

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.1 INTRODUCTION TO ORGANIC CHEMISTRY

SCORE

/280

PERCENTAGE

%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

A hydrocarbon contains 87.8% by mass of carbon and has a relative molecular mass (M_r) of 82.0

The hydrocarbon decolourises bromine water.

Determine the empirical and molecular formulae of the hydrocarbon.

Suggest **two** possible structures for the hydrocarbon.

Name the type of reaction taking place when bromine water reacts with the hydrocarbon.

[illegible]

(Total 6 marks)

Q2.

How many structural isomers with an unbranched carbon chain have the molecular formula $C_4H_8Br_2$?

- A** 4 
- B** 5 
- C** 6 
- D** 7 

(Total 1 mark)

Q3.

The oxidation of propan-1-ol can form propanal and propanoic acid.

The boiling points of these compounds are shown in the table.

2. _____

(2)

- (c) Describe how you would carry out a simple test-tube reaction to confirm that the sample of propanal obtained by distillation does **not** contain any propanoic acid.

(2)

- (d) A student carried out an experiment to determine the enthalpy of combustion of ethanol.
Combustion of 457 mg of ethanol increased the temperature of 150 g of water from 25.1 °C to 40.2 °C

Calculate a value, in kJ mol^{-1} , for the enthalpy of combustion of ethanol in this experiment.

Give your answer to the appropriate number of significant figures.

(The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$)

Enthalpy of combustion _____ kJ mol^{-1}

(3)

- (e) A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced.

Name and outline a mechanism for the reaction producing pent-1-ene.

Name of mechanism _____

Mechanism

(4)

- (f) A pair of stereoisomers is also formed in the reaction in **part (e)**.

Name the less polar stereoisomer formed.
Explain how this type of stereoisomerism arises.

Name _____

Explanation _____

(2)

(Total 16 marks)

Q4.

How many structural isomers with the molecular formula $C_5H_{10}O$ react with Tollens' reagent?

- | | | |
|----------|---|-----------------------|
| A | 3 | ☐ |
| B | 4 | ☐ |
| C | 5 | ☐ |
| D | 6 | ☐ |

(Total 1 mark)

Q5.

This question is about the structures of some organic molecules.

- (a) Draw the **skeletal** formula of 3-methylbutanal.

(1)

- (b) Draw the **displayed** formula of $C_5H_{11}Br$ that is the major product of the reaction of 2-methylbut-2-ene with hydrogen bromide.

(1)

- (c) Thermal cracking of hydrocarbons produces molecules that are attacked by electrophiles because they have a region of high electron density.

Draw the structure of one of these molecules that contains four carbon atoms.

(1)

(Total 3 marks)

Q6.

How many structural isomers are there with the molecular formula C_3H_6BrCl ?

- | | | |
|----------|---|--------------------------|
| A | 4 | ☐ |
| B | 5 | ☐ |
| C | 6 | ☐ |
| D | 7 | ☐ |

(Total 1 mark)

Q7.

Which compound does **not** show stereoisomerism?

- | | | |
|----------|---------------------|--------------------------|
| A | 1,2-dichloropropene | ☐ |
| B | 1,2-dichloropropane | ☐ |

C 1,3-dichloropropene ☐

D 1,3-dichloropropane ☐

(Total 1 mark)

Q8.

Avgas is an aviation fuel used in the internal combustion engines of helicopters. It consists of a large number of hydrocarbons, including a high proportion of hexane, which can exist as several isomers.

(a) Draw the skeletal formulae of **two** branched isomers of hexane.

(1)

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

(1)

(c) Safety signs on the fuselage of the helicopter state that the air inlets to the engine need to be cleaned out regularly.

Write an equation for the combustion of hexane that would happen in the helicopter engine if the air inlets were partially blocked with debris.

(2)

(d) Suggest how this partial blockage might affect the performance of the helicopter engine.

(1)

(Total 5 marks)

Q9.

What is the total number of structural isomers with the molecular formula $C_2HBrClF_3$?

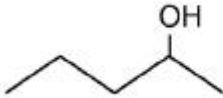
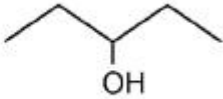
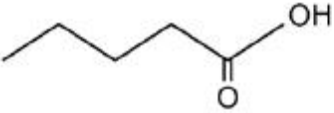
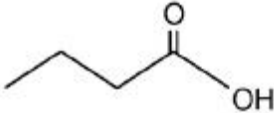
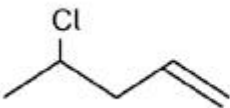
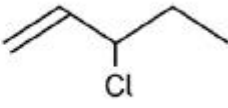
A 2 ☐

- | | | |
|----------|---|--------------------------|
| B | 3 | ☐ |
| C | 4 | ☐ |
| D | 5 | ☐ |

(Total 1 mark)

Q10.

Which is a pair of functional group isomers?

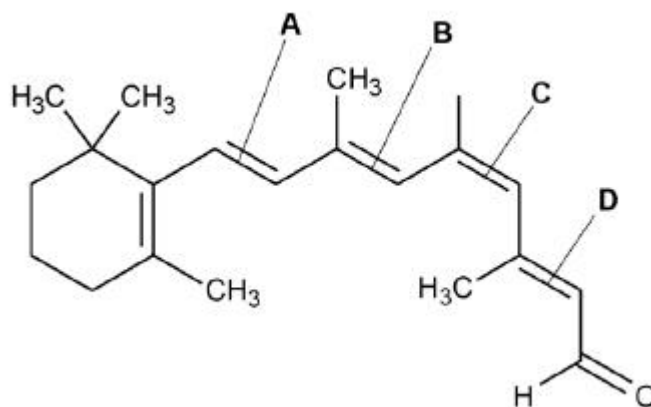
- | | | | |
|----------|---|---|--------------------------|
| A |  |  | ☐ |
| B |  |  | ☐ |
| C |  |  | ☐ |
| D |  |  | ☐ |

(Total 1 mark)

Q11.

Z-Retinal, shown in the diagram, is a component in vitamin A.

Which of the double bonds, labelled **A**, **B**, **C** or **D**, is responsible for the letter Z in the name?



- A ☐
- B ☐
- C ☐
- D ☐

(Total 1 mark)

Q12.

This question is about isomerism.

- (a) How many isomers are represented by the formula C_5H_{12} ?

Tick (✓) **one** box.

2 ☐

3 ☐

4 ☐

5 ☐

- (b) Name the type of structural isomerism shown by the isomers of C_5H_{12}

(1)

- (c) 2-Hydroxypropanenitrile displays optical isomerism.

Draw three-dimensional representations of the two enantiomers of 2-hydroxypropanenitrile, showing how the two structures are related to each other.

(2)

- (d) Describe how separate samples of each of these enantiomers could be distinguished.

(2)

- (e) Butan-2-ol reacts with concentrated sulfuric acid to produce three isomeric alkenes.

Name and outline a mechanism to show how any **one** of the alkenes is formed.

Explain how this reaction can lead to the formation of each of these **three** alkenes.

Name of mechanism _____

Mechanism

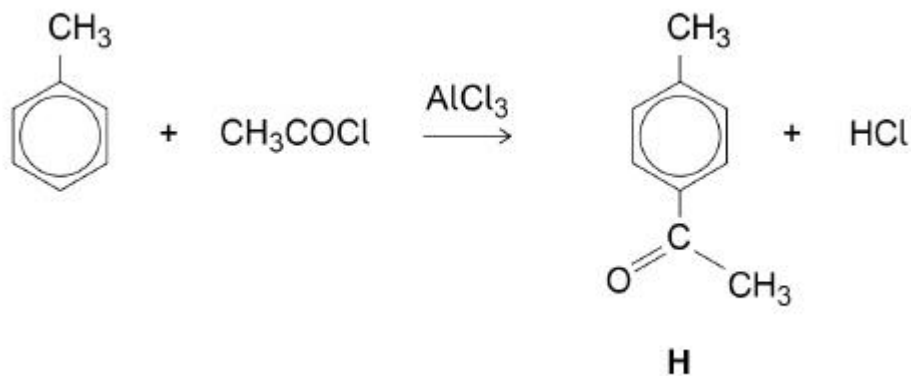
Explanation _____

(8)

(Total 13 marks)

Q13.

When methylbenzene reacts with ethanoyl chloride in the presence of aluminium chloride, the product, **H**, is formed.



- (a) Deduce the molecular formula of **H**.

_____ (1)

- (b) Two other isomers are also produced in the reaction.

Draw the structure of **one** of the other isomers.

Name the type of structural isomerism shown by these three products.

Structure

Type of isomerism _____ (2)

- (c) Name and outline the mechanism for the reaction of ethanoyl chloride with methylbenzene to produce **H**.

Include an equation for the formation of the reactive intermediate that is involved in the reaction.

Name _____

Equation _____

Mechanism

Q14.

Compound **J**, known as leaf alcohol, has the structural formula $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{OH}$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

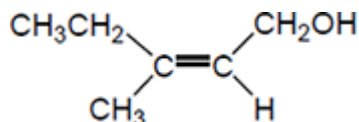
- (a) Give the structure of the *E* isomer of **J**.

(1)

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

(1)

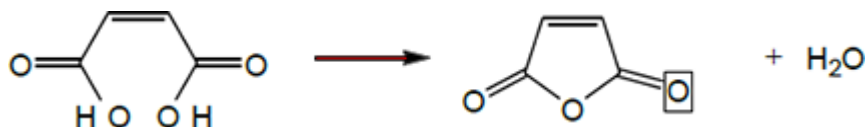
- (c) Another structural isomer of **J** is shown below.



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

(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)

Q15.

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.

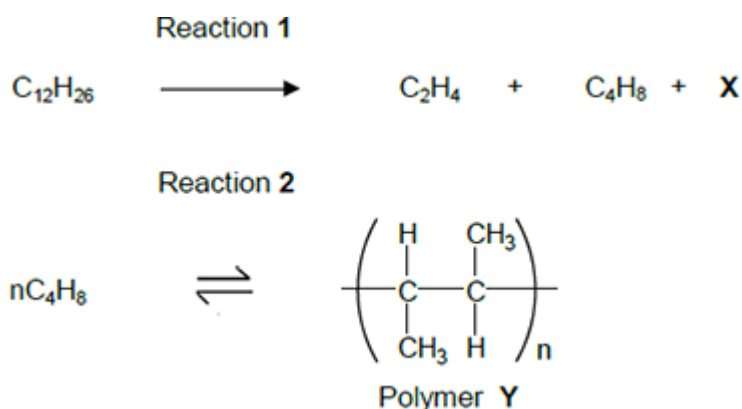
Name of mechanism _____

Mechanism

(5)
(Total 6 marks)

Q16.

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.



- (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.

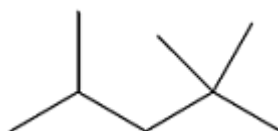
Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

(6)

(Total 11 marks)

Q17.

Isooctane (C₈H₁₈) 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 ¹³C 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)

Q18.

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

- | | | |
|----------|---|--------------------------|
| A | 2 | ☐ |
| B | 3 | ☐ |
| C | 4 | ☐ |
| D | 5 | ☐ |

(Total 1 mark)

Q19.

How many structural isomers have the molecular formula $\text{C}_4\text{H}_9\text{Br}$?

- | | | |
|----------|---|--------------------------|
| A | 2 | ☐ |
|----------|---|--------------------------|

- B** 3 ☐
- C** 4 ☐
- D** 5 ☐

(Total 1 mark)

Q20.

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

- A** 2 ☐
- B** 3 ☐
- C** 4 ☐
- D** 5 ☐

(Total 1 mark)

Q21.

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)

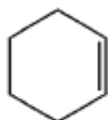
- (b) Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

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

(7)
(Total 8 marks)

Q22.

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)

Q23.

(a) Octane (C_8H_{18}) is an important compound in petrol.

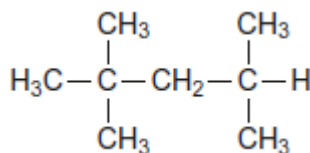
(i) Identify the homologous series to which octane belongs.

(1)

(ii) Write an equation to show the complete combustion of C_8H_{18}

(1)

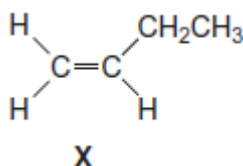
(iii) An isomer of octane used to improve the performance of car engines is shown.



Give the IUPAC name of this isomer.

(1)

- (b) Compound **X** is produced when an alkane is cracked.



- (i) Give the IUPAC name for compound **X**.

(1)

- (ii) One molecule of an alkane is cracked to produce one molecule of compound **X**, one molecule of octane and one molecule of ethene.

Deduce the molecular formula of this alkane.

(1)

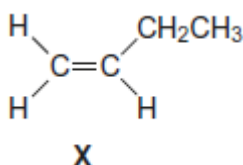
- (iii) Name the type of cracking that produces a high yield of compound **X**.
Give **two** conditions required for this process.

Type of cracking _____

Conditions _____

(2)

- (iv) Compound **X** has several isomers. The structure of **X** is repeated here.



Draw the displayed formula of a chain isomer, a position isomer and a functional group isomer of compound **X**.

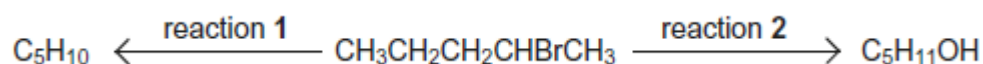
Type of isomer	Displayed formula of isomer of compound X
----------------	--

Chain	
Position	
Functional group	

(3)
(Total 10 marks)

Q24.

Two reactions of 2-bromopentane, (CH₃CH₂CH₂CHBrCH₃) are shown.



The C₅H₁₀ formed in reaction 1 exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

- (a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction 1 and reaction 2.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction 1 for the formation of pent-1-ene.

- (b) All three isomers of C_5H_{10} contain the same functional group.

Draw the displayed formula of pent-1-ene.

Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

- (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

(4)

(Total 17 marks)

Q25.

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)

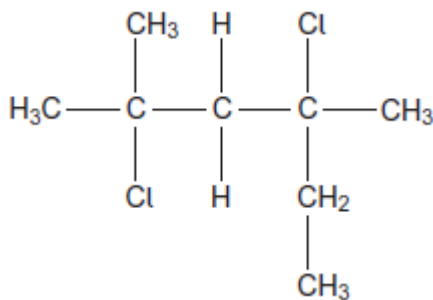
- (e) There are many structural isomers with the molecular formula C_8H_{18}

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)

Q26.

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 ($C_{12}H_{26}$) 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 _____

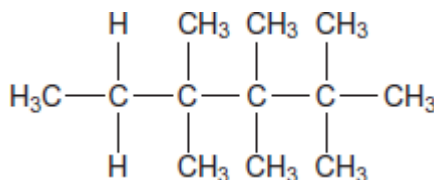
Catalyst _____

(3)

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

(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.

(1)

(Total 16 marks)

Q27.

The following table gives the names and structures of some structural isomers with the molecular formula C_5H_{10} .

	Name of isomer	Structure
Isomer 1	pent-2-ene	$\text{CH}_3\text{CH} = \text{CHCH}_2\text{CH}_3$
Isomer 2	cyclopentane	
Isomer 3	3-methylbut-1-ene	$(\text{CH}_3)_2\text{CHCH} = \text{CH}_2$
Isomer 4	2-methylbut-2-ene	$(\text{CH}_3)_2\text{C} = \text{CHCH}_3$
Isomer 5	2-methylbut-1-ene	$\text{H}_2\text{C} = \text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$

(a) Isomer 1 exists as E and Z stereoisomers.

(i) State the meaning of the term **stereoisomers**.

(2)

(ii) Draw the structure of the E stereoisomer of Isomer 1.

(1)

(b) A chemical test can be used to distinguish between separate samples of Isomer 1 and Isomer 2.

Identify a suitable reagent for the test.

State what you would observe with Isomer 1 and with Isomer 2.

Reagent _____

Observation with Isomer 1 _____

Observation with Isomer 2 _____

(3)

- (c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

- (i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

(1)

- (ii) State **one** way that the infrared spectrum of Isomer 3 is different from the infrared spectrum of Isomer **4**.

(1)

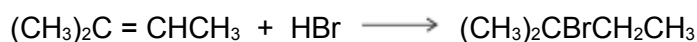
- (d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

(1)

- (e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

- (i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.



Name of mechanism _____

Mechanism

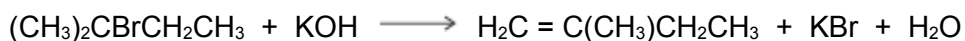
(5)

- (ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

(2)

- (f) Name and outline a mechanism for the following reaction to form Isomer **5**.
State the role of the hydroxide ion in this reaction.



Name of mechanism _____

Mechanism

Role of hydroxide ion _____

(5)

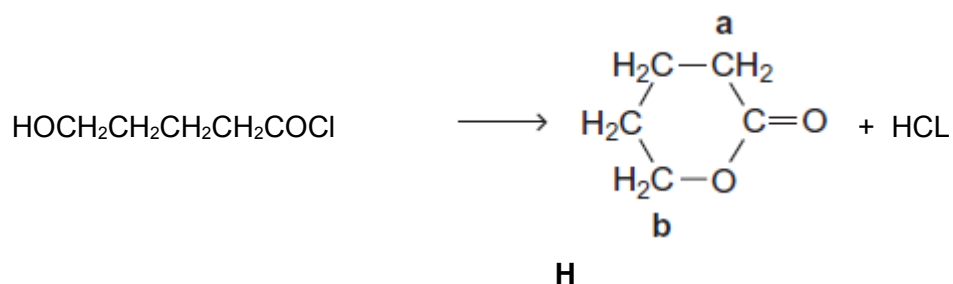
(Total 21 marks)

Q28.

This question is about some isomers of $\text{C}_5\text{H}_8\text{O}_2$

- (a) Compound **H** is a cyclic ester that can be prepared as shown.

On the structure of **H**, two of the carbon atoms are labelled.



- (i) Name and outline a mechanism for this reaction.

Use **Table C** on the Data Sheet to give the ^{13}C n.m.r. δ value for the carbon atom labelled **a** and the δ value for the carbon atom labelled **b**.

This image shows a single page of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on the right side, suggesting it's part of a bound notebook or folder.

(7)

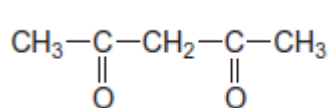
- (ii) $\text{HOCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COCl}$ can also react to form a polyester in a mechanism similar to that in part (i).

Draw the repeating unit of the polyester and name the type of polymerisation involved.

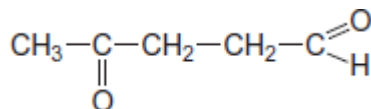
(2)

- (b) State how you could distinguish between compounds **J** and **K** by a simple test-tube reaction.

State how you could distinguish between **J** and **K** by giving the number of peaks in the ^1H n.m.r. spectrum of each compound.



J



K

(5)

- (c) Draw the structure of each of the following isomers of $\text{C}_5\text{H}_8\text{O}_2$. Label each structure you draw with the correct letter **L**, **M**, **N**, **P** or **Q**.

L is methyl 2-methylpropenoate.

M is an ester that shows E-Z stereoisomerism.

N is a carboxylic acid with a branched carbon chain and does **not** show stereoisomerism.

P is an optically active carboxylic acid.

Q is a cyclic compound that contains a ketone group and has only two peaks in its ^1H n.m.r. spectrum.

(5)

(Total 19 marks)

Q29.

- (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 (C₈H₁₈) only.
- (i) Deduce the molecular formula of **Y**.
- _____
- (1)
- (ii) Other than cracking, give **one** common use of **Y**.
- _____
- (1)
- (d) In cars fitted with catalytic converters, unburned octane reacts with nitrogen monoxide to form carbon dioxide, water and nitrogen only.
- (i) Write an equation for this reaction.
- _____
- (1)

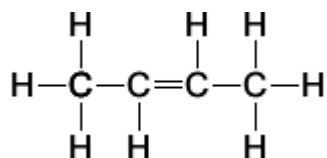
- (ii) Identify a catalyst used in a catalytic converter.

(1)

(Total 11 marks)

Q30.

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 _____

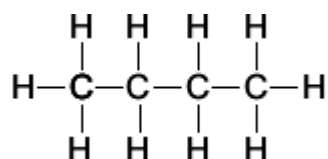
Reason _____

(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)

Q31.

Hexane (C_6H_{14}) is a member of the homologous series of alkanes.

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

(1)

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

(1)

- (b) C_6H_{14} has structural isomers.

- (i) Deduce the number of structural isomers with molecular formula C_6H_{14}

Write the number in this box.

(Space for working)

(1)

- (ii) State **one** type of structural isomerism shown by the isomers of C_6H_{14}

(1)

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

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

(1)

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

Type of cracking _____

Conditions _____

(2)

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

(1)

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



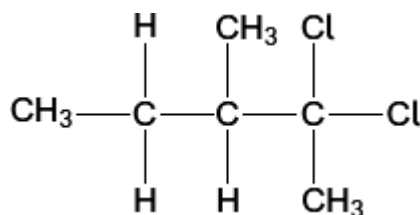
- (i) Both the products are hazardous. The organic product would be labelled 'flammable'. Suggest the most suitable hazard warning for the other product.

(1)

- (ii) Calculate the percentage atom economy for the formation of $\text{C}_6\text{H}_{13}\text{Cl}$ ($M_r = 120.5$) in this reaction.

(1)

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



Name _____

Empirical formula _____

(2)

(Total 12 marks)

Q32.

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.

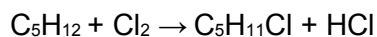
(3)

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

Suggest why this solid pollutant is an environmental problem.

(2)

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

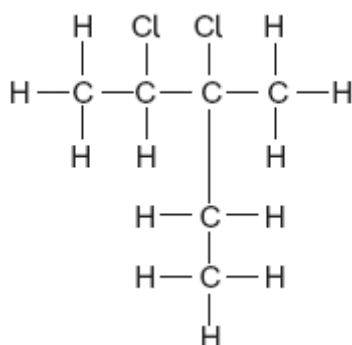


Calculate the percentage atom economy for the formation of $\text{C}_5\text{H}_{11}\text{Cl}$

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

(3)

- (f) Consider the following compound.



Name this compound.

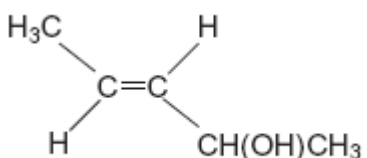
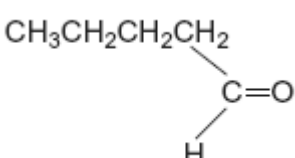
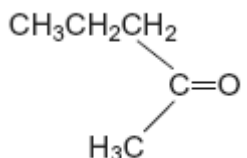
Deduce the empirical formula of this compound.

(2)

(Total 13 marks)

Q33.

The table below shows the structures of three isomers with the molecular formula $\text{C}_5\text{H}_{10}\text{O}$

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

(a) Complete the table by naming Isomer 3.

(1)

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

(1)

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

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

(1)

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

(1)

(d) A chemical test can be used to distinguish between separate samples of Isomer 2 and Isomer 3.

Identify a suitable reagent for the test.

State what you would observe with Isomer 2 and with Isomer 3.

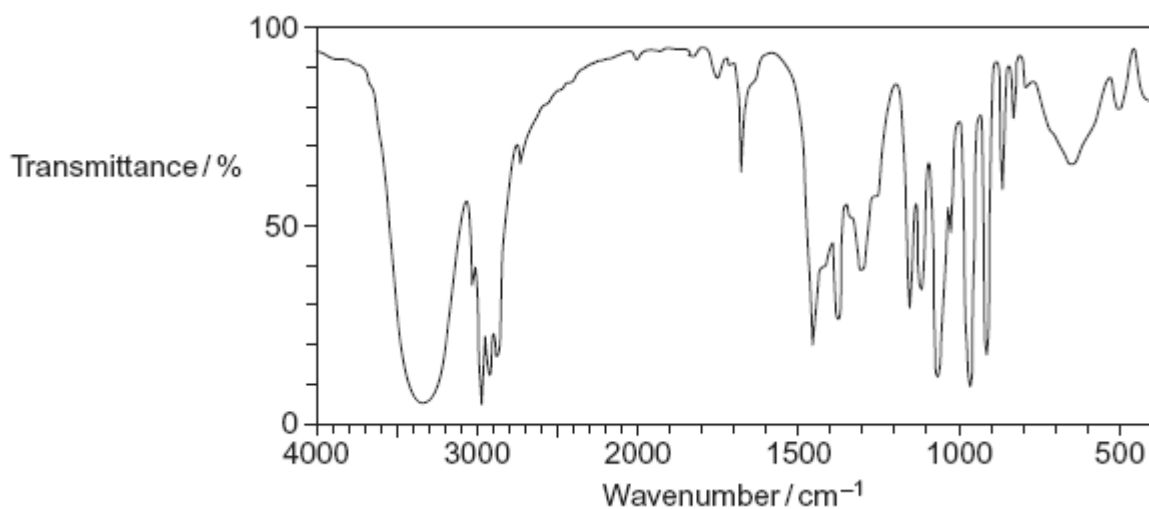
Test reagent

Observation with Isomer 2

Observation with Isomer 3

(3)

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



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

(1)

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

Feature 1 and functional group _____

Feature 2 and functional group _____

(2)

Q34.

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

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

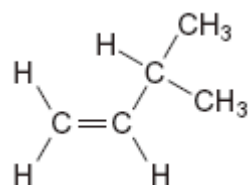
State the physical property of alkenes that allows them to be separated from a mixture by fractional distillation.

_____ (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)

Q35.

Octane is the eighth member of the alkane homologous series.

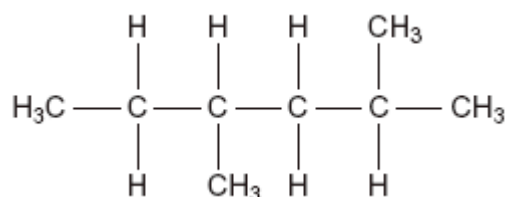
- (a) State **two** characteristics of a homologous series.

(2)

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

(1)

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



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

(4)

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

(2)

(Total 9 marks)

Mark schemes

Q1.

M1 C:H = 7.3 : 12.2 seen

*Extended response: **M1** is for working of some sort leading to the formulae.*

*If C_3H_5 and C_6H_{10} are both shown but it is not indicated which formula is which; or the formulas are stated the wrong way round, then allow 1 mark for **M2** and **M3** combined; if both correct formulas are given with only one stated correctly to be the empirical/molecular formula, then allow **M2** and **M3**.*

1

M2 (converting C:H 7.3 : 12.2 to 3:5)
to give empirical formula = C_3H_5

1

M3 molecular formula = C_6H_{10}

1

M4, 5 two possible structures of C_6H_{10} (in any structural form)
cyclic compounds with 6/5/4/3-membered C ring with one double bond, e.g.



or any dienes with 6 C atoms,

or a molecule with a triple bond

***M4** and **M5** ignore names given in addition to structures*

*Credit **M4** and **M5** for correct names if no structures drawn*

*Apply list principle to structures in **M4** and **M5***

2

M6 (electrophilic) addition

1

Alternative route to C_6H_{10} that could gain credit

***M1** 82/12 gives/suggests 6 C atoms*

***M2** molecular formula = C_6H_{10}*

***M3** empirical formula = C_3H_5*

Alternative route to C_6H_{10} that could gain credit

***M1** $82 \times 0.878 = 72$, $(72/12) = 6$ C atoms*

***M2** molecular formula = C_6H_{10}*

***M3** empirical formula = C_3H_5*

***M6** penalise nucleophilic addition; ignore bromination*

[6]

Q2.

C

[1]

Q3.

- (a) Aldehyde/propanal has dipole-dipole forces (between molecules)

If any 'covalent bonds broken' CE=0 for clip.

Ignore Van der Waal forces

M1

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

Ignore reference to energy

M2

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

M3 only awarded following correct M1 OR M2

Allow converse for M3

M3

- (b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below 97 °C

Allow temperature in range 49-96 inclusive

Allow description of cooling the vessel

M1

Cool the distillate / collecting vessel

Ignore reference to oxidising agents

Penalise lid / sealed container

M2

- (c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

Incorrect chemical CE=0

Allow formula (mark on for incorrect formula)

Allow blue litmus or correct named indicator

M1

Effervescence/fizz/bubbles would confirm presence of acid or converse

Blue litmus turns red confirms acid present or converse

Allow gas/CO₂ produced which turns lime water cloudy OR

gas/H₂ produced which burns with a squeaky pop

M2

- (d) (Temperature difference = 15.1 °C)

If ΔT wrong – AE mark on otherwise can only award M2

If use 457 in M1, can only score M2

$$q = 150 \times 4.18 \times 15.1 \text{ or } 9467.7 \text{ J or } 9.4677\text{kJ}$$

M1

$$\text{amount ethanol burned} = 0.457/46.0 = 9.93 \times 10^{-3} \text{ mol}$$

If use 457 in M2 can score 2 for - 0.953 kJ mol⁻¹

M2

$$\text{Heat change per mole} = (\text{M1}/1000)/\text{M2} = 952.99 \text{ kJ mol}^{-1}$$

$$\Delta H = -953 \text{ kJ mol}^{-1} \text{ must be 3sfs and must be negative}$$

(allow range -953 to -954)

BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1 +953 can score M1 and M2
Allow -950 or -960 for rounding to 2sf

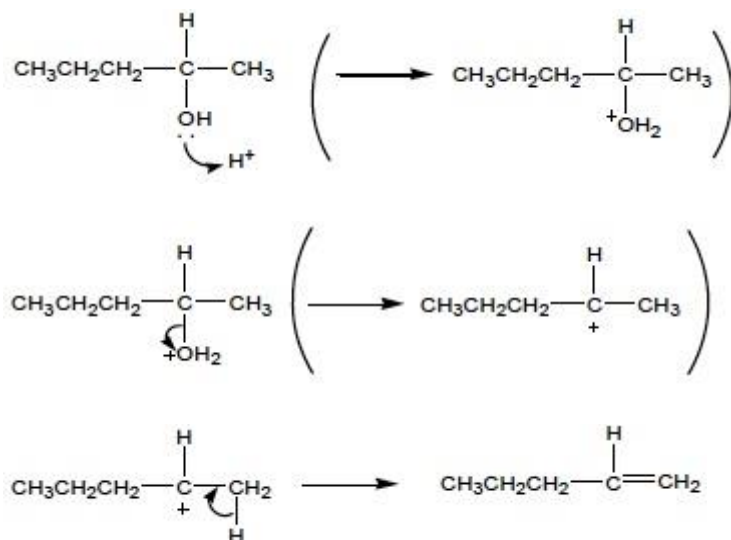
M3

(e) Elimination

Penalise base elimination

M1

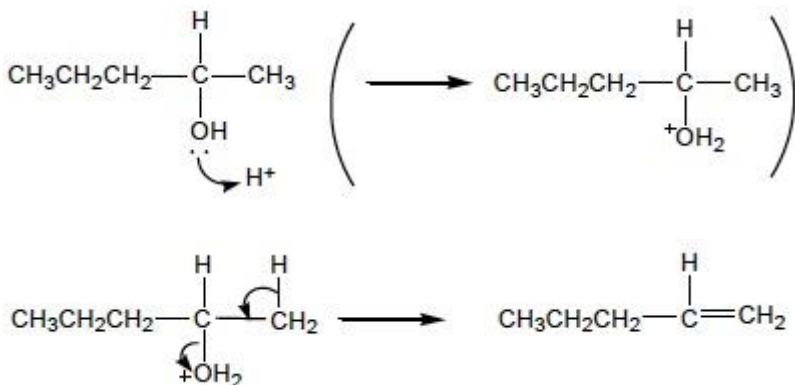
Mechanism : Either (E1)



M2 for protonation of alcohol, i.e. lp plus arrow to H⁺ or to H of H-O- in H₂SO₄ and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H⁺
From correct carbocation (E1)
wrong alcohol used / alkene formed loses M4

3

OR (E2)



M2 for protonation of alcohol, i.e. lp plus arrow to H⁺ or to H of H-O- in H₂SO₄ and from H-O bond to O

M3 for protonated alcohol plus arrow showing loss of water

M4 for arrow showing simultaneous loss of H^+
wrong alcohol used / alkene formed loses M4

3

(f) E-pent-2-ene

Allow trans

M1

C=C bond cannot rotate and

Each carbon in the double bond has (2) different groups attached.

Allow (two) different groups on each/either side of the double bond.

M2

[16]

Q4.

B

[1]

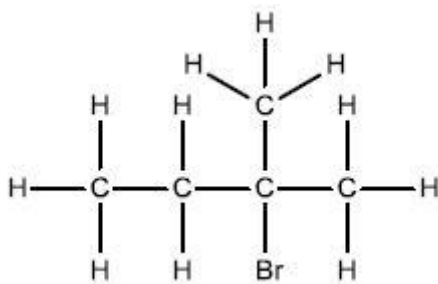
Q5.

(a)



1

(b)



1

(c) Any correct structural representation of alkene with 4 C atoms, either:

but-1-ene or

but-2-ene or

methylpropene

allow butadiene

1

[3]

Q6.
B

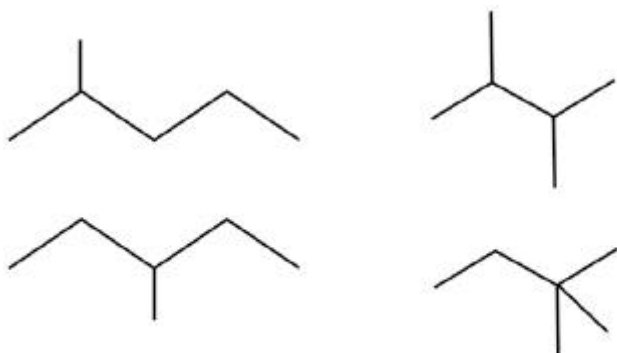
[1]

Q7.
D

[1]

Q8.

- (a) Any two of these isomers



1

- (b) Chain isomerism

Mark consequential to part (a)

1

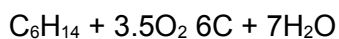
- (c) $\text{C}_6\text{H}_{14} + 6.5\text{O}_2 \rightarrow 6\text{CO} + 7\text{H}_2\text{O}$

M1 Product is CO or C

M2 Balanced equation

1

OR



Allow equations containing CO_2 as long as either C, CO or both are also present

1

- (d) Less energy given out by the fuel / engine is less powerful / less efficient / needs to burn more fuel to get the same energy / increased costs due to need to use more fuel

*Do **not** allow answers linked to CO poisoning or incomplete combustion*

1

[5]

Q9.
C

[1]

Q10.

A

[1]

Q11.

C

[1]

Q12.

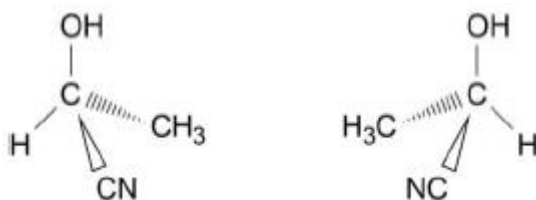
(a) 3

1

(b) Chain.

1

(c)



One 3D enantiomer.

1

Second enantiomer correctly drawn as 3D mirror image of first.

1

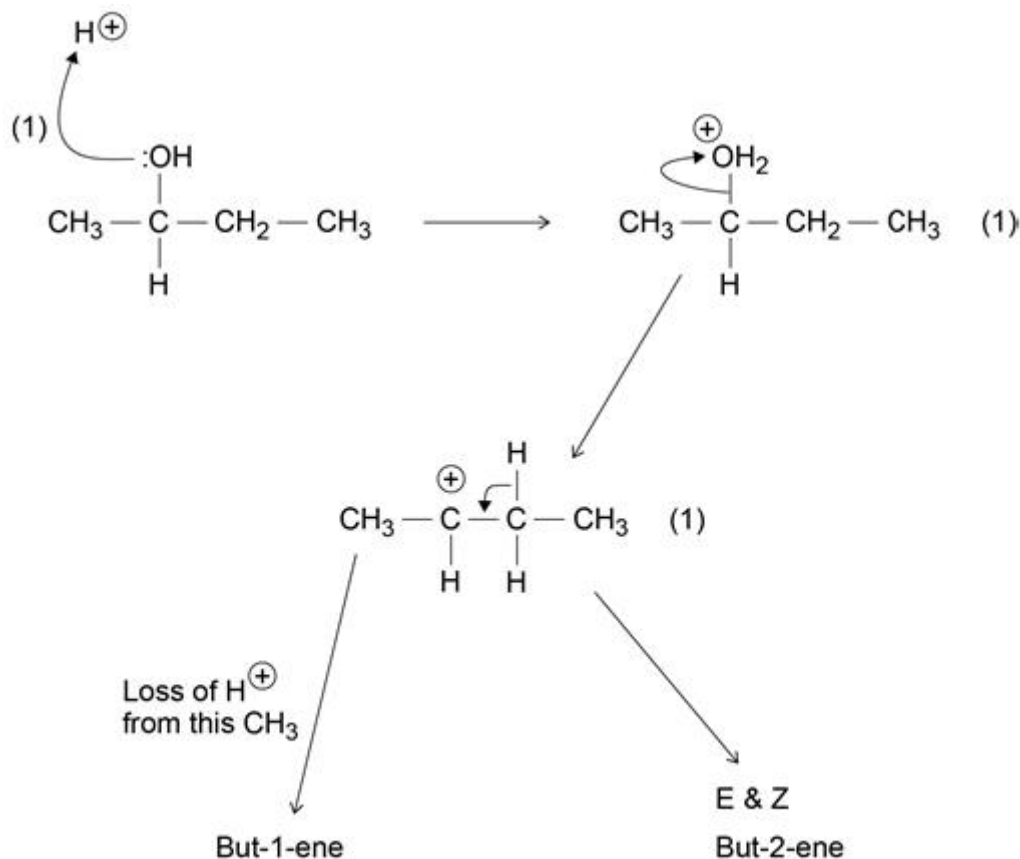
(d) Plane-polarised light.

1

Rotated in opposite directions.

1

(e) Elimination



Extended response question

M1

Mechanism (3 marks)

M2 arrow from lone pair on O to H^+

M3 1st intermediate **and** arrow from $\text{C}-\text{O}^+\text{H}_2$ bond to O (with loss of H_2O)

M4 2nd intermediate (carbocation) **and** arrow from $\text{C}-\text{H}$ bond to $\text{C}-\text{C}$ (with loss of H^+) to form $\text{C}=\text{C}$

M3 and M4 can be scored in one step (see alternative mechanism below).

If carbocation incorrect then answer cannot score maximum marks.

Explanation of formation of 3 alkenes

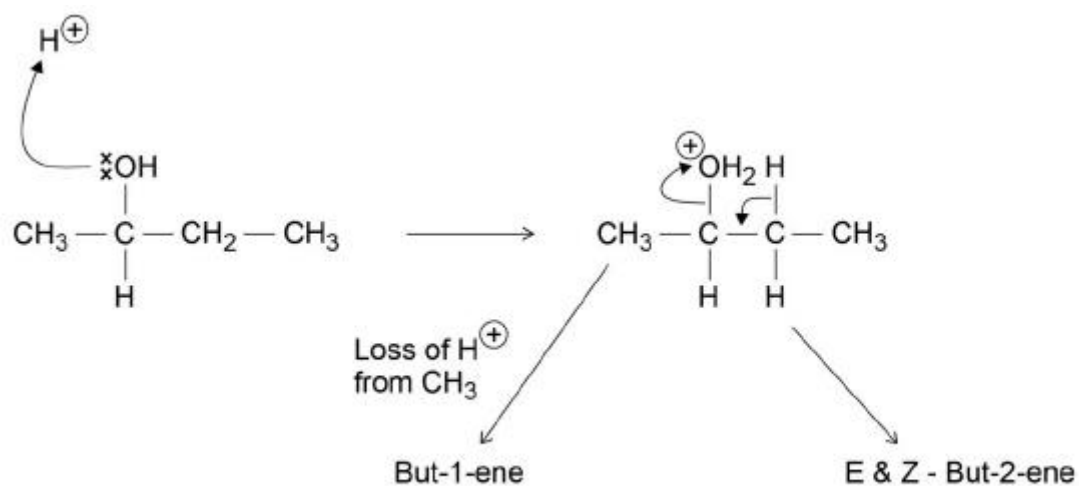
M5 loss of H^+ from C (in carbocation) adjacent to ^+C (to which $-\text{OH}$ was attached)

M6 From $^1\text{C}-^2\text{C}^+-^3\text{C}-^4\text{C}$ leads to but-1-ene

M7 From $^1\text{C}-^2\text{C}^+-^3\text{C}-^4\text{C}$ leads to but-2-ene

M8 But-2-ene formed as mixture of *E-Z* isomers

Alternative mechanism



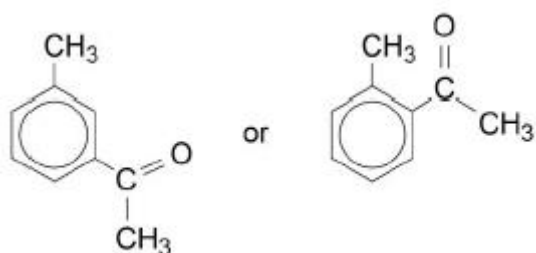
[14]

Q13.

(a) $\text{C}_9\text{H}_{10}\text{O}$

1

(b)



1

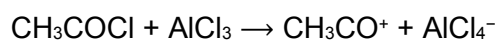
Position (isomerism).

Allow Positional.

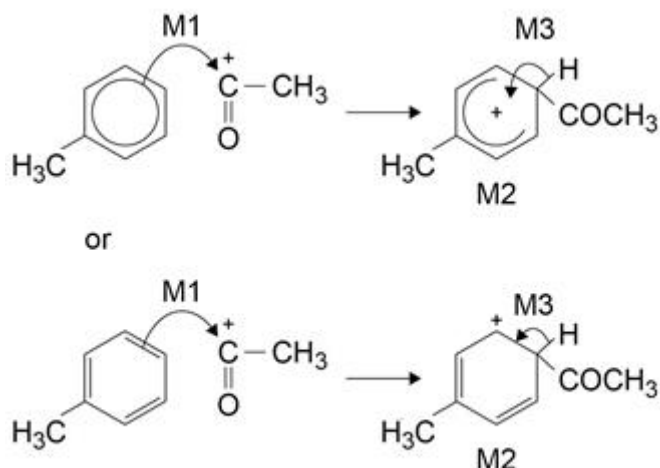
1

(c) Electrophilic substitution

1



1



Mechanism 3 marks:

M1 arrow from circle or within it to C of $\text{CH}_3\text{C}^+\text{O}$ (+ must be on C of $\text{CH}_3\text{C}^+\text{O}$).

1

M2 for Intermediate (**must** be 4-isomer)

CH_3CO must be correctly positioned and bonded to gain M2
horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1.

1

M3 arrow into hexagon unless Kekule

Loss of H^+ (allow from incorrect isomer)

Allow M3 arrow independent of M2 structure

Ignore base removing H in M3.

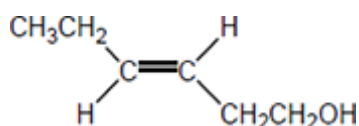
Allow Kekule structures (which must be correct).

1

[8]

Q14.

(a)



1

(b)



1

(c) **Stage 1:** consider the groups joined to right hand carbon of the $\text{C}=\text{C}$ 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

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]

Q15.

- (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

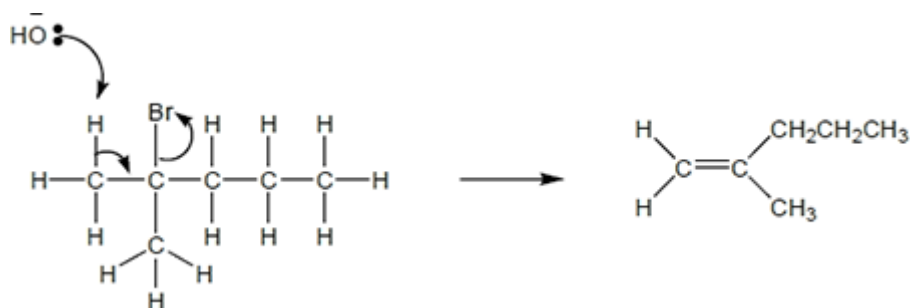
Correct arrow from C-H bond to C-C

1

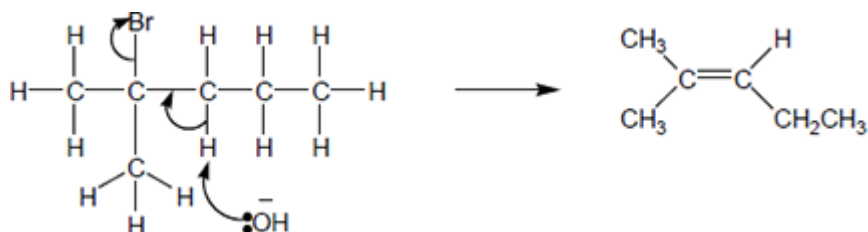
Correct arrow from C-Br bond to Br

1

Structure of chosen product



OR

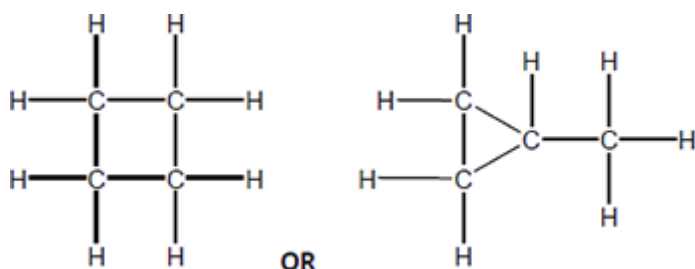


[6]

Q16.

- (a) Alkenes

1



OR

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

1

- (b) C
- ₆
- H
- 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 $E > E_a$
- 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]

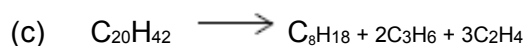
Q17.

- (a) 2,2,4-trimethylpentane

1

(b) 5

1



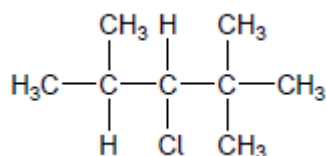
1

(d) Mainly alkenes formed

1

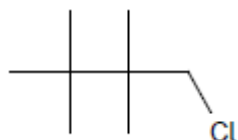
(e) 4 (monochloro isomers)

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]

Q18.

B

[1]

Q19.

C

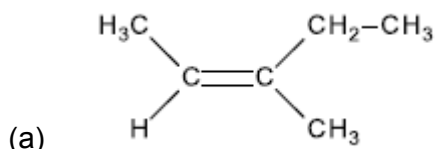
[1]

Q20.

B

[1]

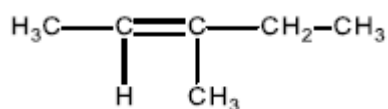
Q21.



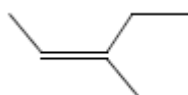
Must show all 4 groups bonded to C=C

Allow CH₃- for methyl group; allow C₂H₅ for ethyl group

Allow correct structure of the style

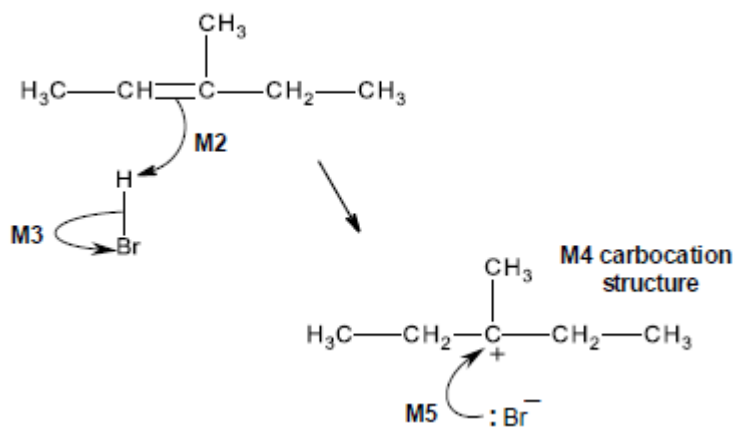


Allow correct skeletal structure



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]

Q22.

B

[1]

Q23.

(a) (i) Alkane(s)

Ignore C_nH_{2n+2}

1

(ii) $C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O$

Allow multiples

1

(iii) 2, 2, 4-trimethylpentane

1

(b) (i) But-1-ene

Ignore (E or Z)

1

(ii) $C_{14}H_{30}$

1

(iii) Thermal

If catalytic CE = 0

1

High pressure / 7000kPa / 70 atm

and

High temperature/temperature in range 400-1000°C (673–1273K)

(Allow ≥ 1000 kPa or ≥ 10 atm – no upper value)

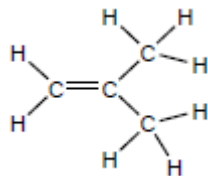
Allow high temperature and pressure or high pressure and temperature

If no units for temperature allow 673-1000

Must show unambiguous structure

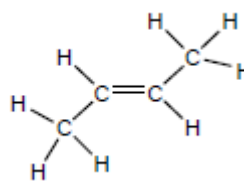
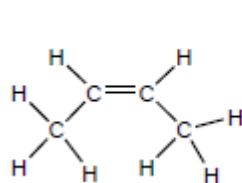
Penalise lack of displayed formula once only

1

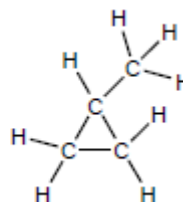
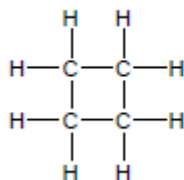


(iv)

1



1



1

[10]

Q24.

(a) NaOH/KOH

IGNORE OH-

NOT M1 if any mention of acidified/ H^+ in reagents or conditions

1

Reaction 1 = ethanolic/alcoholic **AND** reaction 2 = aqueous

IGNORE temp

NOT ethanoic

1

rxn 1 = base/proton acceptor

1

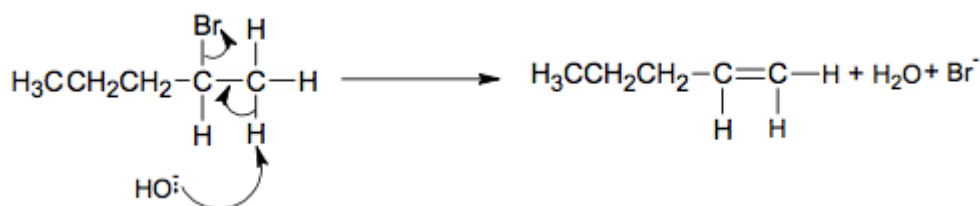
rxn 2 = nucleophile/lone pair donor/electron pair donor

1

(Base) Elimination

NOT nucleophilic

1



M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

M7 must show an arrow from a correct C-H bond on C adjacent to the C of the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M6**

M8 is independent provided it is from their original molecule and shows curly arrow from C-Br to Br

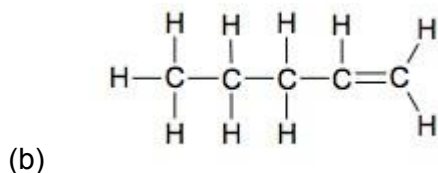
ALLOW correct E1 mechanism

IGNORE incorrect inorganic products

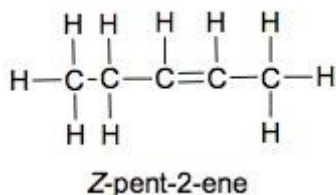
If forming pent-2-ene can award M8 only even if arrows in mechanism correct

If C chain length or halogen wrong in reactant or product max 2/3

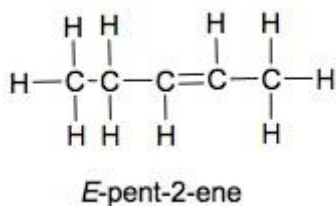
1
1
1



1



1



1

If no M2 and M3 **ALLOW** 1 mark if both structures **OR** both names correct

NOT cis and trans

No free rotation around C=C

ALLOW no rotation of C=C

1

2 different atoms/groups on each of the C=C Cs owtte

IGNORE 'functional'

1

- (c) Same volume/amount of AgNO₃(aq) added to same volume/amount/no. of drops of haloalkane (in beaker/flask) in each experiment

Both volume references needed

IGNORE inappropriate volumes

1

Same temp **OR** same [AgNO₃] each time

1

record time to measure sensible observation about the amount of AgCl ppt

e.g. first appearance of ppt / ppt obscures mark / reading on a colorimeter

IGNORE colour of ppt

ALLOW silver mirror

NOT reference to same time if describing method based on timing how long (for ppt to form)

ALLOW gravimetric method based on same time for each experiment

1

Rate = amount/time **OR** proportional to 1/time **OR** reference to shorter time = higher rate/longer time = lower rate

ALLOW greater mass = higher rate if gravimetric method

1

[17]

Q25.

- (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

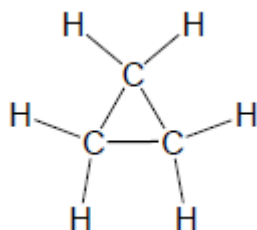
- (ii) polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal

Accept alternative names

Ignore plastic and polymer

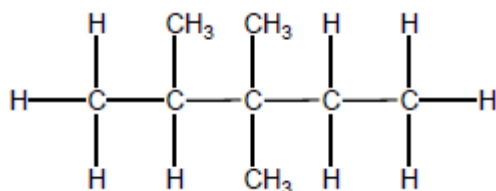
1

- (iii)



1

(e)



Allow any unambiguous representation

1

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

Only but ignore punctuation

1

[10]

Q26.

(a) Crude oil **OR** petroleum

Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1

(b) $\text{C}_{12}\text{H}_{26} + 12.5\text{O}_2 \longrightarrow 12\text{CO} + 13\text{H}_2\text{O}$

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

(ii) $2\text{NO} + \text{O}_2 \longrightarrow 2\text{NO}_2$

Allow multiples.

	(iii)	$4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \longrightarrow 4\text{HNO}_3$ <i>Allow multiples.</i>	1
			1
(d)	(i)	$\text{C}_n\text{H}_{2n+2}$ <i>Allow $\text{C}_x\text{H}_{2x+2}$</i> $\text{C}_n\text{H}_{2n+2}$ <i>Allow $\text{C}_x\text{H}_{2x+2}$</i>	1
	(ii)	$\text{C}_{12}\text{H}_{26} \longrightarrow \text{C}_6\text{H}_{14} + \text{C}_6\text{H}_{12}$ <i>Only.</i>	1
		C_3H_7 <i>Only.</i>	1
		Zeolite / aluminosilicate(s) <i>Ignore aluminium oxide.</i>	1
	(iii)	Larger molecule / longer carbon chain / more electrons / larger surface area	1
		More / stronger <u>van der Waals' forces between molecules</u> <i>Allow dispersion forces / London forces / temporary induced dipole-dipole forces <u>between molecules</u>.</i> <i>If breaking bonds, CE = 0 / 2.</i>	1
(e)		2,2,3,3,4,4-hexamethylhexane <i>Only.</i> <i>Ignore punctuation.</i>	1
		Chain <i>Ignore branch(ed).</i>	1
(f)		Cl_2 <i>Only.</i> $\text{Cl}-\text{Cl}$ <i>Not CL_2 or $\text{Cl}2$ or $\text{CL}2$ or Cl^2 or CL^2.</i> <i>Ignore Chlorine.</i>	1

[16]

Q27.

- (a) (i) **M1** (Compounds / molecules with) the same structural formula

Penalise **M1** if 'same structure' or 'different structural / displayed formula'.

M2 with atoms / bonds / groups arranged differently in space

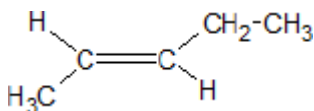
OR atoms / bonds / groups with different spatial arrangements / different orientation

Ignore references to 'same molecular formula' or 'same empirical formula'.

Mark independently.

2

(ii)



Credit C-H₃C

Credit C₂H₅

Penalise C-CH₃CH₂

1

(b) **M1** Br₂ OR bromine (water) OR bromine (in CCl₄ / organic solvent)

If **M1**, has no reagent or an incorrect reagent, **CE=0**.

Ignore 'acidified'.

M2 Isomer 1: decolourised / goes colourless / loses its colour

For **M1** penalise Br (or incorrect formula of other correct reagent), but mark on.

M3 Isomer 2: remains orange / red / yellow / brown / the same **OR** no reaction / no (observable) change **OR** reference to colour going to the cyclopentane layer

For **M1**, 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.

Alternatives : potassium manganate(VII)

M1 KMnO₄ in acid **M2** colourless **M3** purple

M1 KMnO₄ in alkali / neutral **M2** brown solid **M3** purple

Credit for the use of **iodine**

M1 iodine (solution / in KI) **M2** colourless **M3** (brown) to purple (credit no change)

Credit for the use of **concentrated** H₂SO₄

M1 concentrated H₂SO₄ **M2** brown **M3** no change / colourless

Ignore 'goes clear'.

Ignore 'nothing (happens)'.

Ignore 'no observation'.

No credit for combustion observations.

- (c) (i) (Both infrared spectra show an absorption in range) **1620 to 1680** (cm^{-1})
Ignore reference to other ranges (eg for C–H or C–C).
- (ii) The fingerprint (region) / below 1500 cm^{-1} will be different **or** its fingerprinting will be different

1

OR

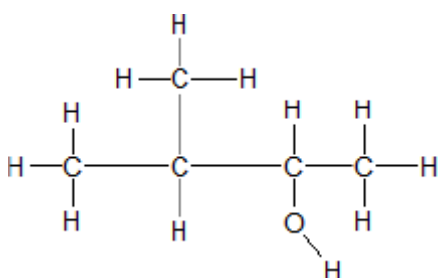
different absorptions / peaks are seen (in the region) below 1500 cm^{-1}
 (or a specified region within the fingerprint range)

*Allow the words 'dip' **OR** 'spike' **OR** 'low transmittance' as alternatives for absorption.*

QoL

1

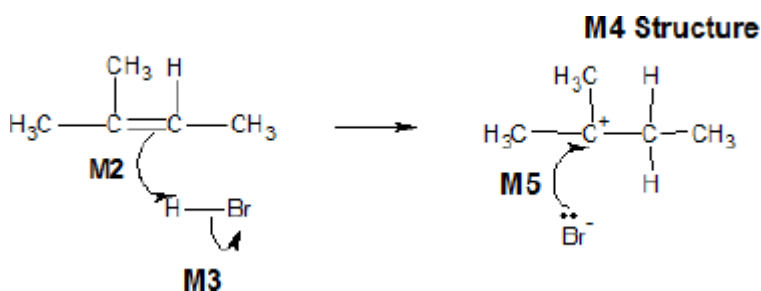
(d)



*All bonds must be drawn.
 Ignore bond angles.*

1

- (e) (i) **M1 Electrophilic addition**
M1 both words needed.



Penalise one mark from their total if half-headed arrows are used.

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

M2 Ignore partial negative charge on the double bond.

M3 must show the breaking of the H–Br bond

M3 Penalise incorrect partial charges on H–Br bond and penalise formal charges.

M4 is for the structure of the tertiary carbocation

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

Penalise once only in any part of the mechanism for a line

and two dots to show a bond.

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

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

Max 3 of any 4 marks in the mechanism 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'.

NB The arrows here are double-headed

5

- (ii) **M1** Reaction goes via intermediate carbocations / carbonium ions
M1 is a lower demand mark for knowledge that carbocations are involved.

M2 (scores both marks and depends on M1)

Tertiary carbocation / carbonium ion is more stable (than the secondary carbocation / carbonium ion)

OR

Secondary carbocation / carbonium ion is less stable (than the tertiary carbocation / carbonium ion)

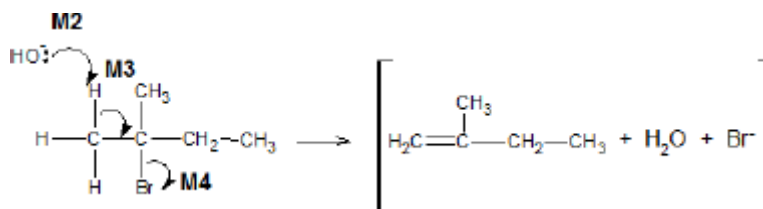
M2 is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.

A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

2

- (f) **M1 Elimination**

M1 credit 'base elimination' but no other qualifying prefix.



Penalise one mark from their total if half-headed arrows are used.

M2 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to a correct H atom

Penalise M2 if covalent KOH

M3 must show an arrow from a correct C-H bond adjacent to the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom

of a correct adjacent C–H bond (in **M2**)

M4 is independent provided it is from their original molecule **BUT** penalise **M2**, **M3** and **M4** if nucleophilic substitution shown

Award full marks for an E1 mechanism in which **M2** is on the correct carbocation

NB The arrows here are double-headed

Penalise **M4** for formal charge on C or Br of the C–Br bond or incorrect partial charges on C–Br.

Penalise **M4** if an additional arrow is drawn from the Br of the C–Br bond to, for example, K⁺.

Ignore other partial charges.

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

Max 2 of any 3 marks in the mechanism for wrong reactant or wrong organic product (if shown) or a correct mechanism that leads to the alkene 2-methylbut-2-ene.

Credit the correct use of “sticks” for the molecule except for the C–H being attacked.

M5 hydroxide ion behaves as a base / proton acceptor / electron pair donor / lone pair donor

Penalise **M5** if ‘nucleophile’.

5

[21]

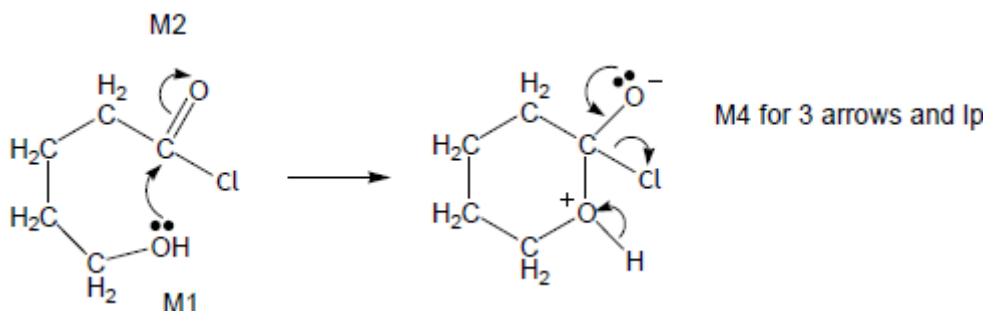
Q28.

(a) (i) (nucleophilic) addition-elimination

Not electrophilic addition-elimination

Ignore esterification

1



M3 for structure

- If wrong nucleophile used or O–H broken in first step, can only score **M2**.
- **M2** not allowed independent of **M1**, but allow **M1** for correct attack on C⁺
- + rather than δ^+ on C=O loses **M2**.
- If Cl lost with C=O breaking lose **M2**.
- **M3** for correct structure with charges but lone pair on O is part of **M4**.

- Only allow M4 after correct / very close M3.
- Ignore HCl shown as a product.

4

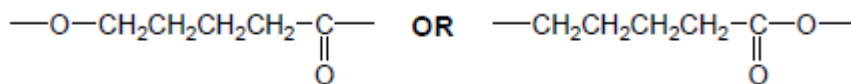
a 20-50 (ppm) or single value or range entirely within this range
If values not specified as a or b then assume first is a.

1

b 50-90 (ppm) or single value or range entirely within this range

1

(ii)

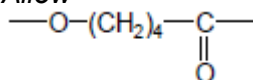


Must have trailing bonds, but ignore n.

1



Allow



but not $\text{---C}_4\text{H}_8\text{---}$

one unit only

Condensation

1

(b)

	Tollens'	Fehling's / Benedicts	Acidified potassium dichromate
--	----------	-----------------------	--------------------------------

Penalise wrong formula for Tollens or missing acid with potassium dichromate but mark on.

1

J	No reaction / no (visible) change / no silver mirror	No reaction / no (visible) change / stays blue / no red ppt	No reaction / no (visible) change / stays orange / does not turn green
----------	--	---	--

Ignore 'clear', 'nothing'.

Penalise wrong starting colour for dichromate.

1

K	Silver <u>mirror</u> / grey <u>ppt</u>	Red <u>ppt</u> (allow brick red or red-orange)	(orange) turns green
----------	--	---	----------------------

1

J Two (peaks)
Allow trough, peak, spike.

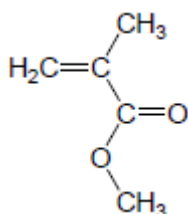
1

K Four (peaks)
Ignore details of splitting.
If values not specified as J or K then assume first is J.

1

- (c) If all the structures are unlabelled, assume that the first drawn ester is L, the second ester is M; the first drawn acid is N, the second P. The cyclic compound should be obvious.

L
 ester



OR $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{COOCH}_3$

All $\text{C}_5\text{H}_8\text{O}_2$ L to P must have $\text{C}=\text{C}$.

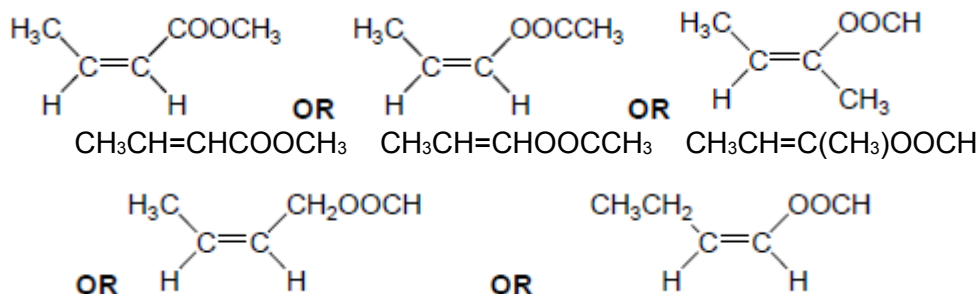
Allow CH_3^- .

Allow $-\text{CO}_2\text{CH}_3$ etc.

Allow $\text{CH}_2\text{C}(\text{CH}_3)\text{COOCH}_3$.

1

M
 ester



$\text{CH}_3\text{CH}=\text{CHCH}_2\text{OOCH}$

$\text{CH}_3\text{CH}_2\text{CH}=\text{CHOOCH}$

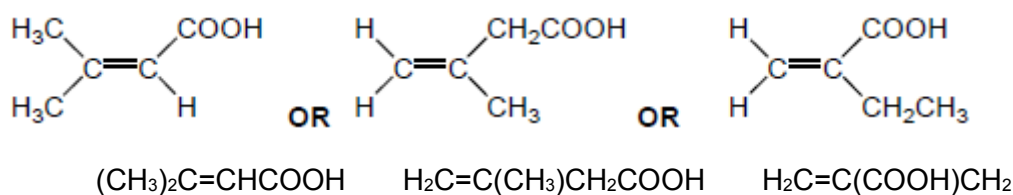
Allow either E-Z isomer.

Allow CH_3^- or C_2H_5^- but not CH_2CH_3^- .

Allow $\text{CH}_3\text{CHCHCOOCH}_3$ etc.

1

N
 acid



$(\text{CH}_3)_2\text{C}=\text{CHCOOH}$

$\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{CH}_2\text{COOH}$

$\text{H}_2\text{C}=\text{C}(\text{COOH})\text{CH}_2$

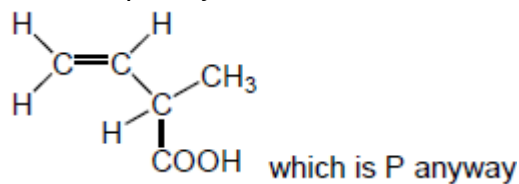
CH₃

Allow CH₃- or C₂H₅- but not CH₂CH₃-.

Allow -CO₂H.

Not cyclic isomers.

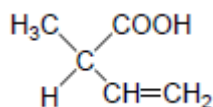
Not the optically active isomer.



Allow (CH₃)₂CCHCOOH etc.

1

P
acid



Allow -CO₂H.

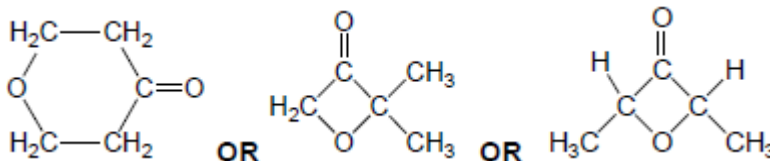


Allow CH₃CH(CO₂H)CHCH₂ or

CH₃CH(CO₂H)C₂H₃.

1

Q



Not cyclic esters.

1

[19]

Q29.

- (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.

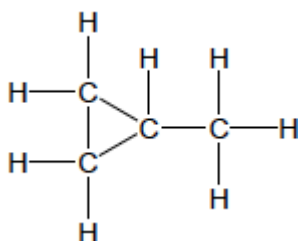
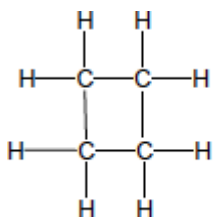
1

(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]

Q30.

- (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) H₂
Only. 1

(ii) Fuel / LPG

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

Do not allow petrol or motor fuel.

Ignore natural gas.

1

(iii) $C_4H_{10} + 2.5O_2 \rightarrow 4C + 5H_2O$

Accept multiples.

1

(iv) SO_2 / sulfur dioxide

If other sulfur oxides, mark on.

1

Calcium oxide / CaO / lime / quicklime

Allow $CaCO_3$ / allow $Ca(OH)_2$ or names.

Allow any solid base.

M2 dependent on M1.

Do not allow limewater.

1

(v) Neutralisation

Allow acid-base reaction.

Allow flue gas desulfurisation / FGD

1

(e) (Molecules) are similar sizes / have similar M_r / have similar number of electrons

Chemical error CE = 0/2 if breaking bonds.

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

Can accept same number of carbon atoms.

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

Ignore similar amount of bonds.

1

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

Not similar incorrect IMF eg dipole-dipole

1

[16]

Q31.

(a) (i) Crude oil / oil / petroleum

Do not allow 'petrol'

1

(ii) Fractional distillation / fractionation / fractionating

Not distillation alone

1

(b) (i) 5

	<i>Allow five / V</i>	1
(ii)	Chain (isomerism) <i>Allow branched chain / chain branched / side chain (isomerism)</i> <i>Ignore position (isomerism)</i> <i>Do not allow straight chain / geometric / branched / function</i>	1
(c) (i)	$C_{12}H_{26} / H_{26}C_{12}$ <i>Only</i>	1
(ii)	<u>Thermal</u> cracking <i>If not thermal cracking, CE = 0/2</i> <i>If blank mark on</i>	1
	High temperature <i>Allow 'high heat' for 'high temperature'</i> $(400^{\circ}\text{C} \leq T \leq 900^{\circ}\text{C})$ or $(650\text{ K} \leq T \leq 1200\text{ K})$ <i>Not 'heat' alone</i> <i>If no T, units must be 650 – 900</i>	
	and	
	High pressure ($\geq 10\text{ atm}$, $\geq 1\text{ MPa}$, $\geq 1000\text{ kPa}$)	1
(iii)	To produce substances which are (more) in demand / produce products with a high value / products worth more <i>Ignore 'to make more useful substances'</i>	1
(d) (i)	Corrosive or diagram to show this hazard symbol <i>Ignore irritant, acidic, toxic, harmful</i>	1
(ii)	$\left(\frac{120.5}{86 + 71} \times 100 \right)$ $=76.75(\%)$ or $76.8(\%)$ <i>Allow answers > 3 sig figs</i>	1
(e)	2,2-dichloro-3-methylpentane <i>Ignore punctuation</i> <i>Any order</i>	1
	C_3H_6Cl	1

[12]

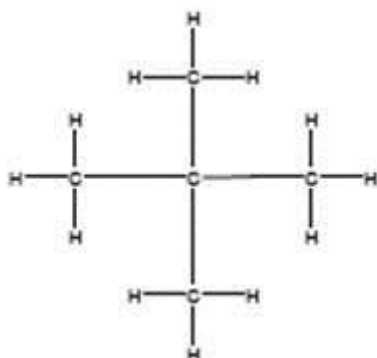
Q32.



Allow x in place of n

1

(b)



Chain

Must show every bond

Allow branched chain

2



Only

1

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

M2=0 if break C=C

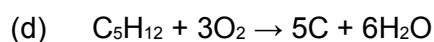
1

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

Not more useful products

Allow specific answers relating to question

1



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) $\frac{106.5}{143} \times 100$

1

74.48%

Allow 74.5%

1

Only

1

- (f) 2,3-dichloro-3-methylpentane
Ignore punctuation

1

C₃H₆Cl

Only

1

[13]

Q33.

- (a) Pentan-2-one

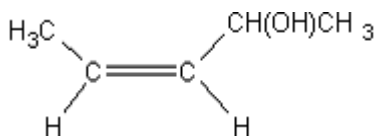
ONLY but ignore absence of hyphens

1

- (b) Functional group (isomerism)
Both words needed

1

- (c) (i)



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

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

Trigonal planar structure not essential

1

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

OR

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

1

- (d)

M1 Tollens' (reagent) (Credit ammoniacal silver nitrate OR a description of making Tollens') (Do not credit Ag⁺, AgNO₃ or [Ag(NH₃)₂⁺] or "the silver mirror test" on their own, but mark M2 and M3)	M1 Fehling's (solution) / Benedict's (Penalise Cu²⁺(aq) or CuSO₄ but mark M2 and M3)
M2 <u>silver mirror</u>	M2 <u>Red solid/precipitate</u>

OR <u>black solid or black precipitate</u>	(Credit <u>orange</u> or <u>brown solid</u>)
M3 (stays) colourless OR no (observed) change / no reaction	M3 (stays) blue OR no (observed) change / no reaction

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

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

Allow the following alternatives

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

M2 (turns) green

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

OR

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

M2 (turns) colourless

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

In all cases for **M3**

Ignore “nothing (happens)”

Ignore “no observation”

3

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

or named or correctly identified

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

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

1

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

- (Strong / broad) absorption / peak in the range **3230 to 3550** cm⁻¹ or specified value in this range or marked correctly on spectrum
and
(characteristic absorption / peak for) OH group / **alcohol** group
- No absorption / peak in range **1680 to 1750** cm⁻¹ or absence marked correctly on spectrum
and
(No absorption / peak for a) **C=O** group / **carbonyl** group / **carbon-oxygen double bond**
- Absorption / peak in the range **1620 to 1680** cm⁻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]

Q34.

- (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

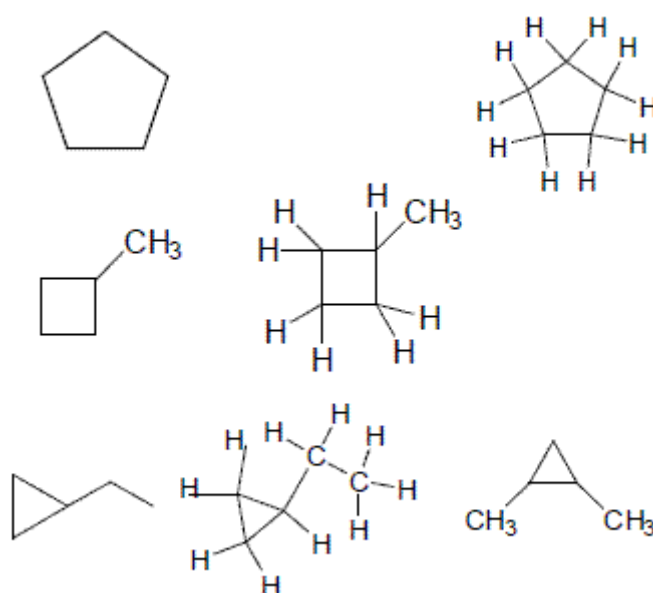
- (ii) 3-methylbut-1-ene

only

ignore commas and hyphens

1

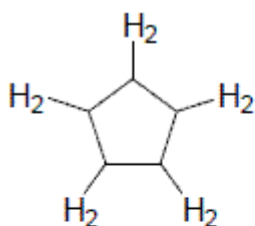
- (iii)



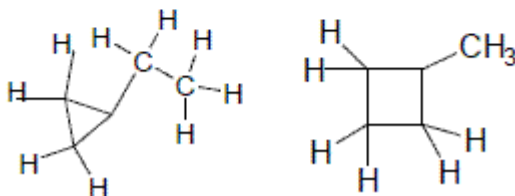
Allow any correct structure with a cyclic alkane

1

Do not allow



or



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]

Q35.

- (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 $CH_2/M_r = 14$

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 $M_1 = 0$ but can allow M_2

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

C_4H_9

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]

Examiner reports

Q1.

Some students could not convert the ratio 7.3 : 13.2 to a whole number ratio, but the question was answered well on the whole and discriminated well.

Q2.

Few students (28.7%) got this correct, with most believing there are fewer isomers than there actually are.

Q3.

- (a) This question discriminated well: 28.3% of students correctly identified the types of intermolecular forces and noted that hydrogen bonding in the alcohol and the acid was stronger than dipole-dipole attractions between propanal molecules. Despite the request in the question to consider intermolecular forces, a few students still discussed the breaking of bonds in the molecules and so gained no marks, although fewer did this than is often the case in this type of question.
- (b) Very few students (4%) scored both marks in this question and only 39.2% scored at least one mark, despite the question being based on one of the required practical activities.
- (c) This part was answered well by nearly two-thirds of the students. The main error was to test for the aldehyde rather than the acid.
- (d) This question discriminated well and there was a good spread of marks. Sadly, some students did not quote their answers to three significant figures and/or remember the negative sign for their exothermic enthalpy change of combustion.
- (e) The major errors in the answers to this acid-catalysed elimination of water were where students confused this mechanism with the elimination of HX from a halogenoalkane using a base. However, just under a third of students scored full marks in a correct mechanism, either via the formation of a carbocation or by showing the simultaneous loss of water and H⁺ from a protonated alcohol.
- (f) This part was challenging and a surprising proportion of students (8%) made no attempt. A large number scored no marks as they discussed the formation of different alkenes, rather than why pent-2-ene shows E-Z isomerism. Sadly, some of those who did gain the first mark failed to gain the second as this required two statements, not only that the C=C bond cannot rotate, but also that each carbon in the double bond has two different groups attached to it.

Q4.

A was the commonest incorrect response to this question which had a 47% success rate. This suggests there were many students who recognised that the answer is an aldehyde, but who then missed a possible isomer. Drawing out possible structures in a logical sequence is the key here. Students are advised to start with a 5C chain, then 4C and find possible positions for the fifth C (carbon 2 or carbon 3), and finally a 3C chain and find positions for the remaining two carbons (both on carbon 2).

Q5.

- (a) This straightforward question was not answered well. Many students drew 2-methylbutanal rather than 3-methylbutanal, not appreciating that the C atom in the aldehyde group is carbon-1.
- (b) Many students drew the displayed structure of the correct product, thereby demonstrating their understanding of the identity of the major product of this addition reaction of hydrogen bromide to the alkene.
- (c) Most students realised that thermal cracking produced an alkene.

Q6.

A minority of students (31.9%) scored this mark, with many incorrectly thinking there were one more or one fewer isomers than there actually were. Students are encouraged to take a systematic approach to deducing all possible structures.

Q21.

Electrophilic addition

Many students could draw the correct structure of the Z isomer in (a).

Many students did well on (b), but a significant number attempted to describe the curly arrow mechanism in words rather than drawing it. The phrase “outline the mechanism” has been used for many years and is explained in the specification to mean drawing a curly arrow diagram. On this occasion, it was decided that credit could stem from an accurate description in words but it was very hard for students to match the level of precision in words that is demanded in the drawing, and so most students who described the curly arrow diagrams did not score well at all. The final two marks were awarded for an explanation of why more of one product was formed than another. The explanation should refer to the relative stability of the two possible carbocation intermediates. Many students were confused and thought that the products were the carbocations. To score these marks, students had to be clear that carbocations are intermediates from which the products are formed and not the products themselves.

Q23.

Most students answered part (a) extremely well. They recognised that octane is an alkane and then correctly balanced an equation for its complete combustion. A number stated 8.5O_2 in the equation having not taken into account that CO_2 contains two oxygen atoms. Most students could give the correct IUPAC names in (a)(iii) and (b)(i). The molecular formula of the alkane produced in (b)(ii) was deduced well and the type of cracking and conditions were mostly stated correctly. A number of students then gave zeolite catalyst as a condition. The displayed formulae in part (b)(iv) were drawn accurately with many students scoring full marks. For those who did not score full marks there was a good attempt at the question with marks two and three being accessed by the majority of students. A number of students did not always show the displayed formula or did not deduce the chain isomer.

Q24.

The lack of structure in part (a) caused problems for some students and they needed to be clearer in some cases whether they were referring to reaction 1 or reaction 2. The mechanism was generally done well although showing attack by OH^- at the wrong C-H lost some marks. In part (b) very few students appreciated the need for two different groups on each C of the $\text{C}=\text{C}$ in addition to the lack of free rotation.

In part (c) it was expected that an experiment based on a 'disappearing cross' approach would be familiar to most students as would the general idea of a 'fair test'. There were, however, many elaborate and often unworkable methods suggested. There was also too much emphasis on things such as 'the same person observing' or 'the same stopwatch being used' instead of making suggestions to ensure that the only variable was the identity of the chloroalkane and that other conditions should be kept constant such as temperature, volumes of solutions and concentration of silver nitrate solution.

Q25.

Most students gave correct answers for part (a) although there were still some who did not state that *only* carbon and hydrogen are present in a hydrocarbon. The equation in part (b) was generally correct although some did have carbon dioxide as one of the two products. In part (c) the majority of students scored the first mark but some just stated that sulfur dioxide was toxic and failed to mention acid rain. A few students suggested that the sulfur compounds themselves escaped into the atmosphere without any mention of combustion. The equation in part (d)(i) was well done; the most common error was having the correct products but then failing to balance the equation. Answers to part (d)(ii) were poor with relatively few stating a correct substance made. Part (d)(iii) was answered by a majority of students; the most common error was to draw propene rather than the functional group isomer. The structure in part (c) was also well done by the majority of students, although some students left out a hydrogen atom from the chain and could not score the mark.

Q26.

Part (a) was very well answered but many students could not give a correct balanced equation in part (b); some gave carbon as a gaseous product. Answers to part (c) were mixed. Some were excellent and gave the correct answer and condition but far too many thought that the nitrogen was from a nitrogen-containing impurity in the paraffin. Equations given in part (c)(ii) were generally good but many students found writing the equation in part (c)(iii) more difficult.

The general formula of the alkanes was well known in part (d)(i). Answers to part (d)(ii) suggested that many students did not read the question carefully and so did not write equations giving two molecules with equal numbers of carbon atoms. Due to this error, the empirical formula was often incorrect. A range of catalysts was seen but many did know the correct one. In part (d)(iii), far too many students thought that covalent bonds were broken during melting. When students realise that the van der Waals forces are broken they must state that these forces are between the molecules. In a few answers, students referred to van der Waals bonds breaking and this is unclear. The IUPAC name in part (e) proved difficult for many students, especially the numbers of the substituent groups. The type of isomerism in part (e) was well known by most students; the most common incorrect answer was positional isomerism.

Q27.

Fewer than a third of students scored both marks for the definition in part (a)(i), often missing the requirement to state that stereoisomers are compounds with the same structural formula. Part (b) was generally well answered with most students scoring all 3 marks. Part (c)(ii) required appreciation of the fingerprint region or some equivalent idea and only about one-third of students scored this mark. The displayed formula in part (d) caused the usual problems and few were able to score this mark. The mechanisms in parts (e)(i) and (f) were the most discriminating questions on the paper, producing a good spread of marks. Part (e)(ii) required an explanation involving the relative stability of carbocations, with a low demand and a much higher demand mark and only the highest-scoring students scored both marks. It was a surprise to see answers that referred

to the 'Markownikoff rule' without any explanation in terms of the stability of carbocations.

Q28.

The nucleophilic addition-elimination mechanism in part (a)(i) presented a real challenge to many students, who were confused by the cyclic nature of the product, failed to identify the correct nucleophile and suggested either separate nucleophiles such as H_2O , CH_3OH and OH^- or alternatively loss of the proton from the OH group before nucleophilic attack. Most students gave the correct range for the carbon atom labelled **b**, but often the range for the carbon atom labelled **a** was given as 160–185 as for a carbonyl carbon. In part (a)(ii), the repeating unit for the polyester was answered well although some students gave twice the repeating unit.

The distinguishing test in part (b) was well done, although a significant number of students thought that substance **K** was an acid and wrongly suggested NaHCO_3 or Na_2CO_3 to distinguish between the compounds. It was common for students to fail to see the symmetry of **J** and so to predict, incorrectly, three peaks in its proton n.m.r. spectrum. Five peaks was a common incorrect answer for **K**, suggesting that students had misread the question and given the ^{13}C n.m.r. result.

Part (c) of this question proved to be very challenging and fewer than 10% of students scored full marks. Isomer **Q** was found particularly difficult where many students omitted one of the O atoms from their suggested structure. Other common errors included missing the double bond in **L**, giving the structure of **P** as the structure of **N** (which suggests a failure to recognise that optical isomerism is a form of stereoisomerism) or writing an unbranched carbon chain for the acid **N**. Answers to part (c) were often very badly presented, with a great deal of crossing out, duplication of answers and poor labelling of structures.

Q29.

Most students answered part (a) well although there were a few who omitted the key word 'molecular' in molecular formula. Most students could give the correct IUPAC name in part (a)(ii) but the name in part (a)(iii) was more problematic. Part (a)(iv) was reasonably well done although some students showed a cyclobutane structure without showing the displayed formula as asked for in the question. The solid product in part (b)(i) was often given as CO or CO_2 and hence the mark for the hazard could not be scored in part (b)(ii). Many those who correctly gave C as the product, simply stated that it was a pollutant without further qualification. Part (c)(i) was answered well as was part (c)(ii). Common incorrect answers to part (c)(ii) were bitumen and plastics. The equation in part (d)(i) was generally answered well although again there were a lot of students who gave the formula of nitrogen gas as N. The catalyst in part (d)(ii) was usually correct with the most common answer being platinum.

Q30.

Part (a) was done well but part (b) proved more difficult for some students. Many simply named the isomer given in part (b)(i) and few knew of the existence of cyclic alkanes in part (b)(ii). Part (c) produced many careless responses; students should know that all equations should be balanced. The type of cracking was not always specified in part (c)(ii) and many students referred to the usefulness of the products rather than to their value. It should be noted that cracking does not produce plastics; it produces alkenes that can be polymerised. Answers to part (c)(iii) showed that some students think that intermolecular forces are the only bonds broken in cracking. There were a vast number of incorrect reagents stated in part (d)(i) and many gave names rather than formulae as asked for in the question. The equation in part (d)(iii) was often not balanced and many students showed carbon monoxide as the solid product. There were many students who did not

know the identity of the toxic gas in (d)(iv) and therefore did not know a chemical that could remove it.

The answers to (d)(v) were very varied. Only the students that knew the answer to part (d)(iv) could get this right. Answers to part (e) showed that many students thought that boiling involved the breaking of covalent bonds.

Q31.

The majority of students knew the answers to parts (a)(i) and (a)(ii) although a common wrong answer to part (a)(ii) was cracking. Deducing the number of structural isomers in part (b)(i) caused problems for many students and several students showed a lot of working but then did not write a number in the box as instructed in the question. The type of structural isomerism in part (b)(ii) was well known but many wrong answers for the molecular formula were seen in part (c)(i). Many students lost marks in part (c)(ii) by identifying the wrong type of cracking. Even when thermal cracking was identified correctly, some students lost a mark by not stating the full conditions.

Most students scored the mark in part (c)(iii) although a few still gave answers in terms of usefulness rather than demand. Most students realised that the product in part (d)(i) was corrosive although 'acidic' was often seen. The atom economy was well answered in part (d)(ii) although weaker students did not give the correct number for the denominator or forgot to multiply by 100. The name in part (e) proved difficult for students with many omitting the numbers or giving the wrong numbers and many putting the chloro and methyl in the wrong order. The empirical formula was generally answered better although a lot of students just gave the molecular formula.

Q32.

The general formula of alkanes was well known although some candidates did not write clearly and the subscripts were often very difficult to read. The displayed formula in part (b) was generally well done although there are still many candidates who do not understand what a displayed formula is. The type of structural isomerism was generally well known.

The molecular formula in part (c) was generally well answered but many candidates could not give a clear answer as to why cracking reactions occur. Many simply stated that 'the chain was broken' with no reference to bonds breaking. There are still a considerable number of candidates who do not understand the concept of 'supply and demand' as applied to the fractions obtained from crude oil. In part (d) equations were often given with no solid product and consequently these candidates could not state the environmental problem. The percentage atom economy in part (e) was generally well attempted although many candidates truncated their answers rather than rounding up. Candidates gave a wide range of answers for the number of isomers. The expected answer of three was often seen since there are three straight chain structural isomers of $C_5H_{11}Cl$. However, there is also an optical isomer of one of the straight chain isomers and candidates repeating this unit with knowledge of CHEM4 may have answered four and so this was also allowed. In part (f) the naming of the organic compound discriminated well but there are quite a number of candidates who did not know the difference between empirical and molecular formula.

Q33.

This was a relatively high-scoring question, although the correct name was only given by 33% of the candidates in part (a). Infrared spectroscopy is an area which candidates are finding very accessible and although 90% identified the correct isomer in part (e), only 51% were able to obtain both marks in part (e)(ii).

Q34.

The idea of boiling point was generally well known although a few stated melting point as being the property in part (a). The definition in (b)(i) was well done with only a few missing the idea of isomers having the same molecular formula. The name in (b)(ii) proved difficult for a large number of candidates and the idea of cyclic alkanes in (b)(iii) was only achieved by the most able candidates. Part (c) was answered reasonably well although many candidates thought that the ethene itself was used as a plastic rather than being used to make plastics.

Q35.

The answers to part (a) were generally quite good although there were some candidates who quoted 'similar properties' without reference to chemical or physical properties. Less able candidates thought that members of the series had the same molecular or empirical formulae. The most common incorrect answer in part (b) was cracking. Part (c) was not well answered. A surprisingly high number of candidates did not know the correct definition and many candidates could not give the name of the structure. Some candidates did not seem to understand how to deduce the empirical formula and often quoted the molecular formula instead. Very few candidates scored full marks in part (d). Many candidates realised that there would be fewer van der Waals forces in the branched chain isomer but found difficulty with the idea of less surface contact. A disappointing number of answers referred to breaking the covalent bonds in the molecules.