1 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** $Br_2 \longrightarrow 2Br^{\bullet}$

Step **2** $Br^{\bullet} + CH_3CH_3 \longrightarrow CH_3CH_2^{\bullet} + HBr$

Step **3** $CH_3CH_2^{\bullet} + Br_2 \longrightarrow CH_3CH_2Br + Br^{\bullet}$

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

.....

(ii) Suggest an essential condition for this reaction.

.....

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

.....

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

Type of step .....

Equation.....

(5)

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

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

.....

(ii) Write an equation for the reaction between bromine and ethane which produces hexabromoethane, C_2Br_6, by this substitution reaction.

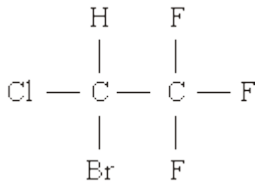
.....

(2)

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

(1)

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



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

.....

(ii) Calculate the M_r of halothane.

.....

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

.....

(3)
(Total 11 marks)

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

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

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

Characteristic 1 .....

.....

Characteristic 2 .....

.....

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

.....

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

.....

.....

(4)

(b) Decane has the molecular formula $C_{10}H_{22}$

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

.....

.....

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

.....

(iii) Write an equation for the incomplete combustion of decane, $C_{10}H_{22}$, to produce carbon and water only.

.....

(3)

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

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

.....

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

.....

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

.....

(3)
(Total 10 marks)

3 (a) Dichloromethane, CH_2Cl_2, is one of the products formed when chloromethane, CH_3Cl, reacts with chlorine.

(i) Name the type of mechanism involved in this reaction and write an equation for each of the steps named below.

Name of type of mechanism .....

Initiation step

.....

First propagation step

.....

Second propagation step

.....

(ii) Write an overall equation for the formation of dichloromethane from chloromethane.

.....

(5)

(b) A compound contains 10.1% carbon and 89.9% chlorine by mass. Calculate the molecular formula of this compound, given that its relative molecular mass (M_r) is 237.0

.....

.....

.....

.....

.....

(3)

(c) Suggest the formulae of two bromine-containing organic compounds formed when dibromomethane, CH_2Br_2, reacts with bromine.

Compound 1 .....

Compound 2 .....

(2)

(Total 10 marks)

4 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.

$$C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + HCl$$

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

(Total 5 marks)

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

.....

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

.....

.....

(iii) Write an equation for the complete combustion of the alkane $C_{11}H_{24}$

.....

(iv) Write an equation for the incomplete combustion of $C_{11}H_{24}$ to produce carbon and water only.

.....

(4)

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

(i) Write an equation for the thermal cracking of one molecule of $C_{10}H_{22}$ to give one molecule of propene and one molecule of an alkane only.

.....

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

(2)

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

Feature 1 .....

.....

Feature 2 .....

.....

(2)
(Total 8 marks)

6 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, CH_3F

Initiation step

.....

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.

.....

(1)
(Total 5 marks)

7 The percentage by mass of carbon is 83.3% in

A propane.

B butane.

C pentane.

D hexane.

(Total 1 mark)

8 (a) Bromomethane, CH_3Br, 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.

.....

(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.

.....

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

.....

(5)

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

$CH_3Br + 2NH_3 \rightarrow CH_3NH_2 + NH_4Br$

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

.....

.....

(ii) Name the organic product of this reaction.

.....

(iii) Outline a mechanism for this reaction.

(6)
(Total 11 marks)

9 (a) State what is meant by the term *homogeneous* as applied to a catalyst.

.....

(1)

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

.....

.....

(ii) Identify the species which acts as an autocatalyst in the reaction between ethanedioate ions and manganate(VII) ions in acidic solution.

.....

(2)

(c) When petrol is burned in a car engine, carbon monoxide, carbon dioxide, oxides of nitrogen and water are produced. Catalytic converters are used as part of car exhaust systems so that the emission of toxic gases is greatly reduced.

(i) Write an equation for a reaction which occurs in a catalytic converter between two of the toxic gases. Identify the reducing agent in this reaction.

Equation .....

.....

Reducing agent .....

(ii) Identify a transition metal used in catalytic converters and state how the converter is constructed to maximise the effect of the catalyst.

Transition metal .....

How effect is maximised .....

.....

(5)

(d) The strength of the adsorption of reactants and products onto the surface of a transition metal helps to determine its activity as a heterogeneous catalyst.

(i) Explain why transition metals which adsorb strongly are not usually good catalysts.

.....

(ii) Explain why transition metals which adsorb weakly are not usually good catalysts.

.....

(2)
(Total 10 marks)

10 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, C_8H_{18}, to produce CO and water only.

.....

(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.

.....

(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 SO_2 in exhaust gases .....

.....

Environmental effect of SO_2 .....

.....

(2)
(Total 7 marks)

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

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

.....

(ii) Name the mechanism for this reaction.

.....

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

.....

(3)

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

(i) Write an equation for this reaction.

.....

(ii) Name the mechanism for this reaction.

.....

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

.....

.....

.....

(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.

.....

(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?

.....

(ii) Name the amine produced in this reaction.

.....

(iii) Outline a mechanism for this reaction.

(6)
(Total 13 marks)

12 (a) Butane, C_4H_{10}, is a hydrocarbon which is used as a fuel.

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

.....

.....

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

.....

.....

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

.....

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

.....

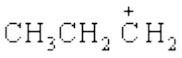
(v) Under what conditions would you expect incomplete combustion to occur?

.....

(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.

.....

(ii) Give a suitable catalyst for this reaction.

.....

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

.....

.....

(3)
(Total 10 marks)

13 When chlorine reacts with trichloromethane, tetrachloromethane, CCl_4, is formed.

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

.....

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

.....

(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

.....

First propagation step

.....

Second propagation step

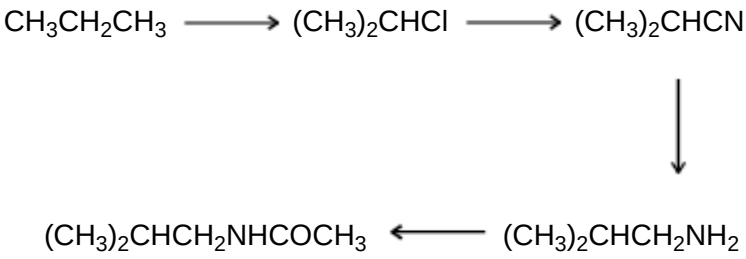
.....

A termination step

.....

(4)
(Total 6 marks)

14 Which one of the following types of reaction mechanism is **not** involved in the above sequence?



A free-radical substitution

B nucleophilic substitution

C elimination

D nucleophilic addition-elimination

(Total 1 mark)

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

.....

.....

.....

.....

.....

(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	**Global demand**
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.

.....

.....

.....

(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 .....

Conditions .....

(4)
(Total 11 marks)

16 In the presence of ultraviolet light, methane and chlorine react to form a number of chlorine-containing products, including CH_2Cl_2 and $CHCl_3$

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

.....

(ii) Write the overall equation for the formation of $CHCl_3$ from CH_2Cl_2 and Cl_2

.....

(iii) Write equations for the two propagation steps by which CH_2Cl_2 is converted into $CHCl_3$

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)

17 Many hydrocarbon compounds burn readily in air.

(i) Write an equation to show the complete combustion of $C_{15}H_{32}$

.....

.....

(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)

18 The equation below represents a reaction between methane and chlorine.

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

(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.

.....

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

Step 1 .....

Step 2 .....

Step 3 .....

(4)

(c) In addition to CH_3Cl, compounds such as CH_2Cl_2 and CH_3CH_2Cl may also be formed when chlorine reacts with methane.

(i) Write equations for the two steps in the mechanism by which CH_2Cl_2 is formed from CH_3Cl

Equation 1 .....

Equation 2 .....

(ii) Write an equation to represent a step in the mechanism in which CH_3CH_2Cl is formed.

.....

(3)
(Total 9 marks)

19 (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 $C_{21}H_{44}$ 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)

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

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

A electrophilic addition

B electrophilic substitution

C nucleophilic substitution

D free-radical substitution

(Total 1 mark)

21 An alkane contains 30 hydrogen atoms per molecule. Its empirical formula is

A C_6H_{15}

B C_7H_{15}

C $C_{14}H_{30}$

D $C_{15}H_{30}$

(Total 1 mark)

22 Which one of the following is least likely to occur in the reaction between methane and chlorine?

A $CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$

B $CH_3\bullet + HCl \rightarrow CH_3Cl + H\bullet$

C $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

D $CH_3Cl + Cl\bullet \rightarrow CH_2Cl\bullet + HCl$

(Total 1 mark)

23 Which one of the following reactions involves nucleophilic addition?

A $CH_3CH = CH_2 + HBr \rightarrow CH_3CHBrCH_3$

B $CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CHClCH_3 + HCl$

C $CH_3CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2OH + NaBr$

D $CH_3CH_2CHO + HCN \rightarrow CH_3CH_2CH(OH)CN$

(Total 1 mark)

Mark schemes

1

(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

$^{\bullet}CH_2CH_3 + Br^{\bullet} \longrightarrow CH_3CH_2Br$

OR $2\,^{\bullet}CH_2CH_3 \longrightarrow C_4H_{10}$

(penalise if radical dot is obviously on CH_3, but not otherwise)

(penalise $C_2H_5^{\bullet}$)

(credit $2Br^{\bullet} \longrightarrow Br_2$)

(ignore "chain" in front of the word termination)

1

(b) (i) Fractional distillation OR fractionation

(credit gas–liquid chromatography, GLC)

1

(ii) $CH_3CH_3 + 6Br_2 \longrightarrow C_2Br_6 + 6HBr$

(credit C_2H_6 for ethane)

1

(c) Correct structure for CF_2BrCF_2Br 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]

2

(a) (i) any two from:
show a gradation/trend/gradual change in physical properties/
a specified property
differ by CH_2
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) $C_{14}H_{30}$ only

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

1

(iii) $C_{10}H_{22} + 5½O_2 \rightarrow 10C + 11H_2O$

(or double this equation)

1

(c) (i) $\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightarrow NO$

(or double this equation)

1

(ii) Platinum or palladium or rhodium

1

(iii) $2CO + 2NO \rightarrow 2CO_2 + N_2$ or

$2NO \rightarrow N_2 + O_2$ or

(ignore extra O_2 molecules provided the equation balances)

$C + 2NO \rightarrow CO_2 + N_2$

(or half of each of these equations)

$C_8H_{18} + 25NO \rightarrow 8CO_2 + 12\frac{1}{2}N_2 + 9H_2O$

(or double this equation)

1

[10]

3

(a) (i) (free–) radical substitution

(both words required for the mark)

1

initiation $Cl_2 \rightarrow 2Cl\cdot$

(credit correct half arrows, but penalise double headed arrows)

1

first propagation $CH_3Cl + Cl\cdot \rightarrow \cdot CH_2Cl + HCl$

1

second propagation $\cdot CH_2Cl + Cl_2 \rightarrow CH_2Cl_2 + Cl$

(penalise the absence of dots on radicals once only)

(penalise radical dot on Cl of CH_2Cl once only)

1

(ii) $CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$

(penalise if any radicals appear in this equation)

1

(b) **M1**: mol C = 10.1/12.0 and mol Cl = 89.9/35.5

1

M2: Ratio 0.842 : 2.53 OR 1: 3 OR CCl3

1

M3: 237.0/Mr of CCl_3 = 237.0/118.5 = 2 Therefore C_2Cl_6

(correct answer gains full credit)

1

OR

M1: 237.0 × 10.1/100 and 237 × 89.9/100

1

M2: Ratio 23.9/12.0 : 213/35.5 OR 2 : 6

1

M3: C_2Cl_6

(correct answer gains full credit)

1

(c) any two from $CHBr_3$ or CBr_4 or $C_2H_2Br_4$ (or $CHBr_2CHBr_2$) or C_2Br_6 (or CBr_3CBr_3)

(ignore HBr or H_2)

(ignore equations and ignore names when given in addition to formulae)

(penalise names alone)

2

[10]

4

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: $Cl_2 \rightarrow 2Cl\cdot$;

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

1

M3: $C_2H_6 + Cl\cdot \rightarrow CH_3CH_2\cdot + HCl$;

(credit CH_3CH_3 for ethane and C_2H_5- for the ethyl radical)

1

M4: $CH_3CH_2\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$;

1

M5: $CH_3CH_2\cdot + CH_3CH_2\cdot \rightarrow C_4H_{10}$;

(penalise the absence of dots once only in this question)
(penalise subsequent ionic reactions as contradictions for each reaction contradicted)

(if <u>neither</u> M3 nor M4 scored, allow $CH_3CH_2\cdot + Cl\cdot \rightarrow C_2H_5Cl$ for one mark)

1

[5]

5 (a) (i) fractional distillation or fractionation

1

(ii) C_9H_{20} <u>only</u>

1

(iii) $C_{11}H_{24} + 17O_2 \rightarrow 11CO_2 + 12H_2O$

1

(iv) $C_{11}H_{24} + 6O_2 \rightarrow 11C + 12H_2O$

1

(b) (i) $C_{10}H_{22} \rightarrow C_3H_6 + C_7H_{16}$

1

(ii) correctly drawn structure of methylpropene

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

1

(c) Any <u>two</u> 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 CH_2

(penalise same molecular formula or same empirical formula)

2

[8]

6 (a) $F_2 \rightarrow 2F\bullet$

1

$CH_4 + F\bullet \rightarrow \bullet CH_3 + HF$

1

$\bullet CH_3 + F_2 \rightarrow CH_3F + F\bullet$

1

$\bullet CH_3 + F\bullet \rightarrow CH_3F$

1

OR $2\bullet CH_3 \rightarrow C_2H_6$

(allow credit on this occasion for $2F\bullet \rightarrow F_2$)

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

(b) $CH_3F + 3F_2 \rightarrow CF_4 + 3HF$

1

[5]

7 C

[1]

8 (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) $2\dot{C}H_3 \rightarrow C_2H_6$

(OR CH_3CH_3 as alternative to C_2H_6)

1

(iv) $CH_3Br + Br_2 \rightarrow CH_2Br_2 + HBr$

1

(b) (i) Electron pair donor

OR species with an electron pair able to form a covalent bond.

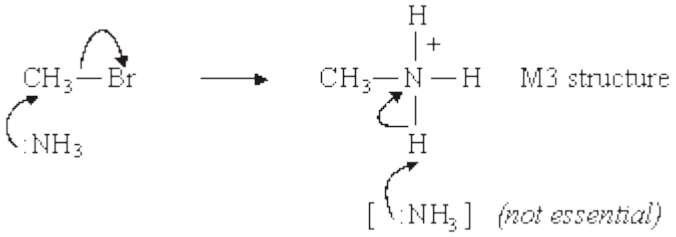
1

(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 NH_3 to form bond with C

1

M4 arrow from bond of N – H to N atom of $CH_3\overset{+}{N}H_3$

(Ignore partial charges on haloalkane but penalise if incorrect)

(Accept $CH_3\overset{+}{N}H_3$ 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]

9

(a) A catalyst in the same phase/phase as the reactants

1

(b) (i) A reaction in which a product acts as a catalyst

1

(ii) Mn^{2+} or Mn^{3+}

"Self-catalysing" not allowed

1

(c) (i) $2CO + 2NO \rightarrow 2CO_2 + N_2$

or $4CO + 2NO_2 \rightarrow 4CO_2 + N_2$

C not allowed as a product

1

Reducing agent CO

1

(ii) Pt, Pd or Rh

1

Deposited on a ceramic honeycomb or matrix or mesh or sponge

1

To increase surface area of catalyst

1

(d) (i) Reactants cannot move on surface or products not desorbed or
Active sites blocked

1

(ii) Reactants not brought together or
No increase in reactant concentration on catalyst surface or
Reactants not held long enough for a reaction to occur or
Reactant bonds not weakened

1

[10]

10 (a) (i) $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ **(1)**

OR double this equation

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

Equation: $N_2 + O_2 \rightarrow 2NO$ **(1)**

OR half this equation

3

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

(ii) $2CO + 2NO \rightarrow N_2 + 2CO_2$ **(1)**

OR half this equation

2

(c) *Reason for SO_2 in exhaust gases*: fraction / petrol / fuels <u>contain sulphur</u> or <u>sulphur-containing</u> impurities (which burn to give SO_2) **(1)**

Environmental effect SO_2: acid rain OR a specific effect **(1)**

NOT greenhouse effect
NOT damages ozone layer

2

[7]

11 (a) (i) UV light OR sunlight OR T ≥ 450°C **(1)**

NOT high T

(ii) (free) <u>radical substitution</u> **(1)**

(iii) CCl_4 **(1)** OR named

3

(b) (i) $CH_3Cl + KCN \rightarrow CH_3CN + KCl$ **(1)**

CN^- Cl^-

(ii) <u>nucleophilic substitution</u> **(1)**

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

Ignore electronegativity

3

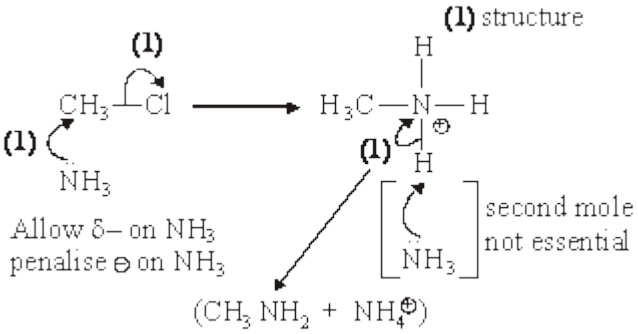
(c) CH_3COOH OR ethanoic acid **(1)**

1

(d) (i) $\overset{\delta+}{C}-\overset{\delta-}{Cl}$ <u>OR C–Cl is polar</u> **(1)** OR C atom is electron deficient / δ+

(ii) methylamine **(1)** <u>only</u>

(iii) S_N1 scores full marks



6

[13]

12 (a) (i) A molecule/compound/it consists/it is composed/it is made up of hydrogen/H and carbon/C <u>only</u> **(1)**

QoL

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

Accept heat ≡ energy
<u>NOT</u> is energy / is heat
NOT burns exothermically

(iii) $C_4H_{10} + 6½O_2 \rightarrow 4CO_2 + 5H_2O$ **(1)**
OR $2C_4H_{10} + 13\ O_2 \rightarrow 8CO_2 + 10H_2O$

ignore state symbols

(iv) $C_4H_{10} + 4½O_2 \rightarrow 4CO + 5H_2O$ **(1)**
OR $2C_4H_{10} + 9O_2 \rightarrow 8CO + 10H_2O$

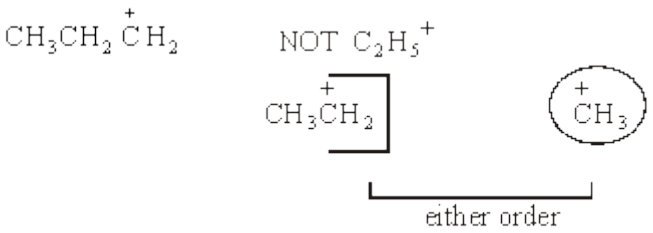
ignore state symbols
(iii) and (iv) if not C_4H_{10} = CE

(v) Limited or reduced supply of air / oxygen **(1)**
OR low temperature OR poor mixing
OR insufficient oxygen / air OR shortage of O_2

<u>NOT</u> 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) C_2H_6 / CH_3CH_3 → $CH_2{=}CH_2$ / $H_2C{=}CH_2$ / $C_2H_4 + H_2$ / CH_2CH_2

NOT $CH_2{\cdot}CH_2$

(ii) Al_2O_3 OR Zeoli(y)te OR aluminosilicate **(1)**

NOT bauxite
ignore SiO_2
NOT Aluminium Silicate
NOT porous pot
NOT SiO_2 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]

13 (a) (i) $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ **(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*: $Cl_2 \rightarrow 2Cl\cdot$ **(1)**

Condition could be on first equation arrow

First propagation step: $CHCl_3 + Cl\cdot \rightarrow \dot{C}Cl_3 + HCl$ **(1)**

Second propagation step: $\dot{C}Cl_3 + Cl_2 \rightarrow CCl_4 + Cl\cdot$ **(1)**

A termination step: $\dot{C}Cl_3 + Cl\cdot \rightarrow CCl_4$ **(1)**

OR $2\dot{C}Cl_3 \rightarrow C_2Cl_6$

Not $2Cl\cdot \rightarrow Cl_2$

Ignore additional termination steps

4

[6]

14 C

[1]

15 (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]

16

Penalise missing • once only

(i) $Cl_2 \rightarrow 2\ Cl\bullet$ **(1)**

(ii) $CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$ **(1)**

(iii) $CH_2Cl_2 + Cl\bullet \rightarrow CHCl_2\bullet + HCl$ **(1)**
$CHCl_2\bullet + Cl_2 \rightarrow CHCl_3 + Cl\bullet$ **(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 Cl_2 bonds broken, more Cl_2 have E_A, increased rate of Cl• production

[6]

17

(i) $C_{15}H_{32} + 23\ O_2 \rightarrow 15\ CO_2 + 16\ H_2O$

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

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

Equation: $CH_4 + \frac{3}{2}\ O_2 \rightarrow CO + 2\ H_2O$ **(1)**

Any balanced equation using CH_4, producing CO
could also make C + CO_2

[4]

18

(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 E_a 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:* $CH_3 + Cl\bullet \rightarrow CH_2Cl\bullet + HCl$ **(1)**
Equation 2: $CH_2Cl\bullet + Cl_2 \rightarrow CH_2Cl_2 + Cl\bullet$ **(1)**

or $CH_2Cl\bullet + Cl\bullet \rightarrow CH_2Cl_2$
Mark equ independently
any order

(ii) $CH_2Cl\bullet + CH_3\bullet \rightarrow CH_3CH_2Cl$ **(1)**
or $CH_3CH_2\bullet + Cl_2 \rightarrow CH_3CH_2Cl + Cl\bullet$
or $CH_3CH_2\bullet + Cl\bullet \rightarrow CH_3CH_2Cl$

Equ must have CH_3CH_2Cl as product
Accept C_2H_5Cl
Penalise absence of • once only

3

[9]

19

(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)**

$C_{21}H_{44} \rightarrow 3\ C_2H_4 + 2\ C_3H_6 + C_9H_{20}$ *correct alkenes* **(1)**

Accept CH_2CH_2 *&* CH_2CHCH_3 *all correct* **(1)**

3

(c) (i) Sulphur (containing impurities) burn to form **or** forms SO_2 **or** oxides of sulphur *(if oxide identified, must be correct)* **(1)**
OR equation: e.g. $S + O_2 \rightarrow SO_2$ **or** $H_2S + 1½O_2 \rightarrow SO_2 + H_2O$

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 N_2 and O_2 from the air **(1)**
OR $N_2 + O_2 \rightarrow 2NO$
High combustion temperature **or** spark in engine **(1)**
provides E_A **or** sufficient heat / energy to break $N \equiv N$ **(1)**

(iii) Need to remove NO as forms acid rain **or** toxic product **or** causes respiratory problems **(1)**
$2NO + O_2 \rightarrow 2NO_2$ **(1)**
$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ **(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 E_A **(1)**
Forms $N_2 + CO_2$ **(1)**
$2NO + 2CO \rightarrow N_2 + 2CO_2$ (*correct equation worth last 2 marks*) **(1)**

Max 10

[17]

20 B **[1]**

21 B **[1]**

22 B **[1]**

23 D **[1]**