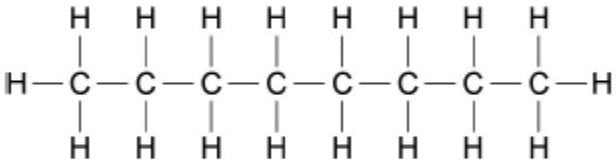
1 Octane and isooctane are structural isomers with the molecular formula C_8H_{18}.
The displayed formulas and boiling points of octane and isooctane are shown in **Figure 1**.

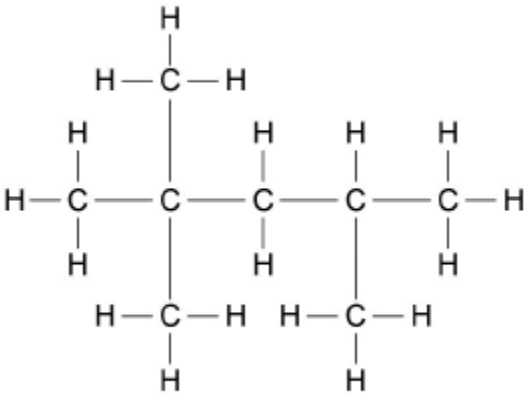
Figure 1

Octane



Boiling point: 125 °C

Isooctane



Boiling point: 99 °C

(a) Give the IUPAC name for isooctane.

.....

(1)

(b) Octane and isooctane can be separated in the laboratory.

Name a laboratory technique that could be used to separate isooctane from a mixture of octane and isooctane.

Outline how this technique separates isooctane from octane.

Name .....

Outline .....

.....

.....

.....

.....

(3)

(c) Isooctane is added to petrol to increase its octane rating. Some high-performance engines require fuel with a higher octane rating.

Write an equation for the complete combustion of isooctane. Use the molecular formula (C_8H_{18}) of isooctane in your equation.

.....

(1)

(d) Explain, in general terms, how a catalyst works.

.....

.....

.....

(2)

(e) Carbon monoxide is produced when incomplete combustion takes place in engines. Nitrogen monoxide is another pollutant produced in car engines.

Write an equation to show how these pollutants react together in a catalytic converter.

.....

(1)

(f) Platinum, palladium and rhodium are metals used inside catalytic converters. A very thin layer of the metals is used on a honeycomb ceramic support.

Explain why a thin layer is used in this way.

.....

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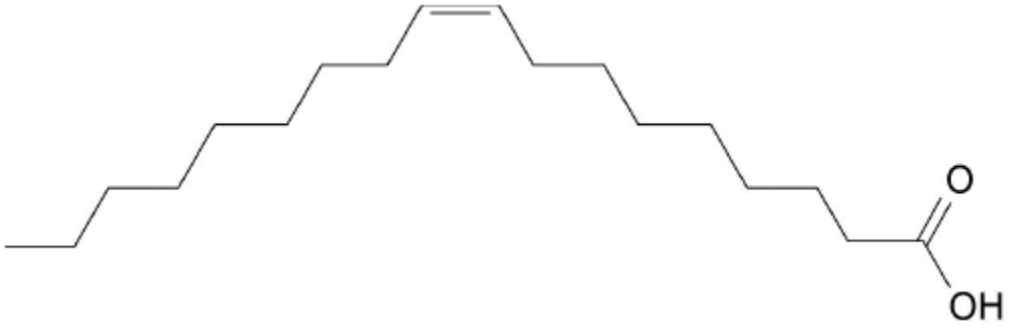
.....

.....

(2)

(g) Oleic acid ($C_{18}H_{34}O_2$) is a straight-chain fatty acid obtained from plant oils. Isooctane can be made from oleic acid. The skeletal formula of oleic acid is shown in **Figure 2**.

Figure 2



Identify a reagent that could be used in a chemical test to show that oleic acid is unsaturated.

State what would be observed in this test.

Reagent .....

Observation.....

.....

(2)
(Total 12 marks)

2 The alkene 3-methylpent-2-ene ($CH_3CH=C(CH_3)CH_2CH_3$) reacts with hydrogen bromide to form a mixture of 3-bromo-3-methylpentane and 2-bromo-3-methylpentane.

(a) The alkene 3-methylpent-2-ene ($CH_3CH=C(CH_3)CH_2CH_3$) exists as *E* and *Z* stereoisomers.

Draw the structure of *Z*-3-methylpent-2-ene.

(1)

(b) Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

Explain why more 3-bromo-3-methylpentane is formed in this reaction than 2-bromo-3-methylpentane.

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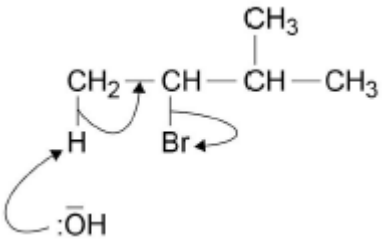
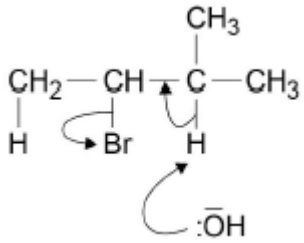
(7)
(Total 8 marks)

3 Which of the following is a correct mechanism for the formation of 2-methylbut-2-ene from 2-bromo-3-methylbutane?

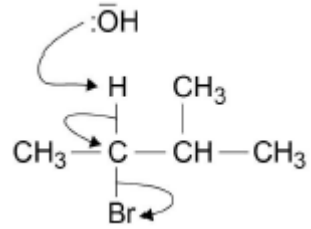
A



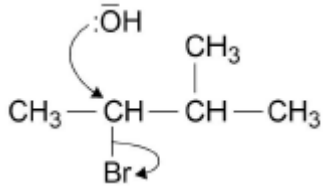
B



C



D



(Total 1 mark)

4 An organic compound is found to contain 40.0% carbon, 6.7% hydrogen and 53.3% oxygen.

Which of the following compounds could this be?

A Ethanol

B Ethanoic acid

C Methanol

D Methanoic acid

(Total 1 mark)

5 The structure of cyclohexene is shown.

Which of the following is the general formula of cyclic alkenes such as cyclohexene?

A C_nH_{2n-4} ⬭

B C_nH_{2n-2} ⬭

C C_nH_{2n} ⬭

D C_nH_{2n+2} ⬭

(Total 1 mark)

6 Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH{=}CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

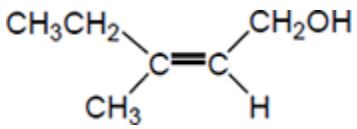
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

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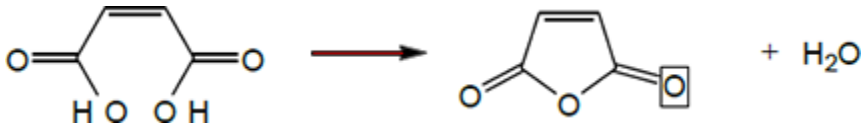
(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment,10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

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(2)
(Total 10 marks)

7 2-bromo-2-methylpentane is heated with potassium hydroxide dissolved in ethanol. Two structural isomers are formed.

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

.....

.....

.....

(1)

(b) Name and draw the mechanism for the formation of **one** of the isomers.

Name of mechanism .....

Mechanism

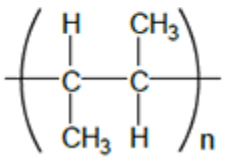
(5)
(Total 6 marks)

8 Dodecane ($C_{12}H_{26}$) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.

Reaction **1**

$C_{12}H_{26} \longrightarrow C_2H_4 + C_4H_8 + \mathbf{X}$

Reaction **2**

$nC_4H_8 \rightleftharpoons$ 

Polymer **Y**

(a) Name the homologous series that both C_2H_4 and C_4H_8 belong to.
Draw a functional group isomer of C_4H_8 that does **not** belong to this homologous series.

Name .....

Functional group isomer

(2)

(b) Identify compound **X**.

.....

(1)

(c) Name polymer **Y**.

.....

(1)

(d) Reaction **1** is an example of thermal cracking and is carried out at a temperature of 750 °C.

State **one other** reaction condition needed.

.....

(1)

(e) Reaction **2** is exothermic. A typical compromise temperature of 200 °C is used industrially for this reaction.

Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

.....

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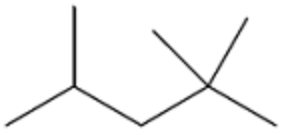
(6)

(Total 11 marks)

9 Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

.....

(1)

(b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5 ⬭

6 ⬭

7 ⬭

8 ⬭

(1)

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

.....

(1)

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

.....

(1)

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers .....

Structure

(2)

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

(1)

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0
Calculate the M_r of this monochlorooctane.

M_r = ...

(2)

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds. One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass. Calculate the molecular formula of this compound.

Molecular formula = ...

(3)
(Total 12 marks)

10 How many isomers have the molecular formula C_5H_{12}?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

11 How many structural isomers have the molecular formula C_4H_9Br?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

12 How many secondary amines have the molecular formula $C_4H_{11}N$?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

13 Central heating fuel, obtained by the fractional distillation of crude oil, contains saturated hydrocarbons with the molecular formula $C_{16}H_{34}$

(a) Give the meaning of the terms **saturated** and **hydrocarbon** as applied to saturated hydrocarbons.

Saturated .....

.....

Hydrocarbon .....

.....

(2)

(b) If the boiler for a central heating system is faulty, a poisonous gas may be produced during the combustion of $C_{16}H_{34}$

Write an equation for the reaction that forms this poisonous gas and one other product only.

.....

(1)

(c) Explain why the sulfur compounds found in crude oil should be removed from the fractions before they are used for central heating fuel.

.....

.....

.....

.....

.....

(2)

(d) A hydrocarbon $C_{16}H_{34}$ can be cracked to form C_8H_{18}, ethene and propene.

(i) Write an equation to show this cracking reaction.

.....

(1)

(ii) Suggest **one** important substance manufactured on a large scale from propene.

.....

(1)

(iii) Draw the **displayed formula** of the functional group isomer of propene.

(1)

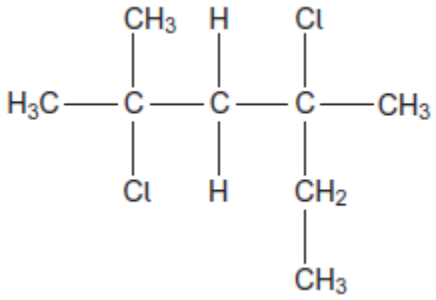
(e) There are many structural isomers with the molecular formula C_8H_{18}

Draw the structure of 2,3,3-trimethylpentane.

(1)

(f) A compound C_8H_{18} reacts with chlorine to give several haloalkanes.

Give the IUPAC name of the following haloalkane.



.....

(1)
(Total 10 marks)

14 There are many uses of halogenated organic compounds despite environmental concerns.

(a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

(i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step

.....

(4)

(ii) State **one** condition necessary for the initiation of this reaction.

.....

(1)

(b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

(i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

$$CBrF_3 \longrightarrow \text{.....} + Br^{\bullet}$$

(1)

(ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

.....

.....

.....

(1)

(iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone. The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst.

Equation 1

.....

Equation 2

.....

Explanation .....

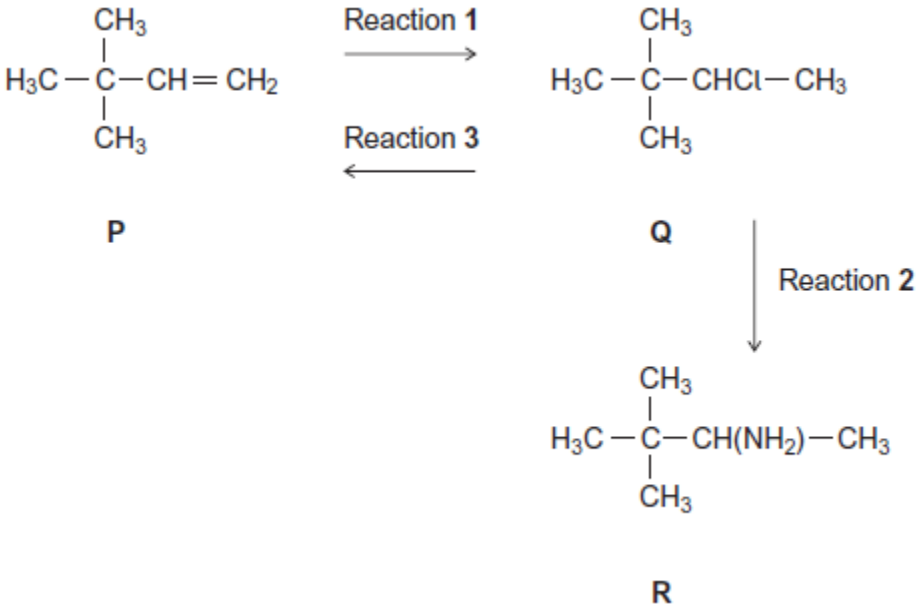
.....

.....

(3)

(Total 10 marks)

15 Consider the following scheme of reactions.



(a) Give the IUPAC name for compound **P** and that for compound **Q**.

P .....

Q .....

(2)

(b) The conversion of **P** into **Q** in Reaction **1** uses HCl

Name and outline a mechanism for this reaction.

.....

(5)

(c) The conversion of **Q** into **R** in Reaction **2** uses NH_3

Name and outline a mechanism for this reaction.

.....

(5)

(d) State the type of reaction shown by Reaction **3**.

Identify a reagent for this reaction.

Give **one** condition necessary for a high yield of product when **Q** is converted into **P**.

.....

.....

.....

.....

.....

(3)

(e) Hydrogen bromide (HBr) could be used in the overall conversion of **P** into **R**, instead of using HCl
Hydrogen bromide is made by the reaction of NaBr with concentrated phosphoric acid.
Concentrated sulfuric acid is **not** used to make HBr from NaBr

Write an equation for the reaction of NaBr with H_3PO_4 to produce HBr and Na_3PO_4 only.

Identify **two** toxic gases that are formed, together with HBr, when NaBr reacts with concentrated H_2SO_4

State the role of H_2SO_4 in the formation of these two toxic gases.

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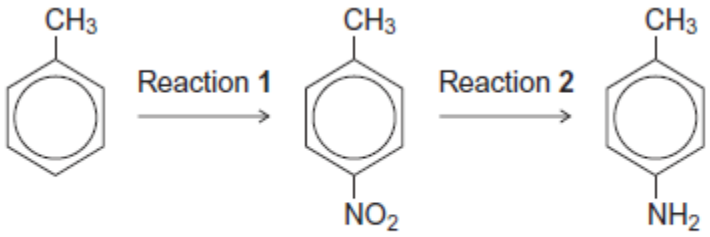
(4)
(Total 19 marks)

16 Consider the following reaction sequence starting from methylbenzene.



J

(a) Name the type of mechanism for reaction **1**.

.....

(1)

(b) Compound **J** is formed by reduction in reaction **2**.

(i) Give a reducing agent for this reaction.

.....

(1)

(ii) Write an equation for this reaction. Use [H] to represent the reducing agent.

.....

(1)

(iii) Give a use for **J**.

.....

(1)

(c) Outline a mechanism for the reaction of bromomethane with an excess of compound **J**.
You should represent **J** as RNH_2 in the mechanism.

(4)

(d) Compound **K** ($C_6H_5CH_2NH_2$) is a structural isomer of **J**.

Explain why **J** is a weaker base than **K**.

.....

.....

.....

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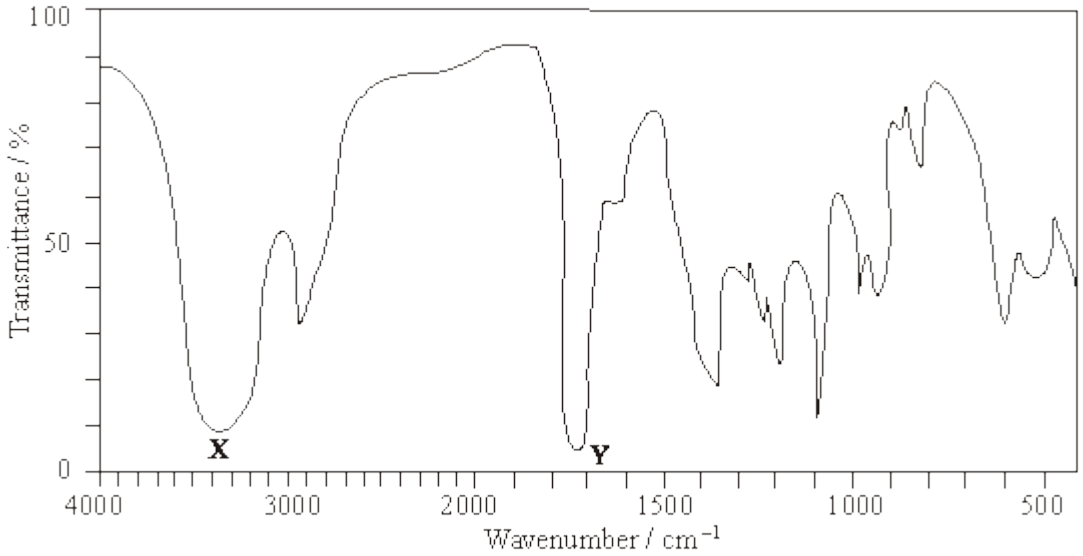
.....

.....

(3)
(Total 11 marks)

17 (a) The infra-red spectrum of compound **A**, $C_3H_6O_2$, is shown below.



Identify the functional groups which cause the absorptions labelled **X** and **Y**.

Using this information draw the structures of the three possible structural isomers for **A**.

Label as **A** the structure which represents a pair of optical isomers.

(6)

(b) Draw the structures of the three **branched-chain** alkenes with molecular formula C_5H_{10}

Draw the structures of the three dibromoalkanes, $C_5H_{10}Br_2$, formed when these three alkenes react with bromine.

One of these dibromoalkanes has only three peaks in its proton n.m.r. spectrum. Deduce the integration ratio and the splitting patterns of these three peaks.

(10)
(Total 16 marks)

18 Which one of the following can exhibit both geometrical and optical isomerism?

A $(CH_3)_2C=CHCH(CH_3)CH_2CH_3$

B $CH_3CH_2CH=CHCH(CH_3)CH_2CH_3$

C $(CH_3)_2C=C(CH_2CH_3)_2$

D $CH_3CH_2CH(CH_3)CH(CH_3)C=CH_2$

(Total 1 mark)

19 How many different alkenes are formed when 2-bromo-3-methylbutane reacts with ethanolic potassium hydroxide?

A 2

B 3

C 4

D 5

(Total 1 mark)

20 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.

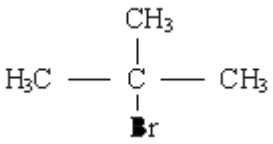
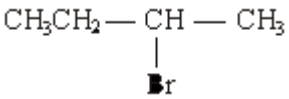
.....

(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)

21 The table below gives some of the names and structures of isomers having the molecular formula C_4H_9Br

Structure	Name
$CH_3CH_2CH_2CH_2Br$	
	2-bromo - 2-methypropane
	1-bromo - 2-methypropane
	2-methypropane

Complete the table.

(Total 2 marks)

22 (a) Name and outline a mechanism for the reaction of 2-bromo-2-methylpropane with ethanolic potassium hydroxide to form the alkene 2-methylpropene, $(CH_3)_2C=CH_2$

Name of mechanism .....

Mechanism

(4)

(b) Two stereoisomers of but-2-ene are formed when 2-bromobutane reacts with ethanolic potassium hydroxide.

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

.....

.....

(ii) Draw the structures and give the names of the **two** stereoisomers of but-2-ene.

Stereoisomer 1 *Stereoisomer 2*

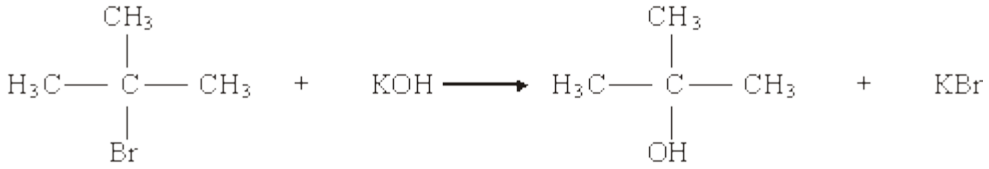
Name ..... *Name* .....

(iii) Name this type of stereoisomerism.

.....

(5)

(c) When 2-bromo-2-methylpropane reacts with aqueous potassium hydroxide, 2-methylpropan-2-ol is formed as shown by the following equation.



State the role of the hydroxide ions in this reaction.

.....

(1)

(d) Write an equation for the reaction that occurs when $CH_3CH_2CH_2CH_2Br$ reacts with an excess of ammonia. Name the organic product of this reaction.

Equation .....

Name of product .....

(3)

(Total 13 marks)

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

$$CH_3CHBrCH_2CH_3 + KOH \xrightarrow[\text{ethanol solvent}]{\text{heat}} \underset{\text{but-2-ene}}{CH_3CH=CHCH_3} + KBr + H_2O$$

(a) Name the haloalkane used in this reaction.

.....

(1)

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

Name of mechanism .....

Mechanism

(4)

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

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

.....

.....

(ii) Draw the structure of this other alkene.

(2)
(Total 7 marks)

24 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)

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

(a) Draw the structures of the **two** straight-chain isomeric alcohols with molecular formula, $C_4H_{10}O$

(2)

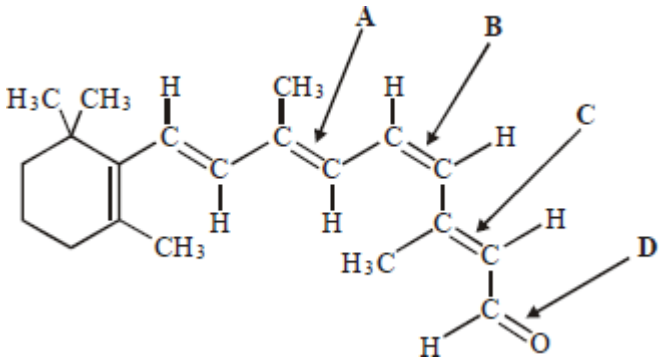
(b) Draw the structures of the oxidation products obtained when the two alcohols from part (a) are oxidised separately by acidified potassium dichromate(VI). Write equations for any reactions which occur, using [O] to represent the oxidising agent.

(6)

(c) Draw the structure and give the name of the alcohol with molecular formula $C_4H_{10}O$ which is resistant to oxidation by acidified potassium dichromate(VI).

(2)
(Total 10 marks)

26 The compound *cis*-retinal is shown below.



Which one of the labelled bonds leads to the prefix in the name?

(Total 1 mark)

27 Which one of the following is a pair of functional group isomers?

A $CH_3COOCH_2CH_3$ and $CH_3CH_2COOCH_3$

B $(CH_3)_2CHCH(CH_3)_2$ and $(CH_3)_3CCH_2CH_3$

C $CH_3CH_2OCH_3$ and $(CH_3)_2CHOH$

D $ClCH_2CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_2Cl$

(Total 1 mark)

28 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.

.....

(1)

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

.....

.....

(1)

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

.....

(1)

(d) One molecule of C_9H_{20} can be cracked to form one molecule of pentane and one other product.

(i) Write an equation for this cracking reaction.

.....

(1)

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

.....

.....

(1)

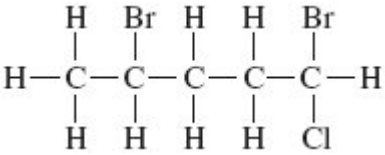
(iii) State why a high temperature is needed for cracking reactions to occur.

.....

.....

(1)

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

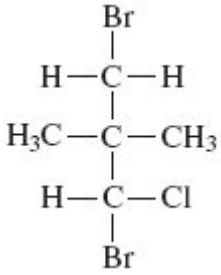


(i) Name **Q**.

.....

(1)

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



.....

(1)
(Total 11 marks)

29 Hexane is a member of the homologous series of alkanes.

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

Characteristic 1 .....

.....

Characteristic 2 …….....

.....

(2)

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

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

Displayed formula

Empirical formula .....

.....

(2)

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

.....

.....

(2)

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

$$C_6H_{14} + 2Cl_2 \rightarrow C_6H_{12}Cl_2 + 2HCl$$

Calculate the percentage atom economy for the formation of $C_6H_{12}Cl_2$ in this reaction.

.....

.....

.....

(2)

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

Alkane	C_4H_{10}	C_5H_{12}	C_6H_{14}
Boiling point / °C	– 0.5	36.3	68.7

(i) Explain the trend in these boiling points.

.....

.....

.....

(2)

(ii) Name a process which can be used to separate C_5H_{12} from C_6H_{14}

.....

(1)

(Total 11 marks)

30 (a) Hexane (C_6H_{14}) 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 .....

.....

Reason 2 .....

.....

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

.....

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

.....

(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.

.....

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

.....

.....

(3)

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

$$CH_4 + 2Cl_2 \rightarrow CH_2Cl_2 + 2HCl$$

(i) Calculate the % atom economy for the formation of CH_2Cl_2 in this reaction.

.....

.....

.....

(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.

.....

.....

.....

(3)
(Total 14 marks)

31 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.

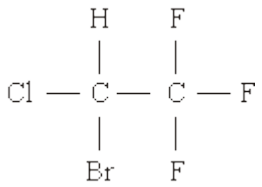
.....

(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)

1

(a) 2,2,4-trimethylpentane

This answer only but ignore punctuation

1

(b) M1 (fractional or simple) distillation

Incorrect process in M1 CE=0

If M1 blank, mark on for M2 and M3 (ignore boiling, condensing)

1

M2 idea that isooctane / the one with the lower boiling point boils (first) (or reaches top of column first)

Ignore reference to octane boiling and being collected at higher temperature

If temperature referred to, should be between 99 and 124°C

"it" refers to isooctane

M2 – allow vaporises/evaporates first

1

M3 idea that isooctane condenses / liquefies and collected

Penalise M2 and M3 if octane boils first

In M2 and M3 – if no specific reference to individual alkanes, could score one mark for M2 + M3 combined if M2 and M3 both otherwise correct

M2 and M3 must refer to a laboratory apparatus (not to an industrial process)

1

(c) $C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$

Accept multiples; ignore state symbols

Accept any correct structural representation of isooctane

1

(d) M1 Alternative route/mechanism/pathway

1

M2 With lower activation energy

Accept E_a for activation energy

1

(e) $2CO + 2NO \longrightarrow 2CO_2 + N_2$

Accept multiples; ignore state symbols

1

(f) M1 to reduce amount of metals needed / small amount of metal needed

Relates to low amount of metal

1

M2 Increase / maximise / produce large surface area or to give catalyst a larger surface area: volume ratio or so that high(er) proportion of atoms/metal is on surface

Is related to large surface area

1

(g) M1 bromine (water or in organic solvent or CCl_4) / Br_2 (aq) / Br_2

No reagent or an incorrect reagent (e.g. bromide), CE=0;

Penalise Br (or incorrect formula of other correct reagent) but mark on for M2

It must be a whole reagent and/or correct formula

If oxidation state given in name, it must be correct

If 'manganate' or 'manganate(IV)' or incorrect formula, penalise M1 but mark on

Ignore 'acidified'

1

M2 (orange/yellow to) colourless / decolourised / loses its colour

Ignore goes clear

Ignore brown/red, but penalise other incorrect colours

1

Alternatives:

M1 = potassium manganate(VII), M2 = colourless

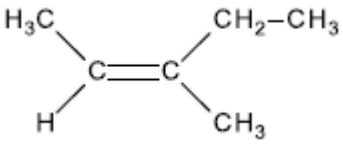
M1 = <u>conc</u> sulfuric acid, M2 = brown

M1 = iodine, M2 = colourless

[12]

2

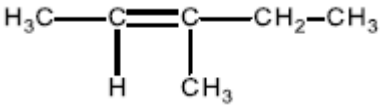
(a)



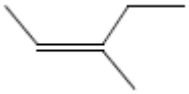
Must show all 4 groups bonded to C=C

Allow CH_3– for methyl group; allow C_2H_5 for ethyl group

Allow correct structure of the style

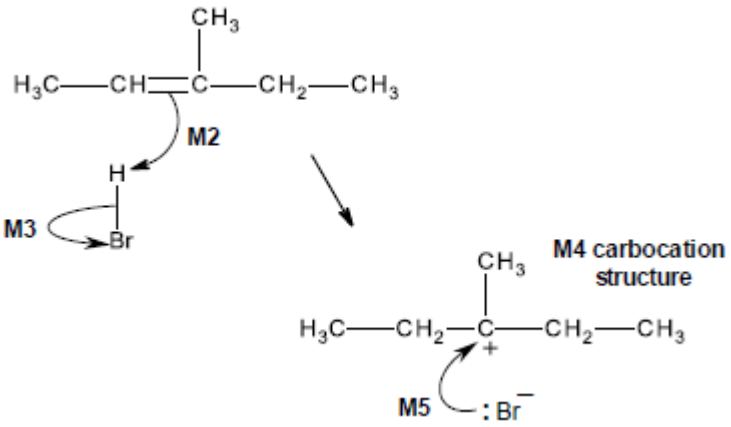


Allow correct skeletal structure



1

(b) M1 electrophilic addition



NB the arrows here are double-headed

1

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

1

M3 must show the breaking of the H-Br bond

1

M4 is for the structure of the tertiary carbocation

1

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged atom (of either a secondary or) of a tertiary carbocation

1

M6 3-bromo-3-methylpentane is formed from 3^{y} carbocation
OR
2-bromo-3-methylpentane is formed from 2^{y} carbocation

1

M7 3^{y} carbocation more stable than 2^{y}

1

M2-M5 *Penalise one mark from their total if half-headed arrows are used*

M2 *Ignore partial negative charge on the double bond*

M3 *Penalise incorrect partial charges on H-Br bond and penalise formal charges*

*Penalise **M4** if there is a bond drawn to the positive charge*

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

Max 3 of any 4 marks (M2-5) *for wrong organic reactant or wrong organic product (if shown) or secondary carbocation*

Max 2 of any 4 marks in the mechanism *for use of bromine*

Do not penalise the "correct" use of "sticks"

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

M6 is high demand and must refer to product being formed from/via correct class of carbocation

M7 is high demand and must be clear answer refers to stability of carbocations (intermediates) not products

Candidate that states that products are carbocations would lose M6 and M7

***M6,7** allow carbonium ion in place of carbocation; or a description of carbocation in terms of alkyl groups/ number of carbon atoms joined to a positive C*

*When asked to outline a mechanism, candidates are **expected** to draw a mechanism with curly arrows (specification 3.3.1.2). On this occasion only we would allow a detailed description as shown.*

***M2** must describe the movement of a pair of electrons / curly arrow from the C=C towards the H atom of the H-Br molecule*

***M3** must describe the breaking of the H-Br bond with the bonding pair of electrons moving to the Br / curly arrow from H-Br bond to Br*

***M4** is for the structure of the tertiary carbocation (i.e. positive C bonded to one methyl and two ethyl groups)*

***M5** must describe the movement of a pair of electrons from the Br^- ion to the positive C atom of the carbocation / curly arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged C atom (of either a secondary or) of a tertiary carbocation*

[8]

3 B

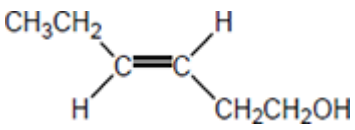
[1]

4 B

[1]

5 B

[1]

6 (a) 

1

(b) 

1

(c) **Stage 1**: consider the groups joined to right hand carbon of the C=C bond

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

Consider the atomic number of the atoms attached

M1 can be scored in stage 1 or stage 2

1

C has a higher atomic number than H, so CH_2OH takes priority

1

Stage 2: consider the groups joined to LH carbon of the C=C bond

Both groups contain C atoms, so consider atoms one bond further away

1

C, (H and H) from ethyl group has higher atomic number than H, (H and H) from methyl group, so ethyl takes priority

1

Stage 3: conclusion

The highest priority groups, ethyl and CH_2OH are on same side of the C=C bond so the isomer is Z

Allow M5 for correct ECF conclusion using either or both wrong priorities deduced in stages 1 and 2

1

The rest of the IUPAC name is 3-methylpent-2-en-1-ol

1

(d) Moles of maleic acid = 10.0 / 116.0 = 8.62×10^{-2}

AND mass of organic product expected = $(8.62 \times 10^{-2}) \times 98.0 = 8.45$ g

Or moles of organic product formed = 6.53 / 98.0 = 6.66×10^{-2}

1

% yield = 100 × 6.53 / 8.45

OR = $100 \times (6.66 \times 10^{-2}) / (8.62 \times 10^{-2})$

= 77.294 = 77.3%

AND statement that the student was NOT correct

1

[10]

7 (a) (Compounds with the) same molecular formula but different structural / displayed / skeletal formula

1

(b) (basic) elimination

1

Mechanism points:

Correct arrow from lone pair on :OH^- to H on C adjacent to C–Br

1

Correct arrow from C–H bond to C–C

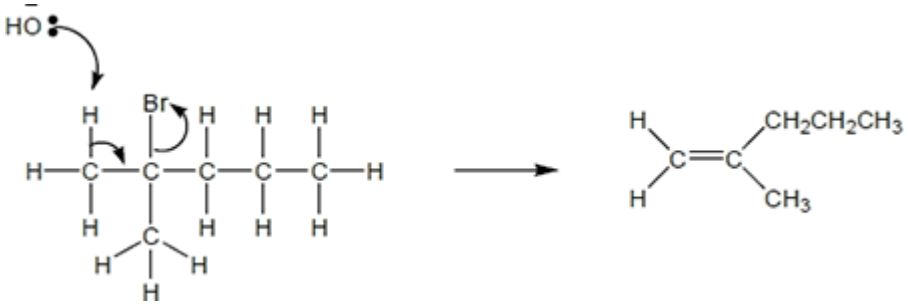
1

Correct arrow from C–Br bond to Br

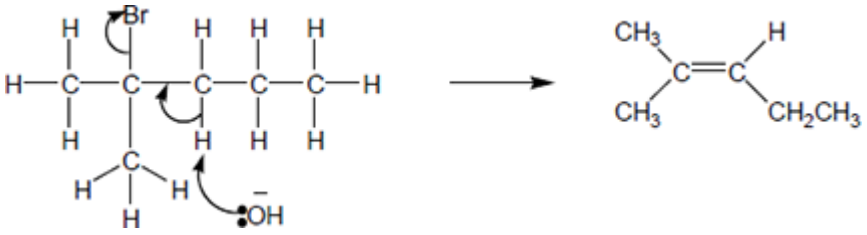
1

Structure of chosen product

1



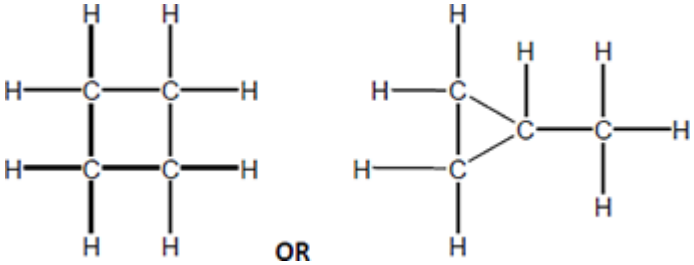
OR



[6]

8 (a) Alkenes

1



OR

Correctly drawn molecule of cyclobutane or methyl cyclopropane, need not be displayed formula

1

(b) C_6H_{14} (or correct alkane structure with 6 carbons)

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure ≥ MPa

Mention of catalyst loses the mark

1

(e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

5–6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

3–4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

1–2 marks

Level 0

Insufficient correct chemistry to gain a mark.

0 marks

Indicative chemistry content

Stage 1*: consider effect of higher temperature on yield*

(Or vice versa for lower temperature)

- *Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature*
- *Exothermic reaction, so equilibrium shifts in endothermic direction / to the left*
- *So a Higher T will reduce yield*

***Stage 2**: consider effect of higher temperature on rate*

(Or vice versa for lower temperature)

- *At higher temperature, more high energy molecules*
- *more collisions have E>Ea*
- *So rate of reaction increases / time to reach equilibrium decreases*

***Stage 3**: conclusion*

Industrial conditions chosen to achieve (cost-effective) balance of suitable yield at reasonable rate

[11]

9

(a) 2,2,4-trimethylpentane

1

(b) 5

1

(c) $C_{20}H_{42} \longrightarrow C_8H_{18} + 2C_3H_6 + 3C_2H_4$

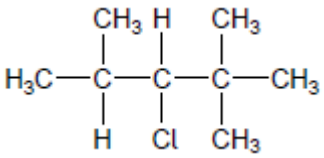
1

(d) Mainly alkenes formed

1

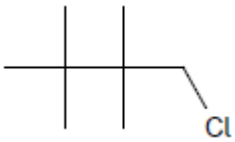
(e) 4 (monochloro isomers)

1



1

(f)



1

(g) $C_8H_{17}{}^{35}Cl = 96.0 + 17.0 + 35.0 = 148.0$
and $C_8H_{17}{}^{37}Cl = 96.0 + 17.0 + 37.0 = 150.0$

Both required

1

M_r of this $C_8H_{17}Cl$ $\frac{(1.5 \times 148.0)}{2.5} + \frac{(1.0 \times 150.0)}{2.5} = 148.8$

1

(h) $\frac{24.6}{12}$ $\frac{2.56}{1}$ $\frac{72.8}{35.5}$ = 2.05 : 2.56 : 2.05

Simplest ratio = $\frac{2.05}{2.05} : \frac{2.56}{2.05} : \frac{2.05}{2.05}$

= 1 : 1.25 : 1

1

Whole number ratio (× 4) = 4 : 5 : 4

1

MF = $C_8H_{10}Cl_8$

1

[12]

10 B

[1]

11 C

[1]

12 B

[1]

13 (a) Saturated − single bonds only / no double bonds

1

Hydrocarbon − contains carbon and hydrogen (atoms) only

1

(b) $C_{16}H_{34} + 16.5O_2 \longrightarrow 16CO + 17H_2O$

Allow multiples

1

(c) (On combustion) SO_2 produced

Allow equation to produce SO_2. Ignore sulfur oxides.

1

Which causes acid rain

If formula shown it must be correct

M2 is dependent on M1. But if M1 is sulfur oxides, allow M2.

For M2 allow consequence of acid rain or SO_2.

Ignore greenhouse effect and toxic

1

(d) (i) $C_{16}H_{34} \longrightarrow C_8H_{18} + C_2H_4 + 2C_3H_6$

Allow multiples

1

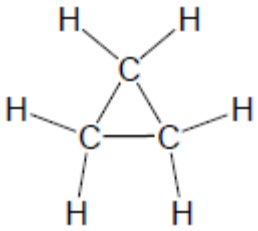
(ii) polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal

Accept alternative names

Ignore plastic and polymer

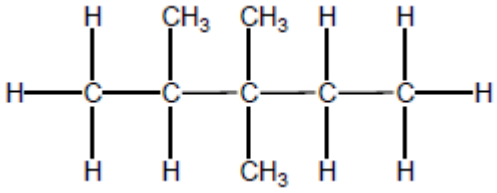
1

(iii)



1

(e)



Allow any unambiguous representation

1

(f) 2,4-dichloro-2,4-dimethylhexane

Only but ignore punctuation

1

[10]

14 (a) (i) **Initiation**

$Br_2 \longrightarrow 2Br\bullet$

First propagation

$Br\bullet + CHF_3 \longrightarrow \bullet CF_3 + HBr$

Second propagation

$Br_2 + \bullet CF_3 \longrightarrow CBrF_3 + Br\bullet$

Termination

$2\bullet CF_3 \longrightarrow C_2F_6$ ***OR*** CF_3CF_3

OR

$2Br\bullet \longrightarrow Br_2$

OR

$Br\bullet + \bullet CF_3 \longrightarrow CBrF_3$

Penalise absence of dot once only

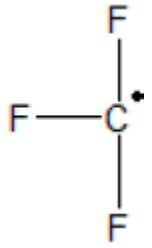
Credit the dot anywhere on the radical

4

(ii) Ultra-violet / uv / sunlight
OR
T > 100°C OR high temperature

1

(b) (i)



Displayed formula required with the radical dot on carbon

1

(ii) (The) C–Br (bond) breaks more readily / is weaker than (the) C–Cl (bond) (or converse)
OR
The C–Br bond enthalpy / bond strength is less than that for C–Cl (or converse)

*Requires **a comparison** between the two bonds*

Give credit for an answer that suggests that the UV frequency / energy may favour C–Br bond breakage rather than C–Cl bond breakage

Ignore correct references either to size, polarity or electronegativity

Credit correct answers that refer to, for example "the bond between carbon and bromine requires less energy to break than the bond between carbon and chlorine"

1

(iii) **M1**

$Br\bullet + O_3 \longrightarrow BrO\bullet + O_2$

M2

$BrO\bullet + O_3 \longrightarrow Br\bullet + 2O_2$

***M1** and **M2** could be in either order*

Credit the dot anywhere on the radical

Penalise absence of dot once only

Penalise the use of multiples once only

M3 One of the following

They / it / the bromine (atom)

- does not appear in the overall equation
- is regenerated
- is unchanged at the end
- has not been used up
- provides an alternative route / mechanism

3

[10]

15 (a) **P** 3,3−dimethylbut−1−ene

OR

accept 3,3−dimethylbutene

Ignore absence of commas, hyphens and gaps

Require correct spelling

Q 3−chloro−2,2−dimethylbutane

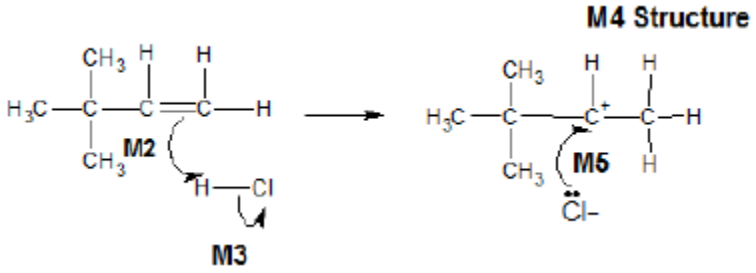
OR

accept 2−chloro−3,3−dimethylbutane

In Q, "chloro" must come before "dimethyl"

2

(b) **M1 <u>Electrophilic addition</u>**



M2 must show an arrow from the double bond towards the H atom of HCl
M3 must show the breaking of the H−Cl bond
M4 is for the structure of the carbocation
M5 must show an arrow from the lone pair of electrons on the negatively charged chloride ion towards the positively charged carbon atom on <u>their</u> carbocation.

NB The arrows here are double−headed

M1 *both words required*

For the mechanism

M3 *Penalise incorrect partial charge on H−Cl bond and penalise formal charges*

Ignore partial negative charge on the double bond.

<u>Maximum 3 of 4 marks for a correct mechanism</u> *using HBr or the wrong organic reactant or wrong organic product (if shown) or a primary carbocation*

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

Credit the correct use of "sticks"

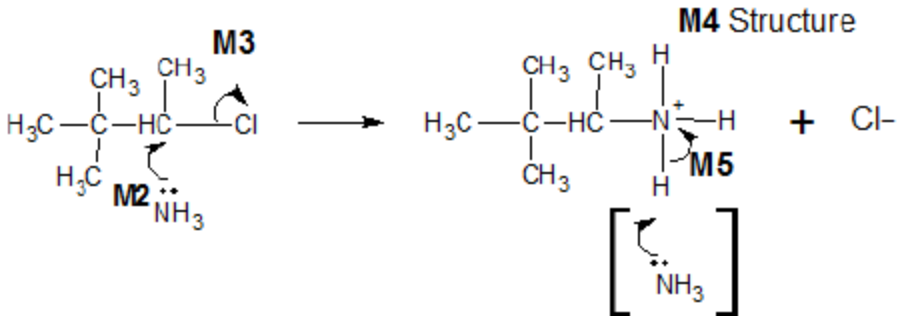
*For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4***

5

(c) **M1** **Nucleophilic substitution**

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

Accept phonetic spelling



M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom
M3 must show the movement of a pair of electrons from the C− Cl bond to the Cl atom. Mark **M3** independently provided it is from their original molecule
M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on, or close to, the N atom.
M5 is for an arrow from the N−H bond to the N atom
Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

NB These are double-headed arrows

For the mechanism

*Penalise **M2** if NH_3 is negatively charged.*

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

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

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

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

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

Accept the correct use of "sticks"

5

(d) **M1** (base) elimination

__M1__ Dehydrohalogenation

M2 KOH **OR** NaOH

M3 Must be consequential on a correct reagent in **M2**, but if incomplete or inaccurate attempt at reagent (e.g. hydroxide ion), **penalise M2 only and mark on**

Any **one** from

- high temperature OR hot OR heat / boil under reflux
- concentrated
- alcohol / ethanol (as a solvent) / (ethanolic conditions)

__M3__ not "reflux" alone

__M3__ if a temperature is stated it must be in the range 78°C to 200 °C

Ignore "pressure"

3

(e) **M1**

$3NaBr + H_3PO_4 \longrightarrow 3HBr + Na_3PO_4$

__M1__ Credit correct ionic species in the equation

M2 and M3

SO_2 **and** Br_2 identified

M4

Concentrated sulfuric acid

- is an oxidising agent
- oxidises the bromide (ion) or Br^- or NaBr or HBr
- is an electron acceptor

In __M2__ and __M3__ the two gases need to be identified. If equations are used using sulfuric acid and the toxic gases are not identified clearly, allow one mark for the formulas of SO_2 and Br_2

- *apply the list principle as appropriate but ignore any reference to HBr*
- *the marks are for identifying the two gases either by name or formula*

4

[19]

16 (a) Electrophilic substitution

Both words needed

Ignore minor misspellings

1

(b) (i) Sn / HCl

OR H_2 / Ni **OR** H_2 / Pt **OR** Fe / HCl **OR** Zn / HCl **OR** $SnCl_2$ / HCl

Ignore conc or dil with HCl,

Allow (dil) H_2SO_4 but not conc H_2SO_4

Not allow HNO_3 or H^+

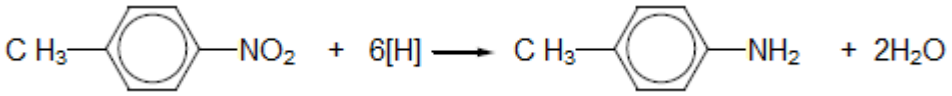
Ignore NaOH after Sn / HCl

Ignore catalyst

1

(ii) $CH_3C_6H_4NO_2 + 6[H] \rightarrow CH_3C_6H_4NH_2 + 2H_2O$

OR



Allow molecular formulae as structures given

$C_7H_7NO_2 + 6[H] \rightarrow C_7H_9N + 2H_2O$

Qu states use [H], so penalised $3H_2$

1

(iii) making dyes

OR making quaternary ammonium salts

OR making (cationic) surfactants

OR making hair conditioner

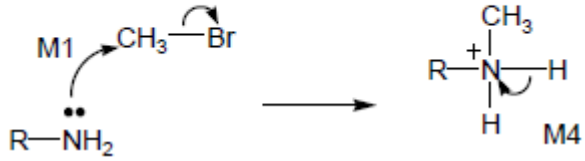
OR making fabric softener

OR making detergents

1

(c)

M2



M3

NO Mark for name of mechanism

Allow SN1

M1 for lone pair on N and arrow to C or mid point of space between N and C

M2 for arrow from bond to Br

M3 for structure of protonated secondary amine

M4 for arrow from bond to N or + on N

For M4: ignore RNH_2 or NH_3 removing H^+ but penalise Br^-

4

(d) lone or electron pair on N

If no mention of lone pair CE = 0

If lone pair mentioned but not on N then lose M1 and mark on

M1

1

in **J** spread / delocalised into ring (or not delocalised in K)

Ignore negative inductive effect of benzene

*Allow interacts with **Π** cloud for M2*

M2

1

less available (for protonation or donation in **J**)

M3

OR

in **K** there is a positive inductive effect / electron releasing)

M2

more available (for protonation or donation in **K**)

M3

1

[11]

17 (a) **X** (O–H) (alcohols)

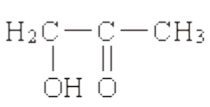
penalise acid or missing "alcohol"

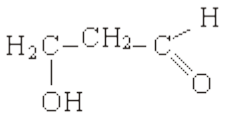
1

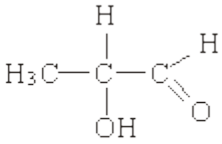
Y C=O

allow carbonyl

1



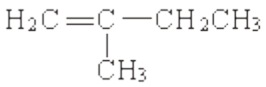
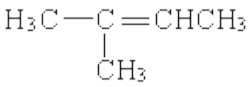
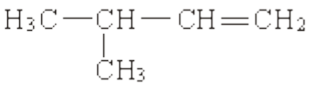




A

NOT acid

4

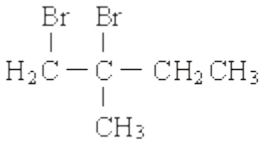
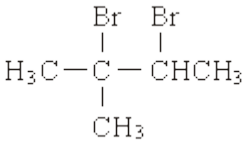
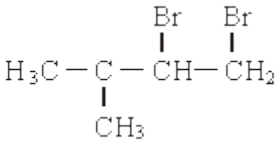
(b)   

Allow conseq dibromocompounds following incorrect unbranched alkenes

NOT allow dibromocompound consequent on a duplicate alkene

NOT allow monobromocompounds if HBr added

3

3

6:3:1 either next to correct structure or to none

1

Allow a mark for identifying correct dibromocompound with three peaks even if integration ratio is wrong

1

if 6:3:1 missing or wrong, no marks for splitting

Only award a mark for splitting if it is clear which integration number it refers to

6 singlet or drawn

1

3 doublet or drawn

1

1 quartet/quadruplet or drawn

1

(max 10 marks)

[16]

18 B

[1]

19 A

[1]

20 (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]

21 1(-)bromobutane

1

correct structure for 1-bromo-2-methylpropane

(C–C bonds must be clear where drawn)

1

[2]

22 (a) (base) elimination

(penalise other words before 'elimination' e.g. nucleophilic)

1

M1: curly arrow from lone pair of electrons on oxygen of hydroxide ion

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

1

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

1

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

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

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

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

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

(award a maximum of two marks for either an incorrect haloalkane or an incorrect organic product)

(maximum 2 marks for use of 'sticks' for the haloalkane, unless RE from 2(b), when credit can be given)

(b) (i) **M1**: compounds with the same structural formula

1

M2: but the bonds/groups/atoms have different spatial arrangements or orientation or configuration/are arranged differently in space/3D

(ignore reference to the same molecular formula for M1)

1

(ii) **M1**: correct structural representation for cis-but-2-ene and its name or its identification as the cis isomer

1

M2: correct structural representation for trans-but-2-ene and its name or its identification as the trans isomer

(accept representations which are 90° to linear)

(award one mark for two correct structures but either wrong/no names)

(maximum 1 mark for an incorrect alkene)

1

(iii) geometric(al) or cis-trans

1

(c) nucleophile or electron pair donor

(penalise 'base')

1

(d) $CH_3CH_2CH_2CH_2Br + 2NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_2 + NH_4Br$

(M1 correct product)

(M2 balanced equation using $2NH_3$ and leading to NH_4Br)

(penalise M1 for use of $C_4H_9NH_2$ or for incorrect haloalkane, but allow consequent correct balancing of equation with 2 moles of ammonia)

2

(1–)butylamine

(credit 1–aminobutane and butyl–1–amine)

(award QoL mark for correct spelling)

1

[13]

23 (a) 2-bromobutane;

1

(b) Elimination;

(penalise "nucleophilic" OR "electrophilic" before the word "elimination")

1

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

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

1

M2: curly arrow <u>from single bond</u> of <u>adjacent C-H to adjacent</u> single bond C-C;

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

1

M3: curly arrow <u>from C-Br bond</u> to side of Br atom;

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

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

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

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

1

[7]

24

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 neither M3 nor M4 scored, allow $CH_3CH_2\cdot + Cl\cdot \rightarrow C_2H_5Cl$ for one mark)

1

[5]

25 (a) M1: $CH_3CH_2CH_2CH_2OH$;

1

M2: $CH_3CH(OH)CH_2CH_3$;

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

1

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

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

3

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

1

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

OR

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

1

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

(Credit condensed structures or molecular formulas in each equation, provided it is obvious to which reaction the equation refers) (Insist that whatever formula is used in each equation that it is a conventional representation of the compound; for example penalise $CH_3CH_2CH_2COH$ for butanal)

1

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

1

OR

methylpropan-2-ol;

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

1

[10]

26 B

[1]

27 C

[1]

28 (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) C_nH_{2n+2}

Formula only
C_xH_{2x+2}

1

(b) (i) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

Accept multiples
Ignore state symbols

1

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

Allow CO_2 or water is greenhouse gas/causes global warming
Acid rain/ozone CE = 0

1

(c) carbon

Allow C
Allow soot

1

(d) (i) $C_9H_{20} \rightarrow C_5H_{12} + C_4H_8$

OR

$C_9H_{20} \rightarrow C_5H_{12} + 2C_2H_4$

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]

29 (a) General formula;

Chemically similar;

Same functional group;

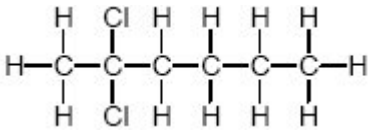
Trend in physical properties eg inc bp as M_r increases;

Contains an additional CH_2 group;

Any two points.

2 max

(b) (i)



All bonds and atoms must be shown.

1

C_3H_6Cl;

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

1

(ii) Same Molecular formula/ both $C_6H_{12}C_{l2}$/ 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

$\frac{155 \times 100}{228}$ = 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]

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

1

(ii) $C_6H_{14} + 6.5O_2 \rightarrow 6CO + 7H_2O$

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) $CH_3CH_2CH_2CH(CH_3)_2$

1

2-methylpentane

1

$CH_3CH_2CH(CH_3)CH_2CH_3$ etc

1

(c) (i) $CH_3CH_2CH_2CH=CH_2$

1

(ii) Alumino silicate etc

1

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

1

(d) (i) % atom economy = mass CH_2Cl_2/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]

31 (a) (i) (free–)radical substitution

(both words required for the mark)

1

(ii) uv light OR sunlight OR <u>high</u> 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]