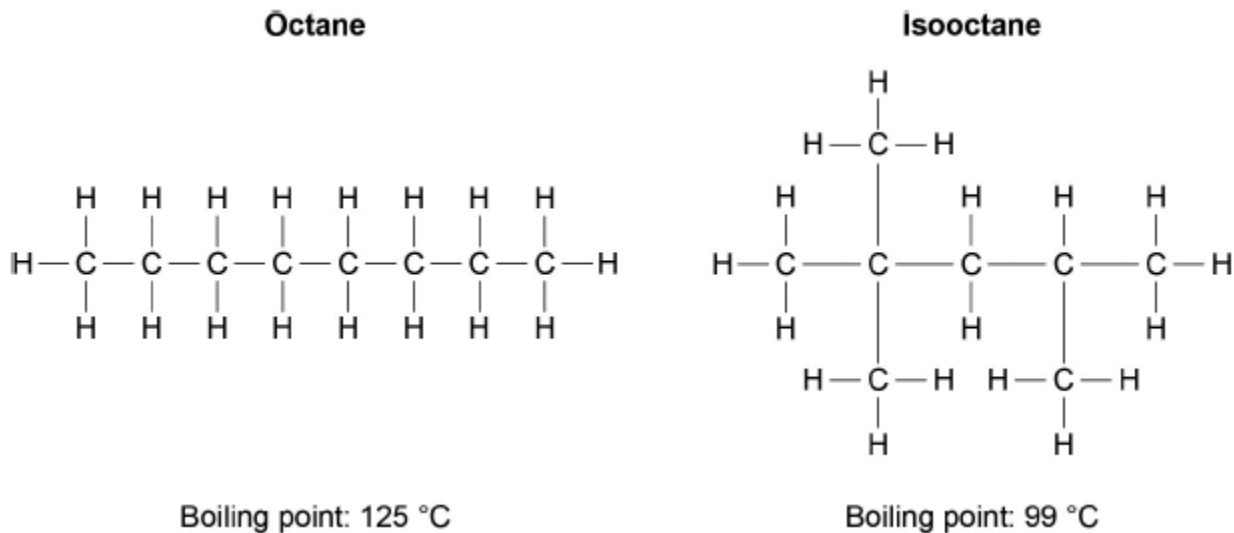


1

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



(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.

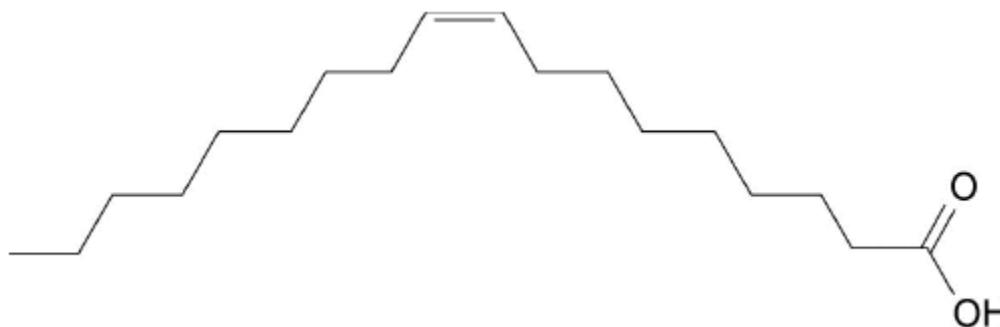
Explain why a thin layer is used in this way.

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

(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

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.

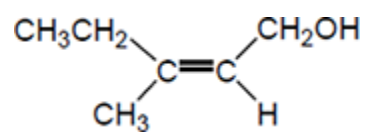
- (a) Give the structure of the *E* isomer of **J**.

(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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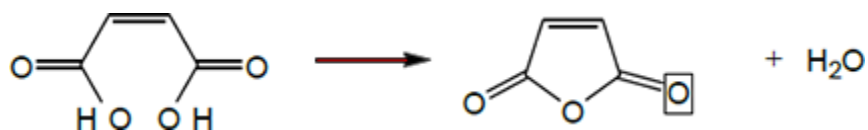
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(6)

(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%.

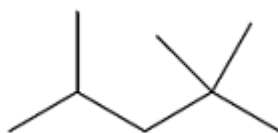
In an experiment, 10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

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

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

(2)
(Total 10 marks)

3 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.

$M_r = \dots\dots\dots$

(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 = $\dots\dots\dots$

(3)

(Total 12 marks)

4

Central heating fuel, obtained by the fractional distillation of crude oil, contains saturated hydrocarbons with the molecular formula $\text{C}_{16}\text{H}_{34}$

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

Saturated $\dots\dots\dots$

$\dots\dots\dots$

Hydrocarbon $\dots\dots\dots$

$\dots\dots\dots$

(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)

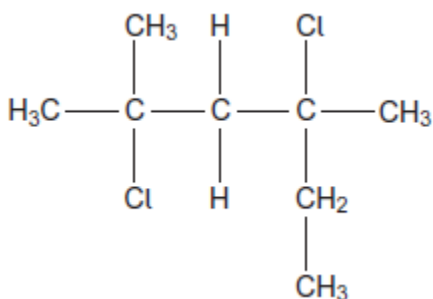
(e) There are many structural isomers with the molecular formula C_8H_{18}

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)

5

Some oil-fired heaters use paraffin as a fuel.

One of the compounds in paraffin is the straight-chain alkane, dodecane ($C_{12}H_{26}$).

(a) Give the name of the substance from which paraffin is obtained.
State the name of the process used to obtain paraffin from this substance.

Substance

Process

(2)

(b) The combustion of dodecane produces several products.

Write an equation for the **incomplete** combustion of dodecane to produce gaseous products only.

.....

(1)

(c) Oxides of nitrogen are also produced during the combustion of paraffin in air.

(i) Explain how these oxides of nitrogen are formed.

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

(2)

(ii) Write an equation to show how nitrogen monoxide in the air is converted into nitrogen dioxide.

.....

(1)

(iii) Nitric acid (HNO_3) contributes to acidity in rainwater.

Deduce an equation to show how nitrogen dioxide reacts with oxygen and water to form nitric acid.

.....

(1)

(d) Dodecane ($\text{C}_{12}\text{H}_{26}$) can be cracked to form other compounds.

(i) Give the general formula for the homologous series that contains dodecane.

.....

(1)

(ii) Write an equation for the cracking of one molecule of dodecane into equal amounts of two different molecules each containing the same number of carbon atoms. State the empirical formula of the straight-chain alkane that is formed. Name the catalyst used in this reaction.

Equation

Empirical formula of alkane

Catalyst

.....

(3)

- (iii) Explain why the melting point of dodecane is higher than the melting point of the straight-chain alkane produced by cracking dodecane.

.....

.....

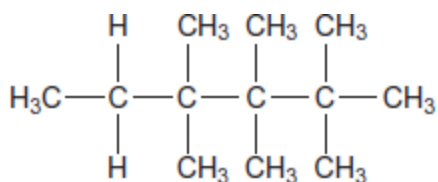
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(2)

- (e) Give the IUPAC name for the following compound and state the type of structural isomerism shown by this compound and dodecane.



IUPAC name

Type of structural isomerism

(2)

- (f) Dodecane can be converted into halododecanes.

Deduce the formula of a substance that could be reacted with dodecane to produce 1-chlorododecane and hydrogen chloride only.

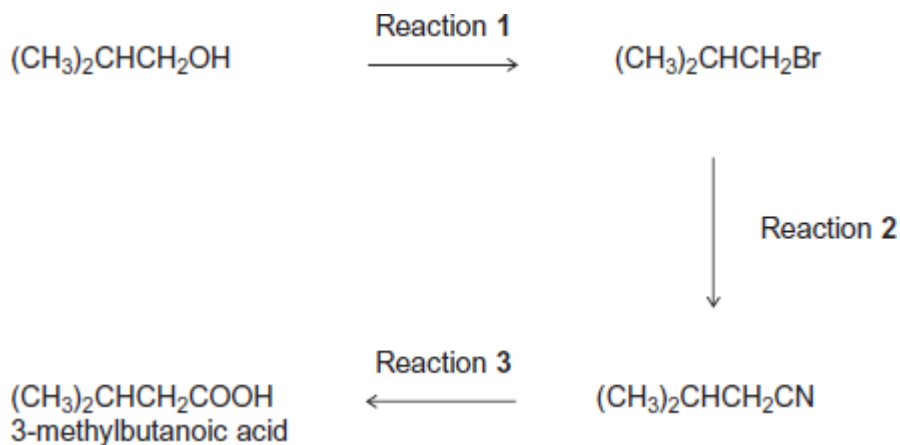
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(1)

(Total 16 marks)

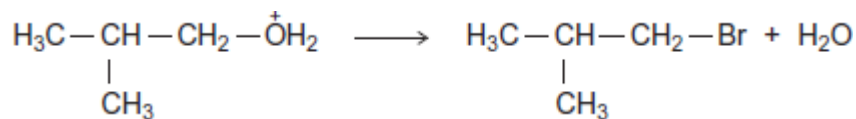
6

The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes. The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



- (a) One of the steps in the mechanism for Reaction 1 involves the replacement of the functional group by bromine.
- (i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.

BF_3 :



(2)

- (ii) Deduce the name of the mechanism in part (i).

Give the IUPAC name of $(\text{CH}_3)_2\text{CHCH}_2\text{Br}$

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

(2)

- (b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(\text{CH}_3)_2\text{CHCH}_2\text{CN}$ and a **different** bond in $(\text{CH}_3)_2\text{CHCH}_2\text{COOH}$ that can be used with infrared spectroscopy to distinguish between each compound.

For each of these bonds, give the range of wavenumbers at which the bond absorbs.

Use **Table A** on the Data Sheet when answering this question.

.....

.....

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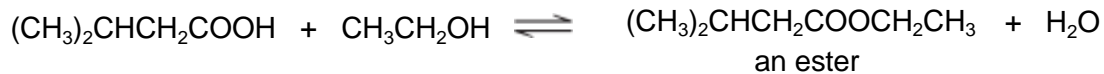
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(3)

- (c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.



The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

- (i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

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(Extra space)
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(3)

- (ii) Explain how a catalyst increases the rate of a reaction.

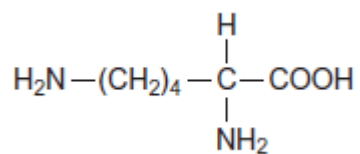
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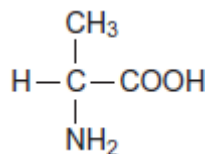
(2)
(Total 12 marks)

7

Lysine and alanine are two amino acids.



lysine



alanine

(a) Give the IUPAC name of lysine.

.....

(1)

(b) Draw structures to show the product formed in each case when lysine reacts with

(i) an excess of aqueous HCl

(1)

(ii) an excess of aqueous NaOH

(1)

(iii) methanol in the presence of a small amount of concentrated H_2SO_4

(1)

- (c) The mass spectrum of alanine gives a major peak at $m/z = 44$

Write an equation for the fragmentation of the molecular ion of alanine to give an ion that produces this peak.

In your answer, draw the displayed formula for this fragment ion.

(2)

- (d) Draw a dipeptide formed from one molecule of lysine and one molecule of alanine.

(1)

- (e) The dipeptide in part (d) is hydrolysed in acid conditions and the mixture produced is analysed by column chromatography. The column is packed with a resin which acts as a polar stationary phase.

Suggest why lysine leaves the column after alanine.

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

(2)

(Total 9 marks)

8

- (a) The hydrocarbon but-1-ene (C_4H_8) is a member of the homologous series of alkenes. But-1-ene has structural isomers.

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

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

(2)

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

.....

(1)

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

.....

(1)

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

(1)

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

(i) Write an equation for this reaction.

.....

(1)

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

.....

(1)

(c) One mole of compound **Y** is cracked to produce two moles of ethene, one mole of but-1-ene and one mole of octane (C_8H_{18}) only.

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

.....

(1)

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

.....

(1)

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

(i) Write an equation for this reaction.

.....

(1)

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

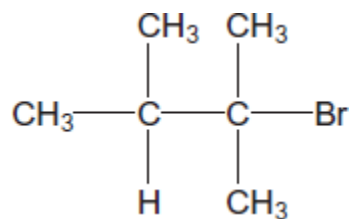
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(1)

(Total 11 marks)

9

(a) The structure of the bromoalkane **Z** is



Give the IUPAC name for **Z**.

Give the general formula of the homologous series of straight-chain bromoalkanes that contains one bromine atom per molecule.

Suggest **one** reason why 1-bromohexane has a higher boiling point than **Z**.

.....

.....

.....

.....

.....

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(Extra space)

.....

.....

(3)

(b) Draw the displayed formula of 1,2-dichloro-2-methylpropane.

State its empirical formula.

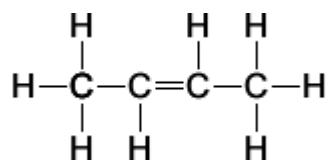
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.....

(2)
(Total 5 marks)

10

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



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

.....

(1)

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

.....

(1)

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

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

.....

(1)

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

(1)

- (c) At high temperatures, one molecule of $\text{C}_{15}\text{H}_{32}$ can be converted into two molecules of **X** and one molecule of another compound.

- (i) Write an equation for this reaction.

.....

(1)

- (ii) State the name of the process used to obtain a high yield of **X** from $\text{C}_{15}\text{H}_{32}$.
Give **one** reason why this process is used in industry.

Name

Reason

.....

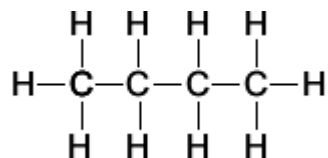
(2)

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

.....
.....

(1)

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



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

.....

(1)

(ii) Give **one** use of **Y**.

.....

(1)

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

.....

(1)

(iv) When a sample of **Y**, contaminated with CH_3SH , is burned completely in air, a toxic gas is formed.
Identify this toxic gas and suggest a compound that could be used to remove the toxic gas from the products of combustion.

Toxic gas

Compound used to remove toxic gas

.....

(2)

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

.....

(1)

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

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

(2)
(Total 16 marks)

11

Pentane is a member of the alkane homologous series.

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

.....

(1)

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

Draw the displayed formula of 2,2-dimethylpropane.

State the type of structural isomerism shown.

.....

(2)

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

Deduce the molecular formula of **Y**.

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

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

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(Extra space)
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(3)

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

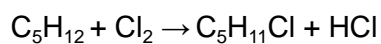
Suggest why this solid pollutant is an environmental problem.

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

(2)

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



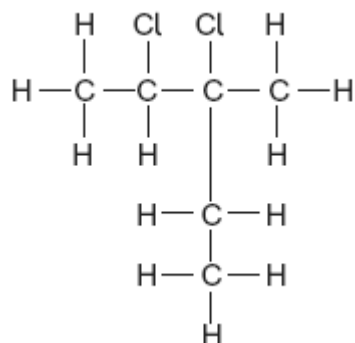
Calculate the percentage atom economy for the formation of $\text{C}_5\text{H}_{11}\text{Cl}$

Deduce how many straight-chain isomers of $\text{C}_5\text{H}_{11}\text{Cl}$ could be formed.

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

(3)

(f) Consider the following compound.



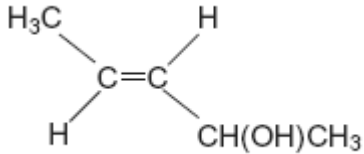
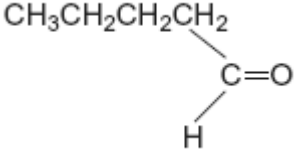
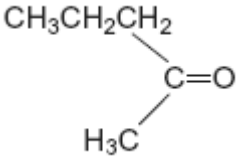
Name this compound.

Deduce the empirical formula of this compound.

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

(2)
(Total 13 marks)

The table below shows the structures of three isomers with the molecular formula $C_5H_{10}O$

<p>Isomer 1</p> 	<p>(<i>E</i>)-pent-3-en-2-ol</p>
<p>Isomer 2</p> 	<p>pentanal</p>
<p>Isomer 3</p> 	

(a) Complete the table by naming Isomer 3.

(1)

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

.....

(1)

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

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

(1)

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

.....

(1)

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

Test reagent

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

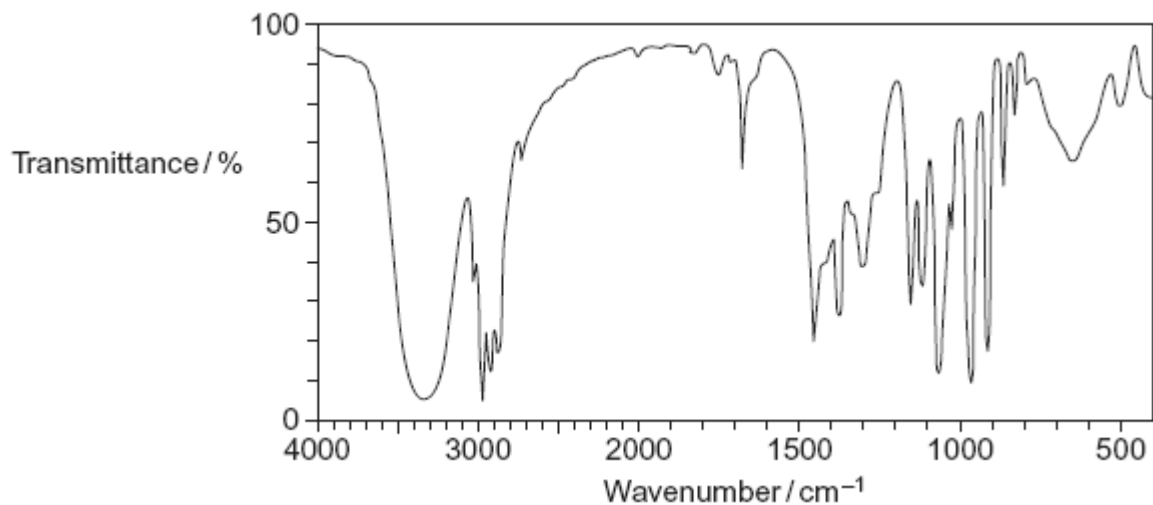
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Observation with Isomer **3**.....

.....

(3)

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



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

.....

(1)

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

Feature 1 and functional group

.....

.....

.....

Feature 2 and functional group

.....

.....

.....

(2)
(Total 10 marks)

13

Octane is the eighth member of the alkane homologous series.

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

.....

.....

.....

.....

(2)

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

.....

.....

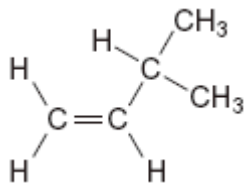
(1)

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

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

(2)

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



.....

(1)

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

(1)

(c) The cracking of one molecule of compound **X** produces pent-1-ene, ethene and butane in a 1:2:1 mol ratio.

Deduce the molecular formula of **X** and state a use for the ethene formed.

Molecular formula of **X**

.....

Use of ethene

(2)

(Total 7 marks)

15

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.

.....
.....

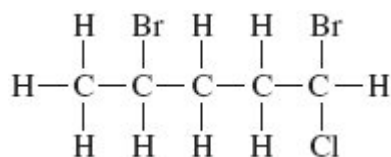
(1)

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

.....
.....

(1)

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

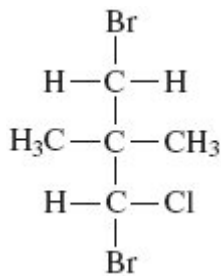


- (i) Name **Q**.

.....

(1)

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



.....

(1)
(Total 11 marks)

16

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)

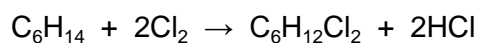
- (ii) Explain why 2,2-dichloro-3-methylpentane is a structural isomer of 2,2-dichlorohexane.

.....

.....

(2)

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



Calculate the percentage atom economy for the formation of $\text{C}_6\text{H}_{12}\text{Cl}_2$ in this reaction.

.....

.....

.....

(2)

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

Alkane	C ₄ H ₁₀	C ₅ H ₁₂	C ₆ H 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 C₅H₁₂ from C₆H₁₄

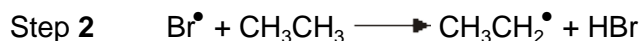
.....

(1)

(Total 11 marks)

17

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



(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.

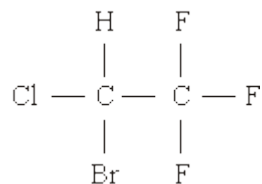
.....

(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)

18

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)

19

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

Structure	Name
$CH_3CH_2CH_2CH_2Br$	
$\begin{array}{c} CH_3 \\ \\ H_3C - C - CH_3 \\ \\ Br \end{array}$	2-bromo - 2-methylpropane
	1-bromo - 2-methylpropane
$\begin{array}{c} CH_3CH_2 - CH - CH_3 \\ \\ Br \end{array}$	2-methylpropane

Complete the table.

(Total 2 marks)

20

Four isomers with the formula C_4H_9OH are given below.

Isomer	Name
$CH_3CH_2CH_2CH_2OH$	butan-1-ol
$\begin{array}{c} CH_3 \\ \\ CH_3 - C - CH_3 \\ \\ OH \end{array}$	2-methylpropan-2-ol
$\begin{array}{c} CH_3 - C - CH_2OH \\ \\ CH_3 \end{array}$	
$\begin{array}{c} CH_3CH_2 - CH - CH_3 \\ \\ OH \end{array}$	

- (i) Complete the naming of the isomers in the table above.
- (ii) Name the type of isomerism shown by these four isomers.

.....

(Total 3 marks)

21

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

methane	CH_4
ethane	CH_3CH_3
propane	$CH_3CH_2CH_3$
butane	$CH_3CH_2CH_2CH_3$

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

.....

.....

(ii) Give the general formula for the alkanes.

.....

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

.....

(3)

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

.....

.....

.....

(2)

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

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

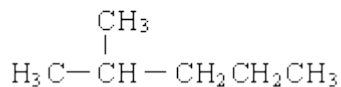
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.....

.....

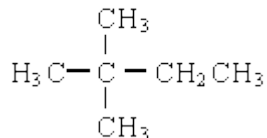
(ii) Name the **two** isomers of hexane shown below.

Isomer 1



Name

Isomer 2



Name

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

Isomer 3

Isomer 4

(6)

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

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

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

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

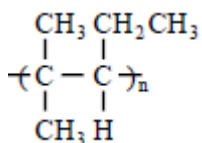
.....
.....

(4)

(Total 15 marks)

22

The correct name for the alkene monomer which forms the polymer shown below is



- A 2-methyl-3-ethylpropene
- B 2-methylpent-2-ene
- C 2-methylpent-3-ene
- D 4-methylpent-2-ene

(Total 1 mark)

23

The correct systematic name for $(\text{CH}_3)_2\text{CHC}=\overset{\text{CH}_2\text{CH}_3}{\underset{\text{CH}}{\text{C}}}\text{CH}_3$ is

- A 2-ethyl-3,4-dimethylpent-2-ene
- B 4-ethyl-2,3-dimethylpent-3-ene
- C 2,3,4-trimethylhex-3-ene
- D 3,4,5-trimethylhex-3-ene

(Total 1 mark)

24

The correct systematic name for $\text{CH}_3\text{CH}_2\overset{\text{CH}_2\text{CH}_3}{\underset{\text{CH}_3}{\text{C}}}=\text{CCH}_3$ is

- A 2,3-diethylbut-2-ene
- B 2-ethyl-3-methylpent-2-ene
- C 4-ethyl-3-methylpent-3-ene
- D 3,4-dimethylhex-3-ene

(Total 1 mark)

25

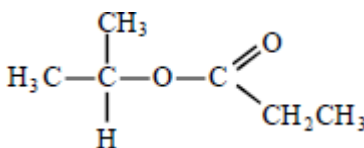
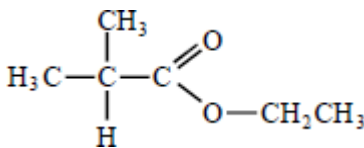
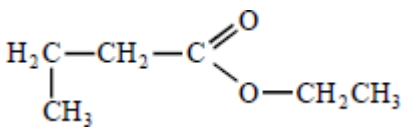
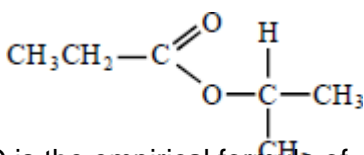
Which one of the following is the correct name for $\text{CH}_3\text{C}(\text{CH}_2\text{CH}_3)=\text{CBrCH}_3$?

- A 2-bromo-3-methylpent-2-ene
- B 2-bromo-3-ethylbut-2-ene
- C 3-bromo-2-ethylbut-2-ene
- D 4-bromo-3-methylpent-3-ene

(Total 1 mark)

26

The structural formula of ethyl 2-methylpropanoate is

- A 
- B 
- C 
- D 

(Total 1 mark)

27

CH_2O is the empirical formula of

- A methanol
- B methyl methanoate
- C ethane-1,2-diol
- D butanal

(Total 1 mark)

Mark schemes

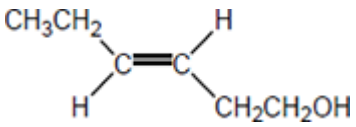

1

- (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) $C_8H_{18} + 12\frac{1}{2}O_2 \rightarrow 8CO_2 + 9H_2O$
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) $2CO + 2NO \rightarrow 2CO_2 + N_2$
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 CCl₄) / Br₂ (aq) / Br₂
*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 = conc sulfuric acid, M2 = brown
M1 = iodine, M2 = colourless*

[12]

2

- (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 CH₂OH 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 CH₂OH 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 = $10.0 / 116.0 = 8.62 \times 10^{-2}$

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

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

1

% yield = $100 \times 6.53 / 8.45$

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]

3

(a) 2,2,4-trimethylpentane

1

(b) 5

1

(c) $\text{C}_{20}\text{H}_{42} \longrightarrow \text{C}_8\text{H}_{18} + 2\text{C}_3\text{H}_6 + 3\text{C}_2\text{H}_4$

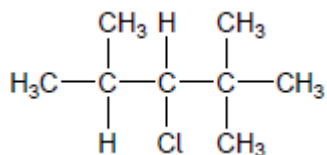
1

(d) Mainly alkenes formed

1

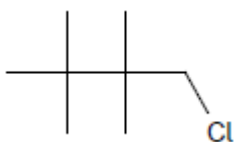
(e) 4 (monochloro isomers)

1



1

(f)



1

- (g) $\text{C}_8\text{H}_{17}^{35}\text{Cl} = 96.0 + 17.0 + 35.0 = 148.0$
and $\text{C}_8\text{H}_{17}^{37}\text{Cl} = 96.0 + 17.0 + 37.0 = 150.0$

Both required

1

$$M_r \text{ of this } \text{C}_8\text{H}_{17}\text{Cl} = \frac{(1.5 \times 148.0)}{2.5} + \frac{(1.0 \times 150.0)}{2.5} = 148.8$$

1

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

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

$$= 1 : 1.25 : 1$$

1

$$\text{Whole number ratio } (\times 4) = 4 : 5 : 4$$

1

$$\text{MF} = \text{C}_8\text{H}_{10}\text{Cl}_8$$

1

[12]

4

- (a) Saturated – single bonds only / no double bonds

1

Hydrocarbon – contains carbon and hydrogen (atoms) only

1

- (b) $\text{C}_{16}\text{H}_{34} + 16.5\text{O}_2 \longrightarrow 16\text{CO} + 17\text{H}_2\text{O}$

Allow multiples

1

(c) (On combustion) SO₂ produced

Allow equation to produce SO₂. 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 SO₂.

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

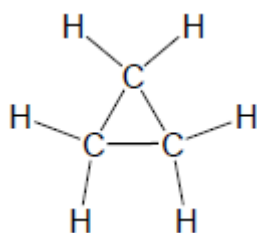
(ii) polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal

Accept alternative names

Ignore plastic and polymer

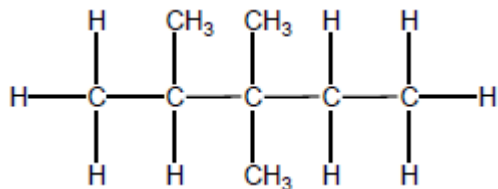
1

(iii)



1

(e)



Allow any unambiguous representation

1

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

Only but ignore punctuation

1

[10]

5

(a) Crude oil **OR** petroleum

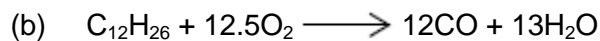
Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1



Allow balanced equations that produce CO_2 in addition to CO.

Accept multiples.

1

(c) (i) M1 Nitrogen and oxygen (from air) react / combine / allow a correct equation

If nitrogen from petrol / paraffin / impurities CE = 0 / 2.

1

M2 at high temperatures

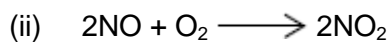
Allow temperatures above 1000 °C or spark.

Not just heat or hot.

M2 dependent on M1.

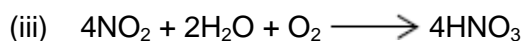
But allow 1 mark for nitrogen and oxygen together at high temperatures.

1



Allow multiples.

1



Allow multiples.

1

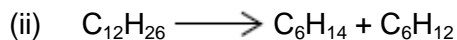
(d) (i) C_nH_{2n+2}

Allow C_xH_{2x+2}

C_nH_{2n+2}

Allow C_xH_{2x+2}

1



Only.

1

C_3H_7

Only.

1

Zeolite / aluminosilicate(s)

Ignore aluminium oxide.

1

(iii) Larger molecule / longer carbon chain / more electrons / larger surface area

1

More / stronger van der Waals' forces between molecules

Allow dispersion forces / London forces / temporary induced dipole-dipole forces between molecules.

If breaking bonds, CE = 0 / 2.

1

(e) 2,2,3,3,4,4-hexamethylhexane

Only.

Ignore punctuation.

1

Chain

Ignore branch(ed).

1

(f) Cl₂

Only.

Cl-Cl

Not CL₂ or Cl2 or CL2 or Cl² or CL².

Ignore Chlorine.

1

[16]

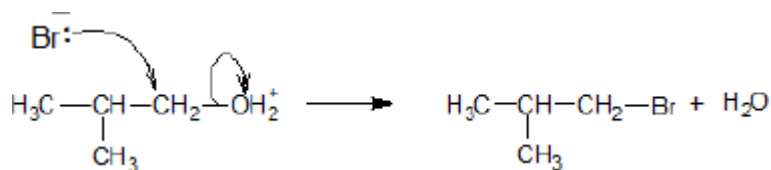
6

(a) (i) **M1** double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH₂

Penalise additional arrows.

M2 double-headed arrow from the bond to the O atom

As follows



2

(ii) **M1** nucleophilic substitution

M1 both words needed (allow phonetic spelling).

M2 1-bromo(-2-)methylpropane

M2 Require correct spelling in the name but ignore any hyphens or commas.

2

(b) **M1** hydrolysis

*For **M1** give credit for 'hydration' on this occasion only.*

M2 C≡N with absorption range 2220–2260 (cm⁻¹)

*Credit 1 mark from **M2** and **M3** for identifying C≡N **and** either O–H(acids) **or** C=O **or** C–O without reference to wavenumbers or with incorrect wavenumbers.*

M3 O–H(acids) with absorption range 2500–3000 (cm⁻¹)

OR

C=O with absorption range 1680–1750 (cm⁻¹)

OR

C–O with absorption range 1000–1300 (cm⁻¹)

*Apply the list principle to **M3***

3

(c) (i) **M1** Yield / product **OR** ester increases / goes up / gets more

M2 (By Le Chatelier's principle) the position of equilibrium is driven / shifts / moves to the right / L to R / in the forward direction / to the product(s)

M3 – requires a correct statement in M2

(The position of equilibrium moves)

to oppose the increased concentration of ethanol

to oppose the increased moles of ethanol

to lower the concentration of ethanol

to oppose the change and decrease the ethanol

*If no reference to **M1**, marks **M2** and **M3** can still score BUT if **M1** is incorrect CE=0*

*If there is reference to 'pressure' award **M1** ONLY.*

3

(ii) **M1**

Catalysts provide an alternative route / pathway / mechanism

OR

surface adsorption / surface reaction occurs

For M1, not simply 'provides a surface' as the only statement.

M1 may be scored by reference to a specific example.

M2

that has a lower / reduced activation energy

OR

lowers / reduces the activation energy

Penalise M2 for reference to an increase in the energy of the molecules.

For M2, the student may use a definition of activation energy without referring to the term.

Reference to an increase in successful collisions in unit time alone is not sufficient for M2 since it does not explain why this has occurred.

2

[12]

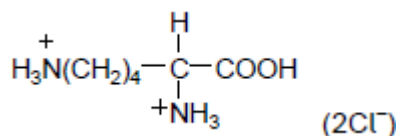
7

(a) 2,6-diaminohexanoic acid

Ignore additional , or – or spaces.

1

(b) (i)



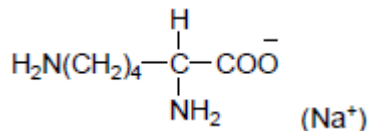
NB both N must be protonated.

Allow $-\text{NH}_3^+$ allow CO_2H Allow $-\text{H}_3\text{N}$.

Penalise $-\text{C}_4\text{H}_8$ – here.

1

(ii)



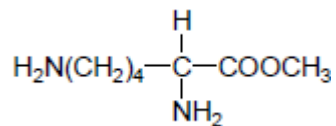
Allow CO_2^- .

Allow $-\text{H}_2\text{N}$.

Allow $-\text{COONa}$ but penalise $\text{O}-\text{Na}$ bond shown.

1

(iii)

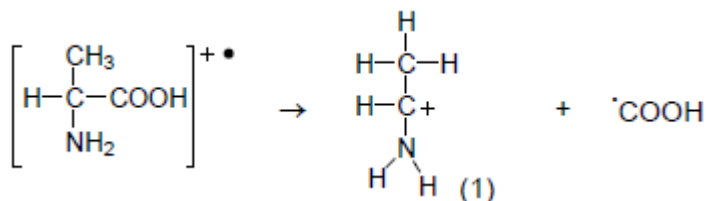


Allow CO_2CH_3 .

Allow $-\text{NH}_3^+$ or $-\text{H}_2\text{N}$.

1

(c)



1 for displayed formula of fragment ion.

1 for molecular ion of alanine AND radical.

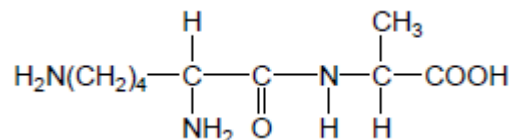
Allow molecular ion without brackets and fragment ion in brackets with outside +.

Allow dot anywhere on radical.

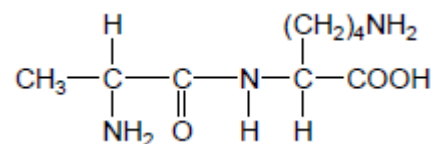
Allow $[\text{C}_3\text{H}_7\text{NO}_2]^+$ for molecular ion.

2

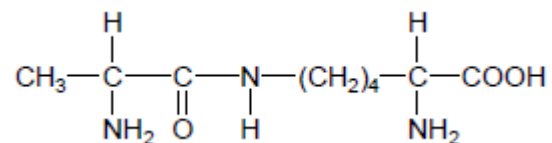
(d)



OR



OR



Dipeptide, not repeating unit /.

Allow CO_2H Allow $-\text{H}_2\text{N}$.

Allow $-\text{CONH}-$.

1

(e) M1 In acid lysine has double positive or more positive charge

1

M2 (Lysine ion) has greater affinity / greater attraction / adheres better / sticks better to polar / stationary phase

M2 only scores after a correct M1.

Ignore greater retention time.

1

[9]

8

(a) (i) (Compounds with the) same molecular formula

Allow same number and type of atom for M1

Ignore same general formula.

1

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

M2 dependent on M1

Not different positions of atoms / bonds in space.

1

(ii) But-2-ene

Allow but-2-ene.

Allow but 2 ene.

Ignore punctuation.

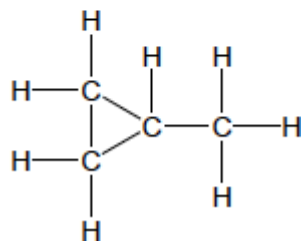
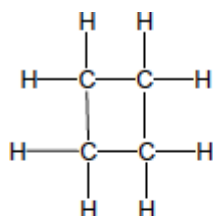
1

(iii) (2)-methylprop-(1)-ene

Do not allow 2-methyleprop-1-ene.

1

(iv)



Do not allow skeletal formulae.

Penalise missing H and missing C

1

(b) (i) $C_4H_8 + 2O_2 \rightarrow 4C + 4H_2O$

Accept multiples.

1

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

Ignore toxic / pollutant / soot / carcinogen.

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

1

(c) (i) $C_{16}H_{34}$

Allow $H_{34}C_{16}$

C and H must be upper case.

1

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

Ignore oil alone.

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

1

(d) (i) $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5 N_2 + 9H_2O$

Accept multiples.

1

(ii) Ir / iridium

OR

Pt / platinum

OR

Pd / palladium

OR

Rh / rhodium

1

[11]

9

(a) 2-bromo-2,3-dimethylbutane

Ignore punctuation.

1

$C_nH_{2n+1}Br$ or $C_nH_{2n+1}X$ or $C_xH_{2x+1}Br$

Any order.

1

Stronger / more vdw (forces) between molecules (of 1-bromohexane)

QoL

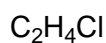
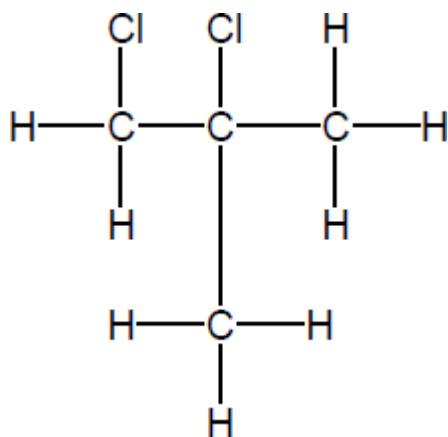
Allow converse arguments for Z

Not just more IMF.

Ignore size of molecule.

1

(b)



Any order

1

1

[5]

10

(a) (i) C_nH_{2n} / C_xH_{2x}

1

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

Do not allow cracking / distillation

1

(b) (i) But-1-ene / but1ene

Ignore hyphens and commas

Do not allow butene-1 / but-2-ene / butane / butane /alkene / C_4H_8 / propene / straight-chain alkene

1

(ii) A structure of cyclobutane or methyl-cyclopropane

Allow skeletal formula.

1

(c) (i) $C_{15}H_{32} \rightarrow 2C_4H_8 + C_7H_{16}$

Do not accept multiples.

1

(ii) Thermal cracking

Not catalytic cracking or cracking.

1

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

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

Ignore more useful products.

1

- (iii) Break (C–C or C–H) bonds
Allow to overcome the activation energy.
Allow to break the carbon chain.
Penalise breaking wrong bonds. 1
- (d) (i) $\underline{\text{H}}_2$
Only. 1
- (ii) Fuel / LPG
Allow camping gas, lighter fuel, propellant, refrigerant, cordless appliances.
Do not allow petrol or motor fuel.
Ignore natural gas. 1
- (iii) $\text{C}_4\text{H}_{10} + 2.5\text{O}_2 \rightarrow 4\text{C} + 5\text{H}_2\text{O}$
Accept multiples. 1
- (iv) SO^2 / sulfur dioxide
If other sulfur oxides, mark on. 1
- Calcium oxide / CaO / lime / quicklime
Allow CaCO_3 / allow $\text{Ca}(\text{OH})_2$ or names.
Allow any solid base.
M2 dependent on M1.
Do not allow limewater. 1
- (v) Neutralisation
Allow acid-base reaction.
Allow flue gas desulfurisation / FGD 1
- (e) (Molecules) are similar sizes / have similar M_r / have similar number of electrons
Chemical error CE = 0/2 if breaking bonds.
Allow similar number of carbon and hydrogen atoms / similar surface area / similar chain length.
Can accept same number of carbon atoms.
Do not accept same number of H atoms / same number of bonds.
Ignore similar amount of bonds. 1

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

Not similar incorrect IMF eg dipole-dipole

1

[16]

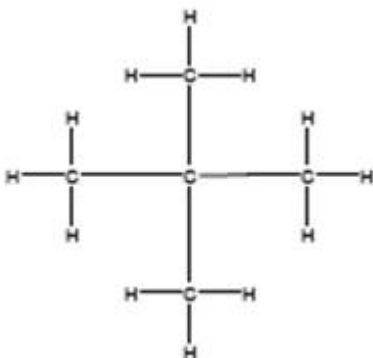
11

(a) $C_n H_{2n+2}$

Allow x in place of n

1

(b)



Chain

Must show every bond

Allow branched chain

2

(c) C_9H_{20}

Only

1

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

M2=0 if break C=C

1

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

Not more useful products

Allow specific answers relating to question

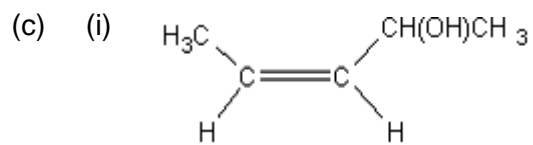
1

- (d) $C_5H_{12} + 3O_2 \rightarrow 5C + 6H_2O$
 Allow other balanced equations which give C and CO/CO₂ 1
- Causes global dimming / exacerbates asthma / causes breathing problems / makes visibility poor / smog
 Apply list principle
 Ignore causes cancer / toxic 1
- (e) $\frac{106.5}{143} (x 100)$ 1
- 74.48%
 Allow 74.5% 1
- 3
 Only 1
- (f) 2,3-dichloro-3-methylpentane
 Ignore punctuation 1
- C₃H₆Cl
 Only 1

[13]

12

- (a) Pentan-2-one
 ONLY but ignore absence of hyphens 1
- (b) Functional group (isomerism)
 Both words needed 1



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

The group needs to be CHOHCH_3 but do not penalise poor C–C bonds or absence of brackets around OH

Trigonal planar structure not essential

1

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

OR

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

1

(d)

<p>M1 Tollens' (reagent) (Credit ammoniacal silver nitrate OR a description of making Tollens') (Do not credit Ag^+, AgNO_3 or $[\text{Ag}(\text{NH}_3)_2]^+$ or "the silver mirror test" on their own, but mark M2 and M3)</p>	<p>M1 Fehling's (solution) / Benedict's (Penalise $\text{Cu}^{2+}(\text{aq})$ or CuSO_4 but mark M2 and M3)</p>
<p>M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u></p>	<p>M2 <u>Red solid/precipitate</u> (Credit <u>orange</u> or <u>brown solid</u>)</p>
<p>M3 (stays) colourless OR no (observed) change / no reaction</p>	<p>M3 (stays) blue OR no (observed) change / no reaction</p>

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

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

Allow the following alternatives

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

M2 (turns) green

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

OR

M1 (acidified) potassium manganate(VII) (solution); mark on from incomplete formulae or incorrect oxidation state

M2 (turns) colourless

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

In all cases for **M3**

Ignore "nothing (happens)"

Ignore "no observation"

3

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

or named or correctly identified

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

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

1

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

- (Strong / broad) absorption / peak in the range **2320 to 3550** cm^{-1} or specified value in this range or **marked correctly** on spectrum
and
(characteristic absorption / peak for) OH group / **alcohol** group
- No absorption / peak in range **1680 to 1750** cm^{-1} or absence marked correctly on spectrum
and
(No absorption / peak for a) **C=O** group / **carbonyl** group / **carbon-oxygen double bond**
- Absorption / peak in the range **1620 to 1680** cm^{-1} or specified value in this range or marked correctly on spectrum
and
(characteristic absorption / peak for) **C=C** group / **alkene** / **carbon-carbon double bond**

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

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

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

2

[10]

13

- (a)
- (Same) General formula/allow a named homologous series with its general formula
 - Chemically similar/same (chemical) reactions
 - Same functional group
 - Trend in physical properties/eg inc bp as M_r increases
 - (Molecules) increase by $\text{CH}_2/M_r = 14$

Any two points

2

(b) Fractional distillation/fractionation/chromatography

Allow GLC

1

- (c) (Molecules/compounds/substances) with the same molecular formula/same number and type of atoms
Allow alkanes with same molecular formula
Allow same chemical formula in M1 = 0 but can allow M2 1

but different structural formula/different displayed formula/different arrangement of atoms/different structures
Not different positions in space 1

2,4-dimethylhexane
M2 dependent on M1 1

C₄H₉
Ignore the absence of dash and/or commas 1

- (d) less surface contact/less surface area/less polarisable molecule 1

so fewer/weaker/less Van der Waals'/vdw forces
Allow more spherical or fewer points of contact
Not smaller molecule/not more compact molecule/not shorter chain
Allow converse arguments
Must be comparative answer ie not just few VDW forces
QoL
Assume 'it' refers to the branched isomer 1

[9]

14

- (a) (Different) boiling points
Ignore mp's, references to imf, different volatilities 1

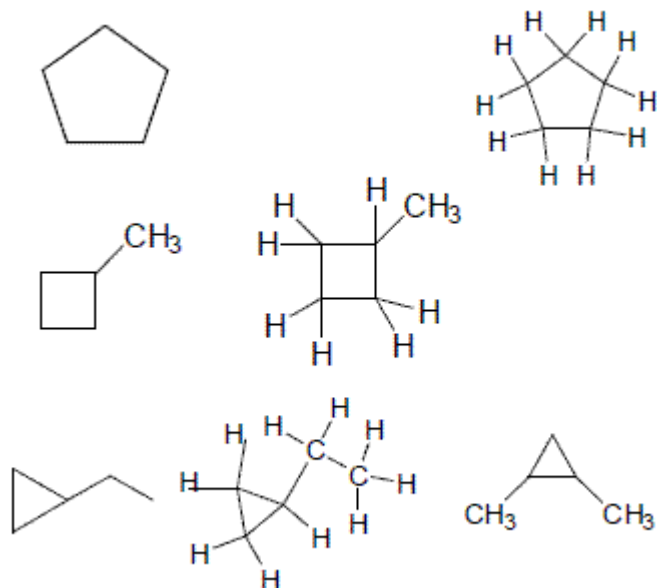
- (b) (i) Compound which have the same molecular formula
Accept same no and type of atom for M1
But If same (chemical) formula M1 = 0 but allow M2
If empirical formula CE = 0/2 1

but different structures/different structural formulae/different displayed formulae
M2 dependent on M1 1

- (ii) 3-methylbut-1-ene
only
ignore commas and hyphens

1

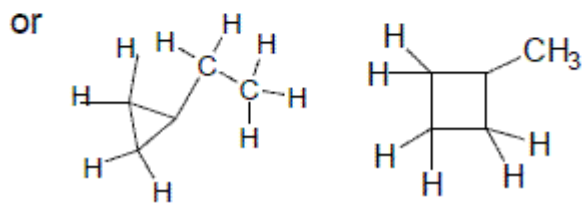
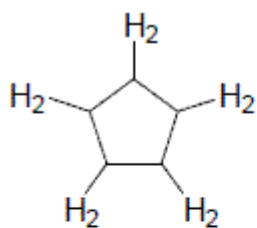
(iii)



Allow any correct structure with a cyclic alkane

1

Do not allow



i.e with an H missing on one C

(c) $C_{13}H_{28}$

only

1

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

not used as a plastic/polymer/antifreeze

not just 'polymers' – we need to see that they are being made

1

[6]

15

(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

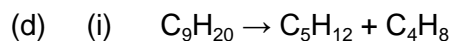
1

(c) carbon

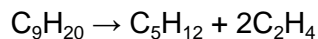
Allow C

Allow soot

1



OR



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]

16

(a) General formula;

Chemically similar;

Same functional group;

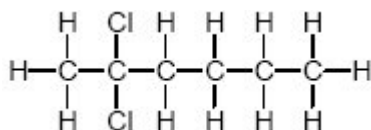
Trend in physical properties eg inc bp as M_r increases;

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 C₆H₁₂C₁₂/ same number and type of atoms;

1

Different structural formula/ different structure/ different displayed formula;

Not atoms or elements with same MF

CE=0.

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]

17

- (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

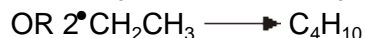
1

- (iii) Propagation

(ignore "chain", "first", "second" in front of the word propagation)

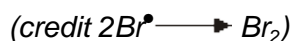
1

(iv) Termination 1



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

(penalise C₂H₅•)



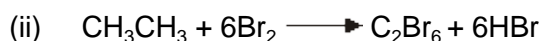
(ignore "chain" in front of the word termination)

1

(b) (i) Fractional distillation OR fractionation

(credit gas-liquid chromatography, GLC)

1



(credit C₂H₆ for ethane)

1

(c) Correct structure for CF₂BrCF₂Br drawn out

(penalise "F" 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) $(57/197.4 \times 100) = 28.9\%$ 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]

18

- (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) $\text{C}_{14}\text{H}_{30}$ only
(penalise as a contradiction if correct answer is accompanied by other structural formulae) 1
- (iii) $\text{C}_{10}\text{H}_{22} + 5\frac{1}{2}\text{O}_2 \rightarrow 10\text{C} + 11\text{H}_2\text{O}$
(or double this equation) 1

(c) (i) $\frac{1}{2}\text{N}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}$
(or double this equation) 1

(ii) Platinum or palladium or rhodium 1

(iii) $2\text{CO} + 2\text{NO} \rightarrow 2\text{CO}_2 + \text{N}_2$ or
 $2\text{NO} \rightarrow \text{N}_2 + \text{O}_2$ or
(ignore extra O_2 molecules provided the equation balances)

$\text{C} + 2\text{NO} \rightarrow \text{CO}_2 + \text{N}_2$
(or half of each of these equations)

$\text{C}_8\text{H}_{18} + 25\text{NO} \rightarrow 8\text{CO}_2 + 12\frac{1}{2}\text{N}_2 + 9\text{H}_2\text{O}$
(or double this equation) 1

[10]

19

1(-)bromobutane 1

correct structure for 1-bromo-2-methylpropane
(C–C bonds must be clear where drawn) 1

[2]

20

(i)

Isomer	Name
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	butan-1-ol
$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_3 \\ \\ \text{OH} \end{array}$	2-methylpropan-2-ol
$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_2\text{OH} \\ \\ \text{CH}_3 \end{array}$	(2-)methyl propan-1-ol (1)
$\begin{array}{c} \text{CH}_3\text{CH}_2 - \text{CH} - \text{CH}_3 \\ \\ \text{OH} \end{array}$	butan-2-ol (1) OR 2-butanol

NOT prop-1-ol

NOT but-2-ol
NOT hydroxy
No RE*Allow e in the names*

2

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

3

[3]**21**

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

- (ii)
- $\text{C}_n\text{H}_{2n+2}$
- (1)

- (iii)
- C_6H_{14}
- only (1)

Do not credit structures alone or in addition.

3

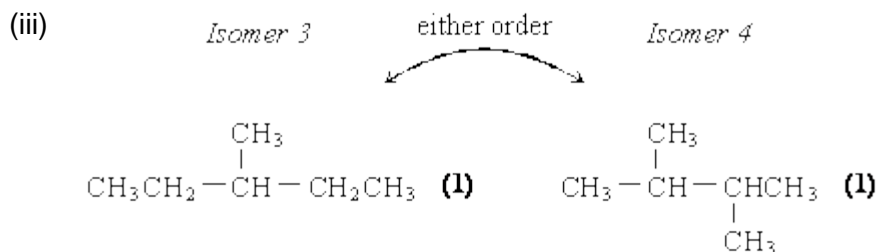
- (b) Chemically similar / react in same way / same chemistry
-
- Differ by
- CH_2
-
- gradation in physical properties OR specified trend e.g. b.p.
-
- same functional group

*Any 2, 2 marks 1 + 1**Not same molecular formula*

2

- (c) (i) Same molecular formula **(1)**
NOT same Mr
- different structural formula / structures **(1)**
(or atoms arranged in different way)
NOT different spatial arrangements
Only credit M2 if M1 correct

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



OR correct condensed / structural formula
Penalise "sticks" once
Penalise absence of vertical bonds once
penalise badly drawn bonds once (vertical between H atoms)

6

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

M3 (ratio 1:1 ∴) CH

Credit variations for M2 e.g. $78 \times \frac{77}{100} = 6$

and $\frac{78}{12} \times \frac{92.3}{100} = 6$

Correct answer = 3 marks

- (ii) (CH has empirical mass of 13 and $\frac{78}{13} = 6 \therefore$) C₆H₆ **(1)**

Correct answer 1 mark

4

[15]

B
22

[1]

C
23

[1]

^D
24

[1]

^A
25

[1]

^B
26

[1]

^B
27

[1]