter fuel, propellant, refrigerant, cordless appliances.*

*Do not allow petrol or motor fuel.*

*Ignore natural gas.*

**1**

(iii)     C4H10 + 2.5O2 → 4C + 5H2O

*Accept multiples.*

**1**

(iv)     SO2 / sulfur dioxide

*If other sulfur oxides, mark on.*

**1**

Calcium oxide / CaO / lime / quicklime

*Allow CaCO3 / allow Ca(OH)2 or names.*

*Allow any solid base.*

*M2 dependent on M1.*

*Do not allow limewater.*

**1**

(v)     Neutralisation

*Allow acid-base reaction.*

*Allow flue gas desulfurisation / FGD*

**1**

(e)    (Molecules) are similar sizes / have similar *M*r / have similar number of electrons

*Chemical error CE = 0/2 if breaking bonds.*

*Allow similar number of carbon and hydrogen atoms / similar surface area / similar chain length.*

*Can accept same number of carbon atoms.*

*Do not accept same number of H atoms / same number of bonds.*

*Ignore similar amount of bonds.*

**1**

Similar van der Waals forces between molecules / similar intermolecular forces
(IMF)

*Not similar incorrect IMF eg dipole-dipole*

**1**

**[16]**

**M34.**(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]**