PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 1: ALKANES

SCORE	PERCENTAGE
/181	%

STEMUP

These questions belong to Pearson Edexcel, not to us.

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

What we do not own

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

Where to find the originals

Pearson Edexcel publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at qualifications.pearson.com 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.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

All alkanes have the same

☒ **A** empirical formula

☒ **B** general formula

☒ **C** molecular formula

☒ **D** structural formula

(Total for question = 1 mark)

Q2.

This question is about alkenes.

(a) An alkene has a molar mass of 112 g mol^{-1}.

Deduce the molecular formula of this alkene.

(1)

(b) There are a number of different alkenes with the molecular formula C_4H_8.

(i) Draw the structure of the **branched-chain** alkene with the molecular formula C_4H_8.

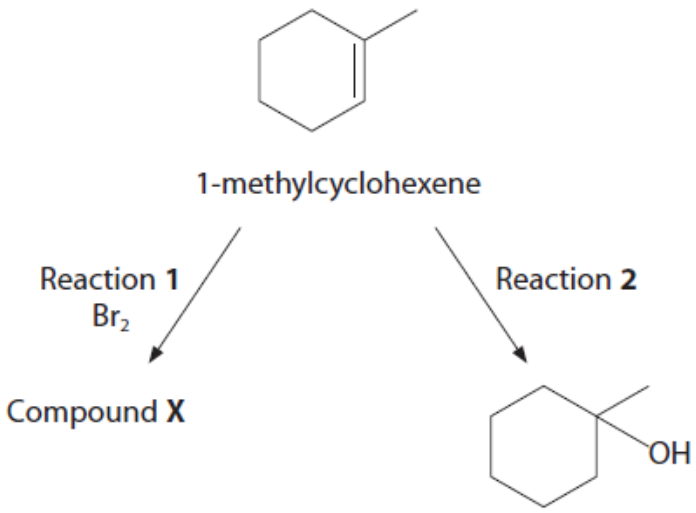
(1)

(ii) Give the structures and names of the two geometric isomers with the molecular formula C_4H_8.

(2)

Structure of geometric isomer 1	Structure of geometric isomer 2
Name of isomer 1	Name of isomer 2

(c) Two reactions of 1-methylcyclohexene are shown.



(i) Draw the **skeletal** formula of compound **X** formed in Reaction **1**.

(1)

(ii) Give the reagent and condition needed for Reaction **2**.

(2)

Reagent

.....

Condition

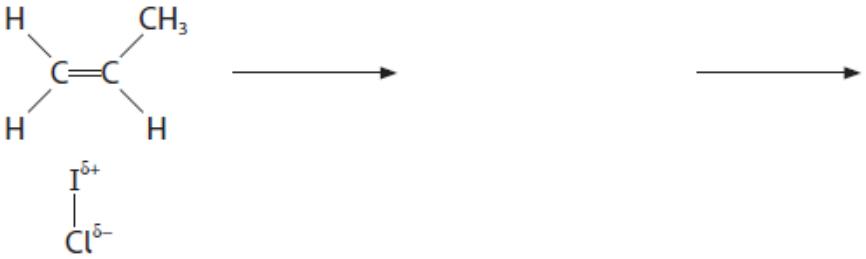
.....

(d) Iodine monochloride, ICl, reacts with alkenes in a similar way to hydrogen bromide.

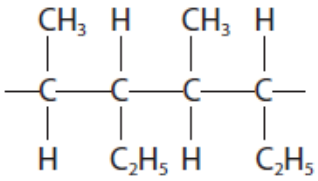
Complete the mechanism for the reaction of iodine monochloride with propene to form the **major** product.

Include curly arrows, the relevant lone pair and the structures of the intermediate and product.

(4)



(e) A section of a polymer showing two repeat units is given.



Give the **name** of the monomer that forms this polymer.

(1)

.....

(f) 0.0100 mol of an alkene reacts completely with exactly 600 cm^3 of hydrogen gas, measured at 298 K and 1.24×10^5 Pa
pressure, to form an alkane.

Use the ideal gas equation to deduce the number of double bonds in **one** molecule of the alkene. You **must** show your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 16 marks)

Q3.

Heptane, C_7H_{16}, is an alkane found in crude oil.

(a) Heptane can undergo incomplete combustion.

(i) Give a reason why incomplete combustion sometimes occurs.

(1)

.....

.....

.....

(ii) Write the equation for the incomplete combustion of heptane, forming carbon monoxide and water as the
only products.
State symbols are not required.

(1)

(b) Heptane is reformed into branched-chain and cyclic hydrocarbons that are used in petrol.

(i) Draw the **skeletal** formulae of a branched-chain alkane and a cycloalkane, each containing **seven** carbon atoms.

(2)

Branched-chain alkane
Cycloalkane

(ii) Write the equation for the reforming of heptane into a cycloalkane.
Use molecular formulae.

(1)

(iii) Give a reason for adding cycloalkanes to petrol.

(1)

.....

.....

.....

(c) Heptane, C_7H_{16} , reacts with chlorine in the presence of ultraviolet radiation.

(i) State the type and mechanism of this reaction.

(2)

.....

(ii) Give the mechanism for the reaction to produce $C_7H_{15}Cl$, $C_{14}H_{30}$ and HCl as the **only** products.

Include the name of each of the steps in your mechanism.

Curly half-arrows are **not** required.

(7)

(Total for question = 15 marks)

Q4.

Heptane, C_7H_{16}, is one of the compounds present in crude oil.

(a) When heptane is reformed, the products include 2,2,3-trimethylbutane and cycloheptane.

(i) Give a reason why petrol should **not** contain a high proportion of heptane.

(1)

.....

.....

(ii) Draw the **skeletal** formula of 2,2,3-trimethylbutane.

(1)

(iii) Write the equation for reforming heptane into cycloheptane.

Use **molecular** formulae.

State symbols are not required.

(1)

(iv) When petrol is burned in a car engine, oxides of nitrogen are formed.

Explain how these compounds result in damage to trees.

(2)

.....

.....

.....

.....

.....

(b) Heptane reacts with chlorine in sunlight.

(i) Chlorine radicals are formed in the first step in the mechanism.

$$Cl_2 \rightarrow 2Cl\bullet$$

Name this step in the mechanism.

(1)

.....

(ii) Give the **two** propagation steps for the formation of chloroheptane.

Use molecular formulae. Curly arrows are **not** required.

(2)

(iii) Give the termination step which forms a hydrocarbon.

(1)

(iv) Explain how some dichloroheptane, $C_7H_{14}Cl_2$, also forms during this reaction.

You may include equation(s) in your answer.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 11 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these atmospheric pollutants is **not** emitted during the combustion of alkane car fuels?

☒ **A** ammonia

☒ **B** nitrogen dioxide

☒ **C** sulfur dioxide

☒ **D** octane

(Total for question = 1 mark)

Q6.

Which of these is not a chemical reaction?

(1)

☒ **A** cracking

☒ **B** fractional distillation

☒ **C** polymerisation

☒ **D** reforming

(Total for question = 1 mark)

Q7.

Members of the homologous series of alkanes have the same

☒ **A** boiling temperature

☒ **B** density

☒ **C** empirical formula

☒ **D** general formula

(Total for question = 1 mark)

Q8.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A single molecule of decane, $C_{10}H_{22}$, is cracked.

Which of these mixtures could **not** be formed?

☒ **A** pentene and pentane

☒ **B** ethene, butene and butane

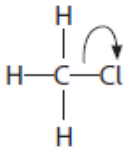
☒ **C** propene, propane and butene

☒ **D** hexene and propane

(Total for question = 1 mark)

Q9.

Curly arrows are used in reaction mechanisms.



The curly arrow shown represents the movement of

(1)

☒ **A** an electron from a bond to an atom, forming free radicals

☒ **B** an electron from a bond to an atom, forming ions

☒ **C** a pair of electrons from a bond to an atom, forming free radicals

☒ **D** a pair of electrons from a bond to an atom, forming ions

(Total for question = 1 mark)

Q10.

This question is about cycloalkanes.

(a) When alkanes from crude oil are reformed, the products include cycloalkanes.

Write the equation for reforming hexane into cyclohexane using **skeletal** formulae for the organic compounds.

(2)

(b) The skeletal formula of cycloalkane **D** is shown.



(i) Give the name of **D**.

(1)

.....

(ii) Give the molecular formula of **D**.

(1)

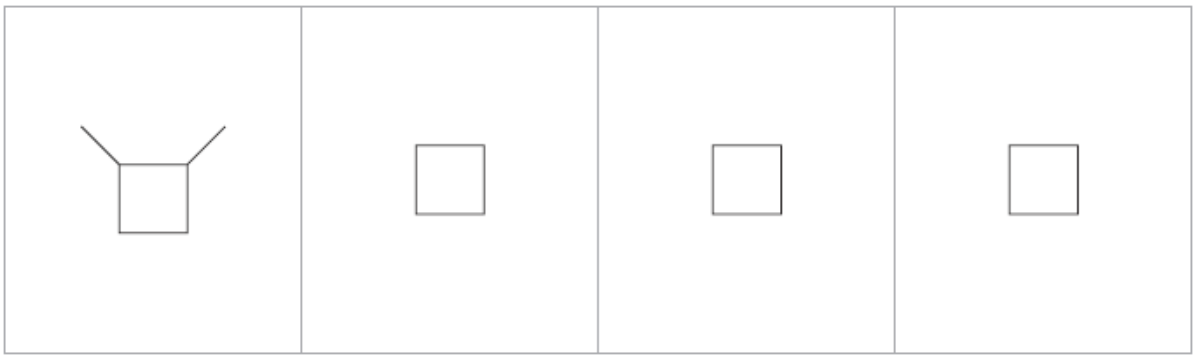
.....

(c) There are four structural isomers of C_6H_{12} with a ring of four carbon atoms.

One of these isomers is shown, in the first box.

Complete the **skeletal** formulae of the other three isomers.

(2)



(d) A cycloalkane, **E**, has a molar mass of 126 g mol^{-1}.

Deduce the molecular formula of **E**.

(1)

.....

(e) A sample of gaseous cyclopentane with a volume of 25 cm^3 was mixed with 250 cm^3 of oxygen (an excess) and the mixture was ignited.

Only gaseous products were formed.

$$2C_5H_{10}(g) + 15O_2(g) \rightarrow 10CO_2(g) + 10H_2O(g)$$

Calculate the volume of each gas remaining after the reaction.
All the gas volumes were measured at the same temperature and pressure.

(3)

(f) Cyclobutane, C_4H_8, reacts with chlorine in sunlight.

(i) Name the mechanism and type of reaction that is occurring.

(2)

.....

(ii) Complete the equation for the initiation step of this reaction mechanism.

Include appropriate curly arrows.

(2)

Cl——Cl →

(iii) Write the equations for the **two** propagation steps to form chlorocyclobutane.

Use C_4H_8 as the formula for cyclobutane.

Curly arrows and state symbols are not required.

(2)

(iv) A small amount of a hydrocarbon forms in this reaction.

Deduce the **skeletal** formula of this hydrocarbon. Justify your answer.

(2)

Skeletal formula of product

Justification

.....

.....

.....

(Total for question = 18 marks)

Q11.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Cyclopentane undergoes free radical substitution with bromine.

(a) Which of these is an overall equation for this reaction?

(1)

☐ **A** $C_5H_8 + Br_2 \rightarrow C_5H_8Br_2$

☐ **B** $C_5H_{10} + Br_2 \rightarrow C_5H_{10}Br_2$

☐ **C** $C_5H_{10} + Br_2 \rightarrow C_5H_8Br_2 + H_2$

☐ **D** $C_5H_{10} + Br_2 \rightarrow C_5H_9Br + HBr$

(b) Which statement is **not** correct about this reaction system?

(1)

☐ **A** only the initiation step involves homolytic bond fission

☐ **B** only some bromine is converted to free radicals in the initiation step

☐ **C** propagation forms more product than termination

☐ **D** further substitution reactions are likely to occur

(c) Which free radical is **least** likely to form in a propagation step in this reaction system?

(1)

☒ **A** $C_5H_9^{\bullet}$

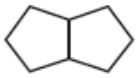
☒ **B** $Br^{\bullet}$

☒ **C** $C_5H_8Br^{\bullet}$

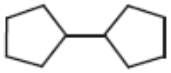
☒ **D** $H^{\bullet}$

(d) Which alkane could be formed in a termination step in this reaction system?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 4 marks)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the empirical formula of butane?

☒ **A** C_4H_{10}

☒ **B** C_2H_5

☒ **C** $CH_{2.5}$

☒ **D** C_nH_{2n+2}

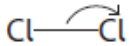
(Total for question = 1 mark)

Q13.

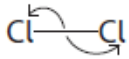
Methane reacts with excess chlorine in UV light.

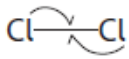
(a) Which process occurs in the initiation step?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(b) Which of these molecules could **not** be formed in a termination step?

(1)

☒ **A** C_2H_6

☒ **B** CH_3Cl

☒ **C** CH_2Cl_2

☒ **D** HCl

(Total for question = 2 marks)

Q14.

Which of these fuels is obtained from fermented sugar cane?

(1)

☒ **A** ethanol

☒ **B** hydrogen

☒ **C** petrol

☒ **D** propane

(Total for question = 1 mark)

Q15.

This question is about fuels and polymers.

Used coffee grounds have been suggested as a carbon-neutral fuel to replace some fossil fuels.

(a) (i) Explain why coffee grounds might be considered a carbon-neutral fuel.

(2)

.....

.....

.....

.....

.....

.....

(ii) Explain how the use of fossil fuels causes climate change.

(2)

.....

.....

.....

.....

.....

.....

(b) Long chain alkanes are not normally used as fuels as they produce soot.

(i) Name another pollutant formed by **incomplete** combustion of alkanes.

(1)

.....

(ii) Write the equation for the **complete** combustion of octane.

State symbols are not required.

(2)

(c) Long chain alkanes are converted into smaller, more useful molecules including alkenes.

(i) Name this process.

(1)

.....

(ii) Give a test for alkenes, including the positive result.

(2)

.....

.....

.....

.....

(d) Alkenes, such as ethene, can be used to make polymers.

(i) Write a balanced equation for the polymerisation of ethene using displayed formulae.

(1)

(ii) Bananas produce ethene as they ripen.

Suggest one advantage and one disadvantage of using ripening bananas as a source of ethene for polymer production.

(2)

.....

.....

.....

.....

.....

.....

(e) Burning poly(chloroethene) in an incinerator results in the formation of hydrogen chloride.

(i) State a **hazard** associated with hydrogen chloride.

(1)

.....

.....

(ii) Suggest how the hydrogen chloride could be removed from the waste gases produced in an incinerator.

(1)

.....

.....

.....

.....

(Total for question = 15 marks)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When carrying out chemical experiments, the hazards and risks must be considered.

For a given chemical

☒ **A** the hazard is fixed but the risk varies

☒ **B** the hazard varies but the risk is fixed

☒ **C** both hazard and risk are fixed

☒ **D** both hazard and risk vary

(Total for question = 1 mark)

Q17.

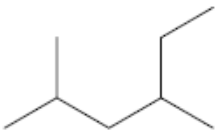
The alkanes are a homologous series of saturated hydrocarbons.

(a) Draw the displayed formulae of the three alkanes with molecular formula C_5H_{12}.

(3)

(b) Give the systematic name of compound **P**.

(1)



Compound **P**

Systematic name

.....

(c) The table shows the boiling temperatures of the first four straight-chain alkanes.

Molecular formula of alkane	Boiling temperature / °C
CH_4	−164
C_2H_6	−89
C_3H_8	−42
C_4H_{10}	−0.5

Predict the molecular formula and boiling temperature of the straight-chain alkane that has five carbon atoms in its molecules.

(2)

Molecular formula .....

Boiling temperature .....

(d) Alkanes undergo incomplete combustion when they burn in a limited supply of air.

(i) Write the equation for the incomplete combustion of propane, C_3H_8, to form carbon, carbon monoxide, carbon dioxide and water.

State symbols are not required.

(1)

(ii) Explain the toxicity of carbon monoxide.

(2)

.....

.....

.....

.....

(e) Propane reacts with chlorine in the presence of ultraviolet radiation. The reaction starts when some chlorine molecules are split into free radicals. A mixture of products is formed.

(i) Write the two propagating steps to show how C_3H_7Cl is formed.

Curly arrows are not required.

(2)

(ii) Identify the different C_3H_7Cl molecules that are produced in this reaction.

(1)

.....

.....

(iii) Give a reason why a mixture of C_3H_7Cl molecules is formed.

(1)

.....

.....

(iv) Give a reason why some hexane is formed in this reaction.

(1)

.....

.....

(v) A small amount of a product with molar mass 113 g mol^{-1} is formed.

Deduce the structure and name of a possible product with this molar mass.

(2)

Structure

.....

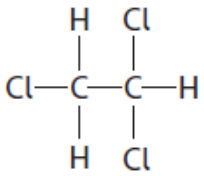
Name

.....

(Total for question = 16 marks)

Q18.

In the upper atmosphere, ozone can react with halogens and with halogen-containing compounds, such as molecule **X**.



molecule **X**

(a) Name molecule **X**.

(1)

.....

(b) The C—Cl bond undergoes homolytic fission in the upper atmosphere.

(i) State the essential condition necessary for this process.

(1)

.....

(ii) Write an equation for this fission in molecule **X**.

Include curly half-arrows.

(2)

(iii) Write an equation for the reaction of a chlorine free radical with a molecule of **X**.

Curly half-arrows are not required.

(2)

(iv) Write an equation, using displayed formulae, for a free radical formed in this sequence to give a molecule with the formula $C_4H_4Cl_6$.

(2)

(v) State the type of reaction occurring in (b)(iv) and the name of the product with the formula $C_4H_4Cl_6$.

(2)

.....

.....

(Total for question = 10 marks)

Q19.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A hydrocarbon **X** has a molar mass of 98 g mol^{-1}. When a sample of **X** is shaken with bromine water, the colour of the bromine water does **not** change.

Which of these could be the structure of **X**?

☐ **A**



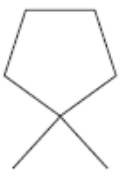
☐ **B**



☐ **C**



☐ **D**



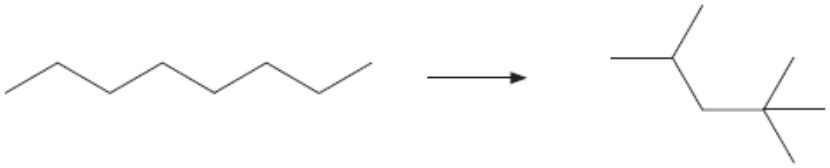
Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q20.

This question is about hydrocarbons obtained from crude oil.

(a) Petrol used in cars has a high proportion of the alkane iso-octane. Iso-octane can be formed by heating octane to 400 °C in the presence of a catalyst.



octane iso-octane

(i) Give the IUPAC name for iso-octane.

(1)

.....

(ii) Name the industrial process used to convert octane into iso-octane.

(1)

.....

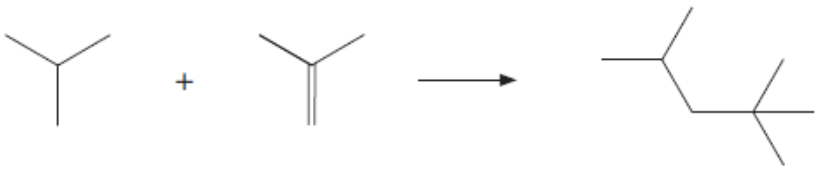
(iii) Give a reason why petrol needs a high proportion of iso-octane.

(1)

.....

.....

(b) Another way to produce iso-octane is by reacting iso-butane with 2-methylpropene.



iso-butane 2-methylpropene iso-octane

Draw the **skeletal** formulae of four isomers of 2-methylpropene.
Include only **one** isomer that does not decolorise bromine water.

(4)

(c) 2-methylpropene reacts with hydrogen bromide to form two possible products.

(i) Draw the mechanism for the formation of the **major** product of the reaction between 2-methylpropene and hydrogen bromide, HBr.

Include curly arrows, and relevant lone pairs and dipoles.

(4)

(ii) Give the reason why your product in (c)(i) is the major product.

(1)

.....

.....

(d) Another component of petrol, compound **X**, contains 92.3 % carbon and 7.7 % hydrogen by mass.

(i) Calculate the empirical formula of compound **X**.

You must show all your working.

(2)

(ii) A sample of compound **X** has a mass of 0.267 g and vaporises at 85.0 °C and 104 kPa to produce a gaseous sample with a volume of 98.0 cm^3.

Calculate the molar mass of compound **X**.
You must show all your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(iii) Deduce the molecular formula of compound **X**, using your answers to (d)(i) and (d)(ii).

(1)

(Total for question = 19 marks)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When $C_{20}H_{42}$ is cracked, each molecule produces one molecule of ethene, one molecule of butane and two molecules of hydrocarbon **E**.

What is the molecular formula of **E**?

☐ **A** C_7H_{13}

☐ **B** C_7H_{14}

☐ **C** $C_{14}H_{26}$

☐ **D** $C_{14}H_{28}$

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q22.

What is the total number of structural isomers with the molecular formula C_6H_{14}?

☐ **A** 4

☐

B 5

☒ **C** 6

☒ **D** 7

(Total for question = 1 mark)

Q23.

Aluminium is an abundant metal with many uses.

(a) The first four ionisation energies of aluminium are shown.

Ionisation number	Energy / kJ mol^{-1}
1	578
2	1820
3	2750
4	11 600

Explain how this information shows that aluminium is in Group 3 of the Periodic Table.

(2)

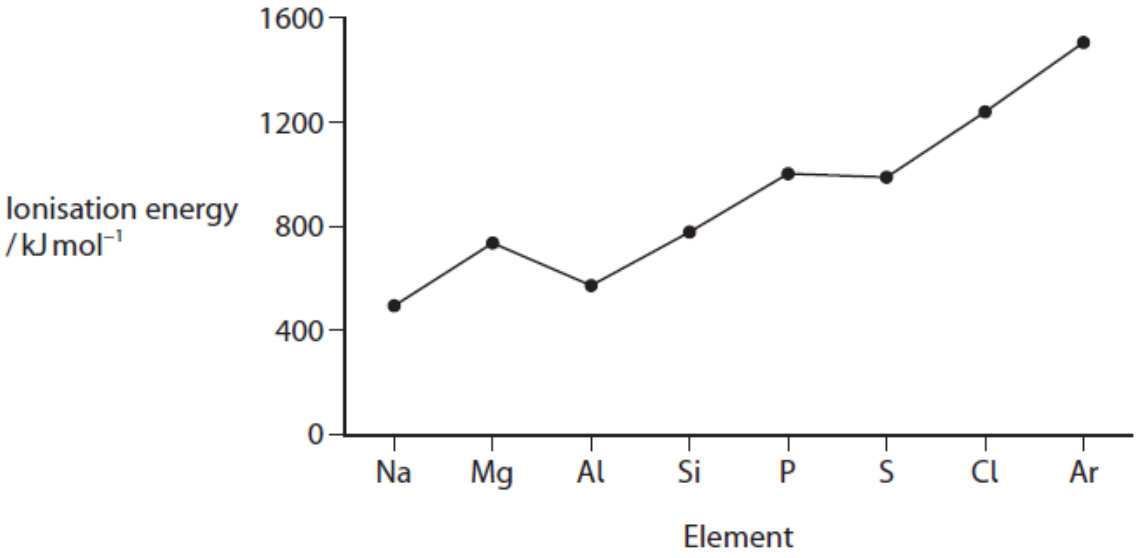
.....

.....

.....

.....

(b) The graph shows the first ionisation energies for the elements in Period 3.



(i) Explain the general increase in the first ionisation energy from sodium to argon.

(2)

.....

.....

.....

.....

(ii) Explain why the first ionisation energy of aluminium is less than the first ionisation energy of magnesium.

(2)

.....

.....

.....

.....

(c) (i) Describe the bonding in aluminium metal.

(2)

.....

.....

.....

.....

(ii) Give two possible reasons why aluminium is used for overhead power cables.

(2)

.....

.....

.....

.....

(d) New uses for waste aluminium cans are being investigated. One possible use is to make nanoparticle alloys to produce hydrogen for fuel.

(i) Aluminium nanoparticles react with water to produce aluminium oxide and hydrogen.

Complete the following equation. State symbols are not required.

(1)

..... Al + ... H_2O → ..... + ...

(ii) Give **two** possible reasons for producing hydrogen from aluminium rather than from fossil fuels.

(2)

.....

.....

.....

.....

.....

(Total for question = 13 marks)

Q24.

A 0.210 g sample of a volatile organic liquid **C** is injected into a gas syringe and heated in an oven.
At 100 kPa and 358 K, the syringe contains 72.5 cm^3 of gas.

(a) Calculate the molar mass of **C**.

[$pV = nRT$ R = 8.31 J mol^{-1} K^{-1}]

(4)

(b) The organic liquid **C** is a hydrocarbon.

Give a possible name or formula for **C**, using your answer in (a).

(1)

(Total for question = 5 marks)

Q25.

During a cracking reaction, each molecule of an alkane with formula $C_{10}H_{22}$ formed only two molecules of ethene and one molecule of hydrocarbon **A**.

What is the molecular formula of **A**?

(1)

- ☒ **A** C_6H_{10}
- ☒ **B** C_6H_{14}
- ☒ **C** C_8H_{16}
- ☒ **D** C_8H_{18}

(Total for question = 1 mark)

Q26.

Organic waste may be disposed of by landfill or incineration.
Both processes produce gases.

(a) The main gases produced from a typical landfill are shown in the table.

Gas	Percentage by volume / %
methane	50
carbon dioxide	45
nitrogen	4
sulfur compounds	1

(i) Name the process that forms these gases in landfill.

(1)

.....

(ii) State the **main** environmental problem caused by landfill gases, identifying the gas or gases responsible.

(2)

.....

.....

(iii) One tonne of landfill waste produces approximately 12.5 dm^3 of landfill gases per day.

Calculate the mass of carbon dioxide produced in a year by a typical landfill site which contains 90 000 tonnes of waste.
Assume that the gas volume is measured at room temperature and pressure (r.t.p.).
[Molar volume of gas at r.t.p. = 24.0 dm^3 mol−1]

(3)

(b) Suggest **two** advantages of incineration over landfill.

(2)

.....

.....

.....

.....

.....

.....

(c) Environmental groups prefer recycling to both landfill and incineration.

Suggest **one** advantage of recycling.

(1)

.....

.....

.....

.....

(Total for question = 9 marks)

Q27.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Petrol, bioethanol and hydrogen are fuels.

All three of these fuels

☒ **A** burn to produce greenhouse gases

☒ **B** are overall carbon neutral

☒ **C** are overall sustainable

☒ **D** biodegrade rapidly

(Total for question = 1 mark)

Q28.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which pollutant **cannot** form when alkane fuels are burned in car engines?

☒ **A** hydrogen chloride

☒

B sulfur dioxide

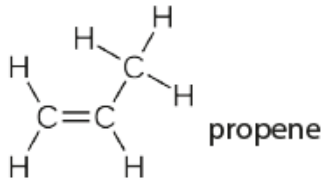
☒ **C** carbon particulates

☒ **D** carbon monoxide

(Total for question = 1 mark)

Q29.

This question is about the reactions of propene.



(a) Write an equation for the incomplete combustion of **one mole** of propene to form carbon dioxide, carbon monoxide,
carbon and water as the only products. Include state symbols.

(2)

(b) State **one** similarity and **one** difference that would be **seen** when propene is mixed with separate samples of
acidified potassium manganate(VII) solution and of bromine water.

(2)

.....

.....

.....

.....

.....

.....

(c) Propene reacts by addition polymerisation to form poly(propene).

Draw the structure of poly(propene), showing **two** repeat units.

(1)

(d) Propene reacts with bromine monochloride, BrCl, to form 1-bromo-2-chloropropane as the

major product.

(i) Complete the diagram of bromine monochloride to show the dipole.

(1)



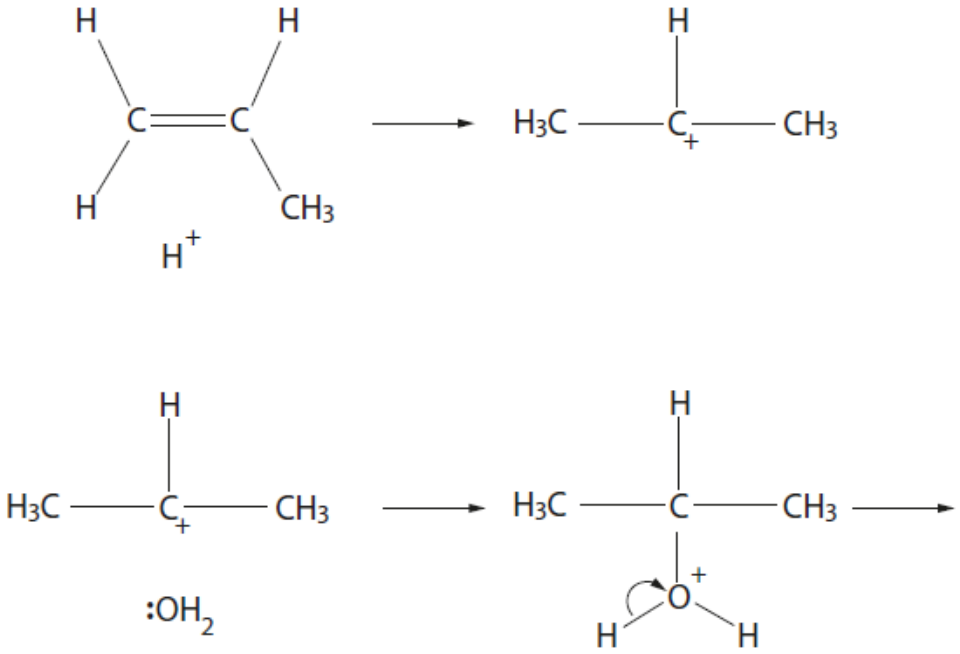
(ii) Draw the mechanism for the formation of 1-bromo-2-chloropropane in this reaction.
Include curly arrows, and relevant lone pairs.

(3)

(e) Propene reacts with steam in the presence of an acid catalyst to form a mixture of the alcohols propan-1-ol and propan-2-ol.

Complete the mechanism for the formation of propan-2-ol, by adding curly arrows.
Include the species formed in the final step.

(3)



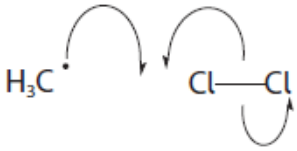
(Total for question = 12 marks)

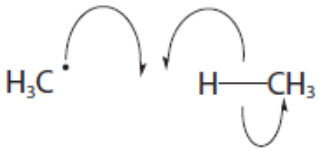
Q30.

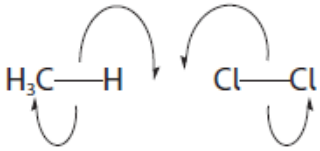
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these occurs in a **propagation** step in the reaction of methane with chlorine?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 1 mark)

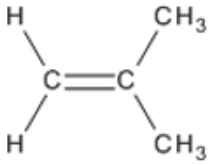
Mark Scheme

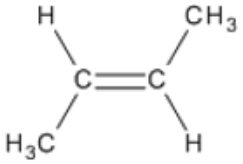
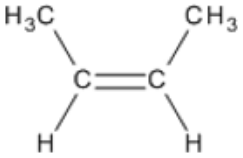
Q1.

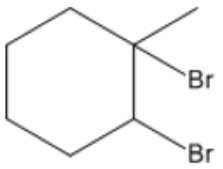
Question Number	Answer	Mark
	The only correct answer is B (general formula) **A** *is not correct because only the general formula is the same for all alkanes* **C** *is not correct because only the general formula is the same for all alkanes* **D** *is not correct because only the general formula is the same for all alkanes*	(1)

Q2.

Q	Answer	Additional guidance	Mark
(a)	• (alkene is) C_8H_{16}	Allow $H_{16}C_8$ Allow large numbers e.g. C8H16 Do not award C^8H^{16}	1

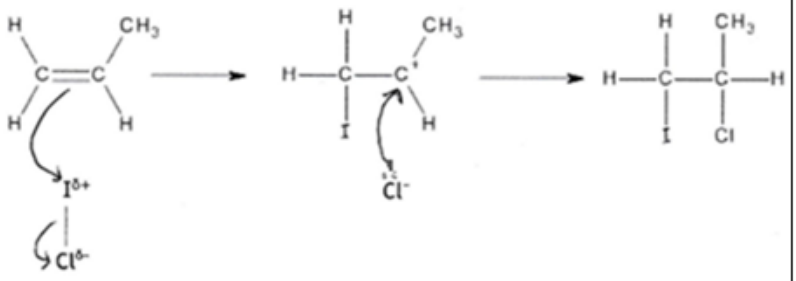
Q	Answer	Additional guidance	Mark
(b)(i)	• structure of C_4H_8 branched alkene	Example of structure:  Allow any unambiguous structure e.g. structural or displayed formula or any combination of these / skeletal formula Ignore name even if incorrect	1

Q	Answer	Additional guidance	Mark
(b)(ii)	• structure of one geometric isomer **and** name **(1)** • structure of the other geometric isomer **and** name **(1)**	Examples of structures and names:  **and** *trans*-but-2-ene / *E*-but-2-ene  **and** *cis*-but-2-ene / *Z*-but-2-ene Allow isomers in either order Allow 2-butene for but-2-ene Allow any unambiguous structures e.g. displayed formulae or skeletal formulae Ignore missing hyphens If no other mark is scored, allow (1) for two correct structures **or** two correct names	2

Q	Answer	Additional guidance	Mark
(c)(i)	• skeletal formula of product	Example of skeletal formula:  Ignore structural / displayed formula	1

Q	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to one of the following pairs: **Either** • steam / $H_2O(g)$ **(1)** • phosphoric((V)) acid (catalyst) / H_3PO_4 **(1)** **Or** • (concentrated) sulfuric acid / H_2SO_4 **(1)** • **followed by** water / H_2O **(1)**	Allow reagent and condition written on either dotted line for the steam and phosphoric acid answer Allow water / H_2O **and** heat / any temperature above 100°C Ignore pressure If oxidation number is given, it must be correct Allow just 'acid catalyst' Ignore hydrochloric acid / just 'H^+' Ignore specified temperature / heat / reflux Do not award $H_2O(g)$	2

STEMUP.CO.UK

Q	Answer	Additional guidance	Mark
(d)	Example of mechanism:  • curly arrow from C=C bond to / towards $I^{\delta+}$ **and** curly arrow from I-Cl bond to, or just beyond Cl **(1)** • intermediate **(1)** • lone pair on Cl^- **and** curly arrow from lone pair to carbon with positive charge **(1)** • structure of major product **(1)**	Do not award δ+ charge on intermediate Do not award δ− charge on chloride ion Allow curly arrow from lone pair to positive charge **Note** Mechanism for the formation of the minor product can score M1, M3 and M4	**4**

Q	Answer	Additional guidance	Mark
(e)	• pent-2-ene	Allow 2-pentene Ignore *E* / *Z* / *cis* / *trans* Do not award just 'pentene'	**1**

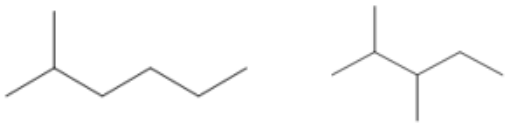
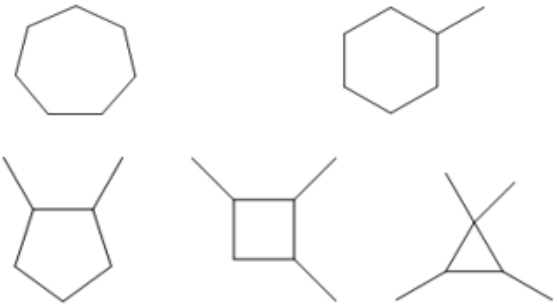
STEMUP.CO.UK

Q	Answer	Additional guidance	Mark
(f)	• conversion of volume to m^3 **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)** • deduction of number of double bonds **(1)**	Example of calculation: volume of H_2 = $\frac{600}{1 \times 10^6}$ = 6×10^{-4} / 0.0006 m^3 $n = \frac{pV}{RT}$ **or** $n = \frac{1.24 \times 10^5 \times 6 \times 10^{-4}}{8.31 \times 298}$ TE on volume n = 0.03004 / 0.0300 / 0.030 / 0.03 TE on volume ratio alkene : H_2 = 0.01 : 0.03 / 1 : 3 **and** so there are 3 double bonds TE on volume Final answer with no working scores (1) Ignore SF including 1SF	**4**
			(Total for Question = 16 marks)

Q3.

Q	Answer	Additional guidance	Mark
(a)(i)	• limited supply of oxygen / air	Accept not enough oxygen / air Allow lack of oxygen / air Ignore excess fuel / burning in an enclosed space Do not award no oxygen / air	**1**

Q	Answer	Additional guidance	Mark
(a)(ii)	• equation	Examples of equation: $2C_7H_{16} + 15O_2 \rightarrow 14CO + 16H_2O$ $C_7H_{16} + 7½O_2 \rightarrow 7CO + 8H_2O$ Allow multiples Ignore state symbols even if incorrect	**1**

Q	Answer	Additional guidance	Mark
(b)(i)	• branched-chain alkane **(1)** • cycloalkane **(1)**	Examples of skeletal formulae:  Allow any branched-chain alkane with 7 carbon atoms  Allow any ring with three or more carbon atoms and additional carbons to give a total of 7 carbon atoms Allow (1) for a correct branched-chain alkane **and** a cyclic alkane with 7 carbon atoms using structural or displayed formulae Ignore molecular formulae / names even if incorrect If no other mark is awarded, allow (1) for correct skeletal formulae of a branched-chain alkane **and** a cycloalkane that do not have 7 carbon atoms	**2**

Q	Answer	Additional guidance	Mark
(b)(ii)	• equation	Example of equation: $C_7H_{16} \rightarrow C_7H_{14} + H_2$ Allow multiples Ignore structural / displayed / skeletal formulae Ignore state symbols even if incorrect Do not award equations for cracking into more than one hydrocarbon	**1**

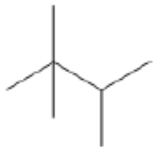
Q	Answer	Additional guidance	Mark
(b)(iii)	An answer that makes reference to the following point: • burns more efficiently / smoothly **or** prevents pre-ignition / knocking / pinking	Allow the octane number would increase Allow research octane number (RON) increases Ignore increases efficiency of the engine / just 'more efficient' / burns more easily / burns better / increase in volatility	**1**

Q	Answer	Additional guidance	Mark
(c)(i)	• (free) radical **(1)** • substitution **(1)**	Allow the words in either order Ignore homolytic /photochemical Do not award heterolytic / nucleophilic / electrophilic Do not award other types of reaction e.g. addition	**2**

Q	Answer	Additional guidance	Mark
(c)(ii)	• initiation (step) **(1)** • equation for initiation step **(1)** • propagation (step(s)) **(1)** • one equation for a propagation step **(1)** • another equation for a propagation step **(1)** • termination (step) **(1)** • equation for termination step **(1)**	Allow structural / displayed formulae Penalise missing • once only Ignore full curly arrows and curly half-arrows even if incorrect Ignore reference to any conditions e.g. uv / heat Allow initiating (step) $Cl_2 \rightarrow 2Cl\bullet$ / $Cl_2 \rightarrow Cl\bullet + Cl\bullet$ / $\frac{1}{2}Cl_2 \rightarrow Cl\bullet$ or Cl-Cl for Cl_2 Allow propagating (step(s)) $C_7H_{16} + Cl\bullet \rightarrow C_7H_{15}\bullet + HCl$ $C_7H_{15}\bullet + Cl_2 \rightarrow C_7H_{15}Cl + Cl\bullet$ Allow propagation steps in either order Allow terminating (step) $2C_7H_{15}\bullet \rightarrow C_{14}H_{30}$ / $C_7H_{15}\bullet + C_7H_{15}\bullet \rightarrow C_{14}H_{30}$ Ignore additional termination steps - $Cl\bullet + Cl\bullet \rightarrow Cl_2$ / $C_7H_{15}\bullet + Cl\bullet \rightarrow C_7H_{15}Cl$ Do not award any other termination steps	**7**
(Total for Question = 15 marks)			

Q4.

Question number	Answer	Additional guidance	Mark
(a)(i)	An answer that makes reference to the following: • Heptane / petrol containing heptane: burns less efficiently / smoothly (than branched chains / cycloalkanes) **or** does not combust efficiently **or** causes pre-ignition / knocking	Allow burns for combusts and vice versa Allow reverse argument e.g. petrol burns more efficiently with no / small amount of heptane Allow the octane number would be low / zero Ignore: It does not ignite / burn easily It is difficult / harder to combust Just 'less efficient' without reference to combustion Incomplete combustion Amount of CO_2 produced Causes auto-ignition References to toxicity and flammability	(1)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• 	Ignore bond lengths and bond angles Ignore structural or displayed formulae as working Ignore skeletal formula with any CH_3 groups specified	(1)

Question number	Answer	Additional guidance	Mark
(a)(iii)	• correct equation	Example of equation: $C_7H_{16} \rightarrow C_7H_{14} + H_2$ Allow multiples Ignore any other type of formulae	(1)

Question number	Answer	Additional guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • (oxides of nitrogen / these compounds) dissolve in / react with / combine with / mix with water **(1)** • (to form nitric / nitrous) acid(s) / acidic solution / acid rain **(1)**	Ignore any reference to oxides of sulfur / sulfur dioxide / sulfuric acid in answer Allow moisture / rain / clouds for water Ignore react with air / oxygen Allow decreases pH of solution / rain	(2)

Question number	Answer	Additional guidance	Mark
(b)(i)	• Initiation (step / reaction)	Allow initiating (step) Ignore free radical / homolytic / chain / initial (step) Do not award heterolytic	(1)

Question number	Answer	Additional guidance	Mark
(b)(ii)	• $C_7H_{16} + Cl\bullet \rightarrow C_7H_{15}\bullet + HCl$ **(1)** • $C_7H_{15}\bullet + Cl_2 \rightarrow C_7H_{15}Cl + Cl\bullet$ **(1)**	Allow propagation steps in either order Allow • anywhere on correct species Ignore curly arrows, even if incorrect Do not award • on species that are not radicals Penalise omission of • or incorrect number of hydrogens in heptane once only in b(ii), b(iii) and b(iv)	(2)

Question number	Answer	Additional guidance	Mark
(b)(iii)	• $C_7H_{15}\bullet + C_7H_{15}\bullet \rightarrow C_{14}H_{30}$	TE on alkyl radical in (b)(ii) Do not award product written as $2C_7H_{15}$ / $C_7H_{15}C_7H_{15}$	(1)

Question number	Answer	Additional guidance	Mark
(b)(iv)	An explanation that makes reference to the following points: • chlorine(free) radical / atom / Cl• removes another hydrogen (atom in the product / chloroheptane) **(1)** • (this free) radical reacts with another chlorine molecule / Cl_2 (to form dichloroheptane) **or** (this free) radical reacts with a chlorine radical / atom / Cl• (to form dichloroheptane) **(1)**	TE on alkyl radical in (b)(ii) Allow $C_7H_{15}Cl + Cl\bullet \rightarrow C_7H_{14}Cl\bullet + HCl$ Ignore Cl• substitutes a H atom Allow $C_7H_{14}Cl\bullet + Cl_2 \rightarrow C_7H_{14}Cl_2 + Cl\bullet$ **or** $C_7H_{14}Cl\bullet + Cl\bullet \rightarrow C_7H_{14}Cl_2$ Ignore just 'further substitution' Ignore $C_7H_{16} + 2Cl_2 \rightarrow C_7H_{14}Cl_2 + 2HCl$ Any answer that shows 2Cl substituted in one step	(2)

Q5.

Question number	Answer	Mark
	The only correct answer is A (ammonia) ***B*** *is not correct because oxides of nitrogen are emitted in the combustion of alkane fuels* ***C*** *is not correct because oxides of sulfur are emitted in the combustion of alkane fuels* ***D*** *is not correct because unburnt hydrocarbons are emitted in the combustion of alkane fuels*	**1**

Q6.

Question number	Answer	Mark
	B fractional distillation	1

Q7.

Question number	Answer	Mark
	The only correct answer is D (general formula) ***A*** *is incorrect because boiling temperature increases as the number of carbon atoms increases* ***B*** *is incorrect because density increases as the number of carbon atoms increases* ***C*** *is incorrect because the alkanes have different empirical formulae*	**(1)**

Q8.

Question Number	Answer	Mark
	The only correct answer is D (hexene and propane) **A** *is not correct because these products are possible* **B** *is not correct because these products are possible* **C** *is not correct because these products are possible*	(1)

Q9.

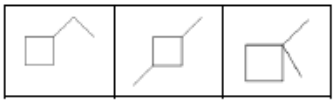
Question number	Answer	Mark
	The only correct answer is D (a pair of electrons from a bond to an atom, forming ions) **A** *is incorrect because movement of an electron is represented by a curly arrow with a half arrow-head and ions are formed when a pair of electrons moves* **B** *is incorrect because movement of an electron is represented by a curly arrow with a half arrow-head* **C** *is incorrect because ions are formed when a pair of electrons moves*	(1)

Q10.

Question number	Answer	Additional guidance	Mark
(a)	• 2 correct skeletal formulae (1) • balanced equation (1)	Example of equation:  Ignore molecular, displayed or structural formulae as working for M1 Allow balanced equation using molecular, displayed or structural formulae e.g. $C_6H_{14} \rightarrow C_6H_{12} + H_2$ Allow TE on any other C_6H_{12} cycloalkane Ignore state symbols / conditions	(2)

Question number	Answer	Additional guidance	Mark
(b)(i)	• 1,3-dimethylcyclopentane	Allow 1,3 dimethylcyclopentane 1 3-dimethylcyclopentane 1 3 dimethylcyclopentane cyclopentane-1,3-dimethyl Allow methy / methly for methyl Do not award 1,3-dimethylpentane	(1)

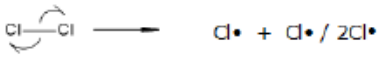
Question Number	Answer	Additional guidance	Mark
(b)(ii)	• C_7H_{14}	Allow $H_{14}C_7$ / C7H14 / H14C7 Ignore any other symbols as working e.g. $CH_2CHCH_3CH_2CH_2CHCH_3$ Do not award superscripts e.g. C^7H^{14}	(1)

Question number	Answer	Additional guidance	Mark
(c)	• All 3 correct (2) • Any 2 correct (1)	Examples of isomers:  Allow isomers in any order Allow CH_3 and C_2H_5 for side chains Ignore bond angles and bond lengths Do not award any structure with 2 or more rings	(2)

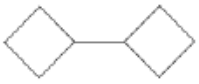
Question number	Answer	Additional guidance	Mark
(d)	• (**E** is) C_9H_{18}	Allow $H_{18}C_9$ Allow large numbers Ignore working Do not award superscripts	(1)

Question number	Answer	Additional guidance	Mark
(e)	• calculation of volume of CO_2(g) **and** H_2O(g) (1) • calculation or working of volume of O_2(g) used (1) • calculation of volume of O_2(g) left (1)	Example of calculation: 25 cm^3 of C_5H_{10} produces $\frac{25 \times 10}{2}$ = 125 (cm^3) CO_2 **and** 125 (cm^3) H_2O(g) 25 cm^3 of C_5H_{10} needs $\frac{25 \times 15}{2}$ = 187.5 (cm^3) O_2 Volume of O_2 left = 250 – 187.5 = 62.5 (cm^3) TE on volume of O_2 reacted (volume of C_5H_{10} = 0) Correct answers with no working scores (3) Allow volumes in dm^3 provided unit is given Penalise rounding to 1 or 2 SF once only Penalise correct volumes not linked to specific gases once only Penalise incorrect units e.g. cm once only	(3)

Question number	Answer	Additional guidance	Mark
(f)(i)	• (free) radical (1) • substitution (1)	Allow words in either order Mark independently Ignore homolytic (fission) / initiation / propagation / termination / photochemical Do not award heterolytic / electrophilic / nucleophilic for M1 only Ignore halogenation / S_N1 / S_N2 Do not award addition / elimination for M2 only	(2)

Question number	Answer	Additional guidance	Mark
(f)(ii)	• both curly half-arrows (1) • two chlorine (free) radicals with dot (1)	Example of equation:  Ignore two dots shown to represent electrons above and below the Cl–Cl bond Full arrow loses M1 only Penalise missing • once only in (f)(ii), (iii), (iv)	(2)

Question number	Answer	Additional guidance	Mark
(f)(iii)	• first propagation step (1) • second propagation step (1)	Example of equations: $C_4H_8 + Cl\bullet \rightarrow C_4H_7\bullet + HCl$ $C_4H_7\bullet + Cl_2 \rightarrow C_4H_7Cl + Cl\bullet$ Allow equations in either order Allow displayed or skeletal formulae Ignore curly arrows and state symbols, even if incorrect Do not award any equations involving H•	(2)

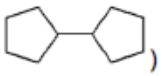
Question number	Answer	Additional guidance	Mark
(f)(iv)	An explanation that makes reference to the following points: • correct skeletal formula (1) • (two) $C_4H_7\bullet$ / cyclobutyl radicals join together (1)	Mark independently Example of skeletal formula:  Allow any 2 squares joined by a bond Ignore bond lengths and bond angles No TE on incorrect radicals Allow $2C_4H_7\bullet \rightarrow C_8H_{14}$ Allow cyclobutane / hydrocarbon radicals join together Ignore just '(two) radicals join together'	(2)

Q11.

Question number	Answer	Mark
(a)	**The only correct answer is D** ($C_5H_{10} + Br_2 \rightarrow C_5H_9Br + HBr$) ***A*** *is incorrect because C_5H_8 is the formula of cyclopentene and the reaction is not addition* ***B*** *is incorrect because the reaction is not addition and this product is not formed* ***C*** *is incorrect because these products are not formed*	1

Question number	Answer	Mark
(b)	**The only correct answer is A** (only the initiation step involves homolytic bond fission) ***B*** *is incorrect because not all of the bromine is converted to radicals in the initiation step* ***C*** *is incorrect because many more propagation than termination reactions occur* ***D*** *is incorrect because additional substitution products are likely to form*	1

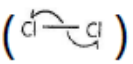
Question number	Answer	Mark
(c)	**The only correct answer is D** ($H^{\bullet}$) ***A*** *is incorrect because $C_5H_9^{\bullet}$ radicals form in propagation reactions* ***B*** *is incorrect because $Br^{\bullet}$ radicals form in propagation reactions* ***C*** *is incorrect because $C_5H_8Br^{\bullet}$ radicals may form in secondary propagation reactions*	1

Question number	Answer	Mark
(d)	**The only correct answer is C** () ***A*** *is incorrect because the molecule does not contain 10 carbon atoms* ***B*** *is incorrect because the molecule does not contain 10 carbon atoms* ***D*** *is incorrect because the molecule does not contain 18 hydrogen atoms*	1

Q12.

Question number	Answer	Mark
	The only correct answer is B (C_2H_5) ***A*** *is incorrect because this is the molecular formula* ***C*** *is incorrect because this is a ratio based on one atom of carbon* ***D*** *is incorrect because this is the general formula of an alkane*	(1)

Q13.

Question Number	Answer	Mark
(a)	**The only correct answer is B**  ***A*** *is incorrect because the curly arrow indicates heterolytic fission* ***C*** *is incorrect because both arrows are full arrows rather than half arrows* ***D*** *is incorrect because the arrows are in the wrong direction*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is D** (HCl) ***A*** *is incorrect because ethane could be formed by the combination of two methyl radicals* ***B*** *is incorrect because chloromethane could be formed by the combination of a methyl radical and a chlorine radical* ***C*** *is incorrect because dichloromethane could be formed from the combination of* CH_2Cl *radical and a chlorine radical*	**(1)**

Q14.

Question number	Answer	Mark
	A ethanol	1

Q15.

Question Number	Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • the carbon dioxide released when the fuel is used/burnt/combusted (is equal) **(1)** • (to the carbon dioxide that is) used/absorbed/taken in by the plant/during photosynthesis **(1)**	Ignore answers relating to fuel burnt on transport affecting carbon neutrality / energy spent on processing and drying MP1 do not award carbon for carbon dioxide Marks are independent Ignore sustainable resource **If no other marks awarded, for 1 mark:** Accept "no net CO_2 produced when using coffee grounds as a fuel" Accept "carbon intake = carbon release" Allow "renewable resource"	**(2)**

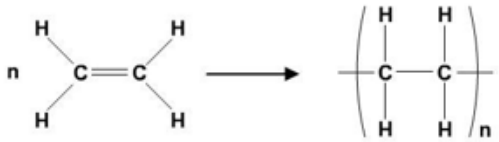
Question Number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • fossil fuels release carbon dioxide (that has been locked up for millions of years) / carbon dioxide is a greenhouse gas **(1)** • increases the greenhouse effect / leads to global warming / causes temperature increase (and climate change) **(1)**	Ignore answers relating to the consequences of climate change Ignore an explanation of the greenhouse effect Ignore CO_2 is harmful Marks are independent Do not award answers relating to: • UV light • ozone • SO_2 • NO_x • methane as a product of burning • carbon monoxide • acid rain	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(i)	• carbon monoxide	Allow CO Ignore unburnt hydrocarbons Do not award carbon Do not award nitrogen oxides	(1)

Question Number	Answer	Additional guidance	Mark
(b)(ii)	• formulae **(1)** • balancing **(1)**	$C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$ Accept 12.5 and 25/2 Allow multiples MP2 is dependent on MP1, but allow MP2 for correctly balanced equation for complete combustion of C_8H_{16} Ignore state symbols, even if incorrect Ignore references to energy on RHS eg *E* or *Q* or ΔH	**(2)**

Question Number	Answer	Additional guidance	Mark
(c)(i)	• cracking		(1)

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• bromine water / bromine solution / $Br_2(aq)$ **(1)** • yellow / orange / (red-)brown to colourless **(1)**	MP2 is dependent on a correct reagent for MP1 Allow bromine / liquid bromine Ignore heat Do not award "in UV light" Do not award iodine Allow decolourises or "turns colourless" Accept: $KMnO_4$ **with acid / H^+** scores 1 mark purple to colourless scores 1 mark (allow decolourises) Allow $KMnO_4$ **with alkali / OH^-** scores 1 mark purple → green scores 1 mark	**(2)**

Question Number	Answer	Additional guidance	Mark
(d)(i)	• displayed equation for the polymerisation of ethene	 Accept 90° bond angles for the monomer Allow letters other than n if used on both sides Allow square brackets around the polymer Ignore brackets around the monomer Ignore any names even if incorrect Do not award answers where • the polymer does not have brackets • the polymer continuation bonds do not pass through the brackets	**(1)**

Question Number	Answer	Additional guidance	Mark
(d)(ii)	• one advantage **(1)** • one disadvantage **(1)**	eg bananas are a renewable resource / more bananas can be grown / crude oil is running out / limited supply of crude oil Ignore references to: eco-friendly / carbon neutral / does not pollute / clean environment / idea of ethene produced by bananas does not pollute / banana skin being biodegradable / sustainable Do not award "no shortage of bananas" eg many bananas would be needed to produce a small amount of plastic / bananas only produce a small quantities of ethene / it would take a long time / loss of food source / less land available for growing food / not economically viable / only grow in certain climates / bananas would need to be transported long distances / banana transport would burn fossil fuels / inefficient process Ignore references to cost and biopolymers Do not award • polythene is non-biodegradable • impure ethene is produced	**(2)**

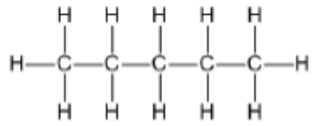
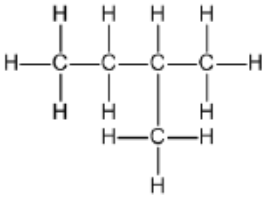
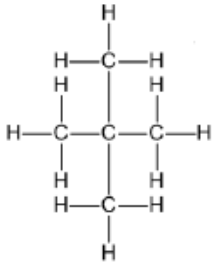
Question Number	Answer	Additional guidance	Mark
(e)(i)	• (HCl is) toxic / corrosive	Allow poisonous Allow irritant Ignore acidic Ignore harmful Ignore damage Do not award: • acid rain • ozone depletion • global warming • greenhouse gas • chlorine is toxic • flammable	**(1)**

Question Number	Answer	Additional guidance	Mark
(e)(ii)	• use of basic/alkaline (scrubbers) / form a ppt/salt/solid or injection of powdered activated carbon (to the flue) or pass through water / dissolve the HCl in water	Allow named examples of basic/alkaline chemicals e.g. NH_3, NaOH, $CaCO_3$ etc Scrubbers alone is insufficient Accept adsorption in granular activated carbon or coke beds Allow dissolve in steam Ignore fractional distillation of gases Do not award general descriptions of recycling	(1)

Q16.

Question number	Answer	Mark
	The only correct answer is A (the hazard is fixed but the risk varies) ***B*** *is not correct because the hazard is fixed and the risk varies* ***C*** *is not correct because the risk varies* ***D*** *is not correct because the hazard is fixed*	1

Q17.

Question number	Answer	Additional guidance	Mark
(a)	•  (1) •  (1) •  (1)	Allow CH_3 in branches Allow 2 marks for 3 correct structural or skeletal formulae or any combination of these	3

Question number	Answer	Additional guidance	Mark
(b)	• 2,4-dimethylhexane	Ignore punctuation errors	1

Question number	Answer	Additional guidance	Mark
(c)	• molecular formula: C_5H_{12} (1) • boiling temperature 25 - 40 °C (1)	Allow any temperature or range within the given range	2

Question number	Answer	Additional guidance	Mark
(d)(i)	• $C_3H_8 + 3½O_2 \rightarrow C + CO + CO_2 + 4H_2O$	Allow multiples Ignore state symbols, even if incorrect	1

Question number	Answer	Additional guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • (carbon monoxide) reacts with haemoglobin (in the blood) (1) • preventing it from carrying oxygen (around the body). (1)	Allow forms carboxyhaemoglobin	2

Question number	Answer	Additional guidance	Mark
(e)(i)	• $C_3H_8 + Cl\bullet \rightarrow C_3H_7\bullet + HCl$ (1) • $C_3H_7\bullet + Cl_2 \rightarrow C_3H_7Cl + Cl\bullet$ (1)	Allow equations in either order Penalise missing • once only	2

Question number	Answer	Additional guidance	Mark
(e)(ii)	• the products are 1-chloropropane and 2-chloropropane	Allow any unambiguous formulae Ignore molecular formulae	1

Question number	Answer	Additional guidance	Mark
(e)(iii)	• the chlorine free radical can remove a hydrogen from either the end carbon atoms or the central carbon atom		1

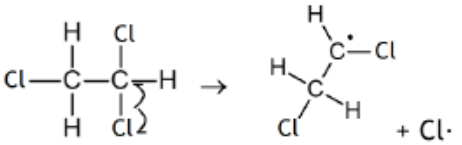
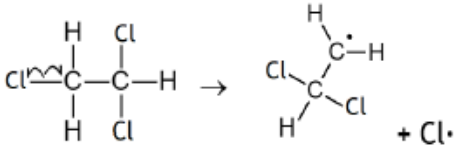
Question number	Answer	Additional guidance	Mark
(e)(iv)	• two propyl (free) radicals react together or • $C_3H_7\bullet + C_3H_7\bullet \rightarrow C_6H_{14}$	Ignore just '(two free) radicals react together' Do not allow molecules/ions	1

Question number	Answer	Additional guidance	Mark
(e)(v)	• structure (1) • corresponding name (1)	Examples of structures and names: $CH_3CH_2CHCl_2$ 1,1-dichloropropane $CH_3CHClCH_2Cl$ 1,2-dichloropropane $CH_3CCl_2CH_3$ 2,2-dichloropropane $CH_2ClCH_2CH_2Cl$ 1,3-dichloropropane Allow displayed, structural or skeletal formulae or any combination of these	2

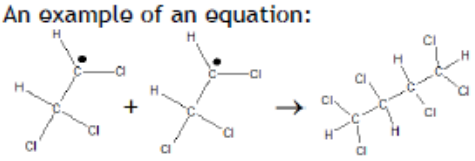
Q18.

Question Number	Answer	Additional guidance	Mark
(a)	1,1,2-trichloroethane	Do not award 1, 2, 2-trichloroethane	(1)

Question Number	Answer	Additional guidance	Mark
(b)(i)	• uv light OR uv radiation	Allow sunlight Allow uv Do not award "light"	(1)

Question Number	Answer	Additional guidance	Mark
(b)(ii)	A displayed reaction equation including: • curly half arrows showing the breaking of a bond (1) • the formation of two free radicals (Cl• and one being from molecule X) (1)	Penalise the omission of the unpaired electron once only in (b)(ii) and (b)(iv) Allow the fission of a bond in isolation for MP1 Allow multiple fissions if all are correct Mark independently  or 	(2)

Question Number	Answer	Additional guidance	Mark
(b)(iii)	A reaction equation showing: • a chlorine radical with 1,1,2-trichloroethane (1) • formation of two products (1)	Example of Equation: $Cl^{\cdot} + C_2H_3Cl_3 \rightarrow HCl + C_2H_2Cl_3^{\cdot}$ $Cl^{\cdot} + C_2H_3Cl_3 \rightarrow Cl_2 + C_2H_3Cl_2^{\cdot}$ Ignore further reactions Allow displayed formulae Allow radical dots placed in any location	(2)

Question Number	Answer	Additional guidance	Mark
(b)(iv)	A reaction equation showing: • **displayed formula** of any radical with a formula $C_2H_3Cl_2$• or $C_2H_2Cl_3$• (1) • balanced equation with two radicals and showing the **displayed formula** of the product (1)	An example of an equation: 	(2)

Question Number	Answer	Additional guidance	Mark
(b)(v)	An answer that makes reference to the points: • termination reaction (1) • suitably named product that can be derived from X (1)	Do not award addition reaction i.e. 1,1,2,3,4,4-hexachlorobutane, 1,2,2,3,3,4-hexachlorobutane, or 1,1,2,3,3,4-hexachlorobutane Allow TE name from $C_4H_4Cl_6$ structure shown in (b)(iv)	(2)

Q19.

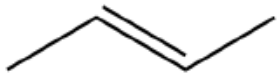
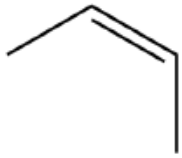
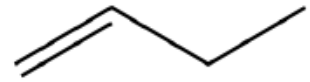
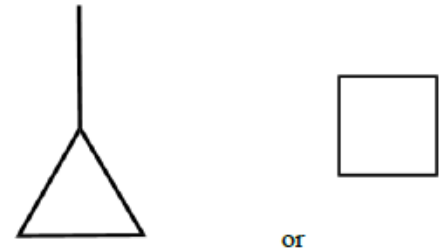
Question number	Answer	Mark
	The only correct answer is D  ***A*** *is not correct because this compound has a molar mass of 100 g mol^{-1}* ***B*** *is not correct because this compound has a molar mass of 114 g mol^{-1}* ***C*** *is not correct because this compound would decolourise bromine water*	1

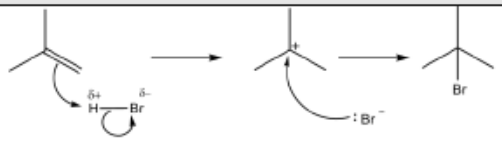
Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• 2,2,4-trimethylpentane	Ignore any incorrect or absent commas, hyphens etc Allow 2,2-dimethyl-4-methylpentane Note : ignore minor misspelling of methyl e.g. 'methly'	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• reforming	Allow reformation / reform Do not award cracking / fractional distillation Ignore rearrangement / isomerisation	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• prevents knocking / prevents pre-ignition / prevents pinking	Allow smoother combustion / smoother burning / increases octane number / improves octane number / increases RON IGNORE increases the volatility of a fuel / ignites more easily / is a better fuel / burns more cleanly / has a lower boiling temperature / is a safer fuel / burns more efficiently	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	•  (1) •  (1) •  (1) •  or (1)	Penalise use of displayed or structural formulae once only If displayed / semi-displayed formulae used ignore connectivity of CH_3 groups Ignore names even if incorrect	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	• dipole on hydrogen bromide molecule **and** structure of final product (1) • curly arrow from C=C to H and curly arrow from H-Br bond to, or just beyond, Br (1) • carbocation intermediate (1) • lone pair on Br− and curly arrow from lone pair to positive charge (1)	 Allow any combination of displayed, structural or skeletal formulae Allow + on bracket around the structure Do not award δ+ on intermediate Do not award δ− on Br in M4 Penalise use of half-arrows once only If minor product is shown then do not award M1 NOTE – incorrect starting alkene can score M2 and M4 only	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• the **tertiary** carbocation is (more) stable (than the primary carbocation)	Accept the 3° carbocation is more stable (than the 1° carbocation) Allow a description of a 3° carbocation e.g. '3 methyl groups attached to the positive C' Ignore explanations of stability even if incorrect / Ignore references to Markovnikov's law	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	• expression for calculation of moles of C and H (1) • deduction of empirical formula (1)	Example of calculation Element: C | H Expression to calculate moles: 92.3 / 12 | 7.7 / 1 Moles (mol): =7.7 (mol) | = 7.7 (mol) Ratio: 1 | 1 Empirical formula = CH / HC No TE from M1 to M2	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	• conversion of volume to m^3 (1) • conversion of temperature to K and pressure to Pa (1) • rearrangement of ideal gas equation and calculation of n (1) • calculation of molar mass (1)	Example of calculation 98 x 10^{-6} (m^3) – if V in dm^3 then pressure must be in kPa 358 (K) and 104 000 (Pa) $n = pV \div RT$ = (104 000 x 98 x 10^{-6}) ÷ (8.31 x 358) = 3.4259 x 10^{-3} (mol) Molar mass = (0.267) ÷ (3.4259 x 10^{-3}) = 77.9 / 78 (g mol^{-1}) Comment Do not penalise grams given as units for molar mass Allow TE throughout M1 and M2 could be subsumed within M3 Answer of 78 with no working scores M4 only	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	C_6H_6	Standalone mark No TE from di and dii	1

Q21.

Q	Answer	Mark
	The only correct answer is B (C_7H_{14}) ***A*** *is incorrect because this would be correct if ethane was formed instead of ethene* ***C*** *is incorrect because this would be correct if only one molecule of* ***E*** *was produced and ethane was formed instead of ethene* ***D*** *is incorrect because this would be correct if only one molecule of* ***E*** *was produced*	1

STEMUP.CO.UK

Q22.

Question number	Answer	Mark
	The only correct answer is B (5) ***A*** *is incorrect because there are 5 structural isomers – hexane, 2-methylpentane, 3-methylpentane,* ***C*** *is incorrect because there are 5 structural isomers* ***D*** *is incorrect because there are 5 structural isomers*	**(1)**

Q23.

Question Number	Answer	Additional Guidance	Mark
(a)	• there is a "jump"/much bigger increase between the third and fourth ionisation energies **(1)** • (First) 3 electrons in outer shell **(1)**	Accept fourth electron is removed from a different (quantum) **shell** (which is closer to the nucleus)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• the number of protons increases /nuclear charge increases **(1)** • the additional electrons are in the same shell/same energy level/ little additional shielding from electrons **(1)**	Allow "same shielding" Ignore references to atomic radius even if incorrect Ignore electron repulsion	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• the first electron is removed from a (3)p orbital/subshell in aluminium/ (3)s orbital/subshell from magnesium **(1)** **(1)** • p electron(s) shielded by the s electrons (so requires less energy)/ p energy level is higher than s energy level	Do not award 2p/2s	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(i)	An answer that makes reference to • delocalised /free (to move) electrons /sea of electrons **(1)** • attracted to (a lattice of) metal/aluminium/positive **ions/cations** **(1)**	Allow charges up to 3+ Correct fully labelled diagram scores 2 marks Ignore attraction of electrons to nuclei	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to **two** of the following: • (delocalised) electrons can move/carry charge **(1)** • aluminium has low density/light (weight) **(1)** • aluminium is ductile/can be drawn into wires **(1)** • aluminium forms an inert/oxide layer	Allow good conductor of **electricity** Ignore malleable, strong, heat resistant, high melting temperature.	**(2)**

Question Number	Answer	Additional Guidance	Mark
(d)(i)	**2** Al + **3** H_2O → **Al_2O_3** + **$3H_2$**	Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to **two** of the following: • reduces greenhouse gas emissions / carbon dioxide **and** which affects climate change / global warming **(1)** **(1)** • the production of hydrogen is portable **(1)** • fossil fuels are non-renewable (unlike water) **(1)** • aluminium can be recycled	Allow reduces sulfur dioxide emissions **and** which reduces acid rain Do not award references to ozone depletion, carbon neutral Ignore renewable Ignore landfill, atom economy, references to cost	**(2)**

Q24.

Question Number	Answer	Additional Guidance	Mark
(a)	• M1conversion of volume to m^3 **(1)** • M2 rearrangement of Ideal Gas Equation **(1)** • M3 conversion of pressure and evaluation to give number of moles **(1)** • M4 calculation of molar mass **(1)**	Example of calculation $72.5 \times 10^{-6} = 7.25 \times 10^{-5}$ / 0.0000725 (m^3) $n = \frac{pV}{RT}$ $\frac{100000 \times 7.25 \times 10^{-5}}{8.31 \times 358} =$ 2.4370×10^{-3} / 0.002437(mol) Allow TE on volume from M1 $\frac{0.210}{2.4370 \times 10^{-3}} = 86.172 = 86$ (g mol^{-1}) Allow TE on moles from M3 Ignore SF except 1SF Ignore units even if incorrect	**(4)**

Question Number	Answer	Additional Guidance	Mark
(b)	• hexane or any alkane with the molecular formula of C_6H_{14}	Allow name or structural/displayed/skeletal formula Allow TE on sensible mass from (a) If no mass allow hexane If both name and formula/structure given they must match The name or formula must match the mass in (a)	(1)

Q25.

Question number	Answer	Mark
	The only correct answer is B (C_6H_{14}) *A is incorrect because this would show the loss of two ethane molecules* *C is incorrect because this would show the loss of one ethane molecule* *D is incorrect because this would show the loss of one ethene molecule*	(1)

Q26.

Question number	Answer	Additional guidance	Mark
(a)(i)	An answer that makes reference to one of the following: • biodegradation / putrefaction / decomposition • fermentation • anaerobic respiration	Ignore decay Allow any indication of a biological process e.g. 'bacterial action' Do not award "**thermal** decomposition"	1

Question number	Answer	Additional guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • climate change / global temperature (1) • methane / CH_4 **and** (1) carbon dioxide / CO_2	 Allow global warming Ignore greenhouse effect / increase in temperature Do not award ozone depletion / acid rain Do not award ammonia/NO_x/SO_x/H_2S	2

Question number	Answer	Additional guidance	Mark
(a)(iii)	• calculation of annual volume of carbon dioxide (1) • calculation of moles of carbon dioxide (1) • calculation of mass of carbon dioxide (1)	Example of calculation = (45 ÷ 100) × 365 × 90000 × 12.5 = = 1.8478×10^8 (dm^3) = $1.8478 \times 10^8 \div 24(.0) = 7.6992 \times 10^6$ (mol) = $7.6992 \times 10^6 \times 44 = 3.3877 \times 10^8$ (g) / 3.3877×10^2 tonnes / 338.77 tonnes Answers not in grams must have units for M3 TE at each stage Allow 365.25 / 366 days Ignore SF except 1 SF Correct answer with some working scores (3)	3

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to any **two** of the following points: • decreases quantity of waste / less space is needed (1) • can be used (more easily) to generate electricity / produce heat (energy) (1) • pollutants can be trapped more easily (1) • transport costs lower (because sites can be sited near urban centres) (1) • prevents release of **methane** into the atmosphere (1) • high temperatures eliminate harmful bacteria / fungi (1) • residue can be used in construction products (1) • can deal with polymers/plastics/wastes that do not biodegrade (1) • reduced risk of water / soil pollution (by leaching) (1)	Allow less land needed Allow no land needed **for waste** Ignore no waste products Do not award generate energy Allow is a source of power Do not award incineration is less polluting / produces less CO_2 without referring to capture Allow residue can be used as fertiliser Ignore "reduces pollution" Ignore cost, appearance, time and contaminants	2

Question number	Answer	Additional guidance	Mark
(c)	An answer that makes reference to **one** of the following points: • resources conserved (1) (by recycling) • less energy is used (1) (in recycling)	Allow reverse arguments Allow produces **less** toxic or greenhouse gases Do not award answers relating to cost Ignore renewable / sustainable	1

Q27.

Question number	Answer	Mark
	The only correct answer is A (burn to produce greenhouse gases) ***B*** *is incorrect because they are not all carbon neutral* ***C*** *is incorrect because they are not all sustainable* ***D*** *is incorrect because they do not all biodegrade rapidly*	1

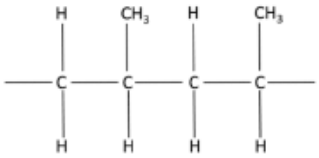
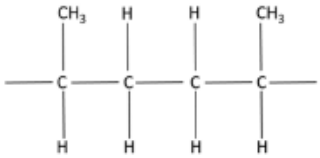
Q28.

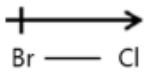
Question Number	Answer	Mark
	The only correct answer is A (hydrogen chloride) **B** *is not correct because sulfur is an impurity in alkane fuels and so sulfur dioxide can be produced during their combustion* **C** *is not correct because carbon particulates can be produced during the combustion of alkane fuels* **D** *is not correct because carbon monoxide can be produced during the combustion of alkane fuels*	(1)

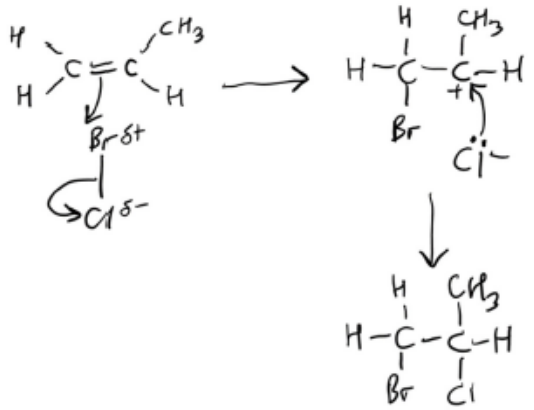
Q29.

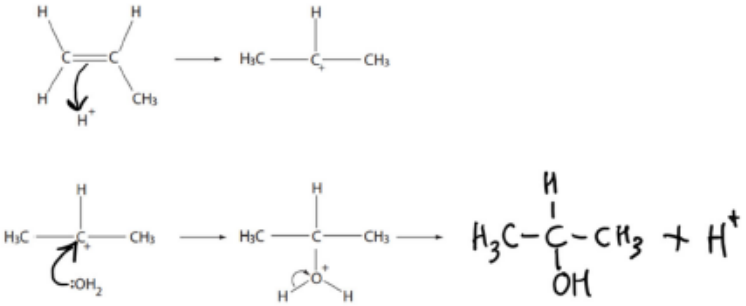
Question Number	Answer	Additional guidance	Mark
(a)	• balanced equation with **1 mol** C_3H_6 and correct products (1) • state symbols (1)	Example of equation: $C_3H_6(g) + 3O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + 3H_2O(l)$ Allow structural, displayed or skeletal formulae Allow $H_2O(g)$ Do not award $H_2O(aq)$ M2 dependent on correct species for the incomplete combustion of any C_nH_{2n} / C_nH_{2n+2} hydrocarbon forming $CO_2(g)$, $CO(g)$, $C(s)$ and $H_2O(l)/(g)$ If no other mark awarded, a correctly balanced equation, with correct state symbols, for the incomplete combustion of propene scores (1) eg $C_3H_6(g) + 3O_2(g) \rightarrow 3CO(g) + 3H_2O(l)/(g)$ eg $2C_3H_6(g) + 7O_2(g) \rightarrow 2CO_2(g) + 4CO(g) + 6H_2O(l)/(g)$	2

Question Number	Answer	Additional guidance	Mark
(b)	• both solutions decolourise / turn colourless (1) • from purple with (potassium) manganate((VII))/$KMnO_4$/MnO_4^- **and** from orange with (aqueous) bromine/Br_2 (1)	Ignore any reference to breaking of the C=C bond / type of reaction Ignore any reference to layers / effervescence Ignore any reference to reaction products / formation of solids Ignore turn clear / change colour Allow pink for purple or any combination of purple/pink Allow yellow or brown for orange or any combination of orange/yellow/brown Do not award any mention of red (eg red-brown) If neither M1 nor M2 awarded, either of the following scores (1): (potassium) manganate((VII))/$KMnO_4$/MnO_4^- decolourises from purple/pink or bromine decolourises from orange/yellow/brown	2

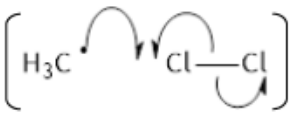
Question Number	Answer	Additional guidance	Mark
(c)	• poly(propene) structure containing two repeat units with extension bonds	Example of diagram:  Accept CH_3 groups on same or opposite sides Allow head-to-head and tail-to-tail configurations eg  Allow displayed, structural, skeletal formulae or any combination of these Ignore connectivity of vertical C–CH_3 bond Ignore brackets and 'n'	1

Question Number	Answer	Additional guidance	Mark
(d)(i)	• correct dipole	Example of correct diagram: $\delta+$ $\delta-$ Br — Cl Allow correct indication of net dipole moment:  Br — Cl Ignore horizontal arrow from Br to Cl, on or above the bond Ignore bond pair electrons on diagram Ignore lone pairs on Br/Cl Ignore electron density map Ignore double-headed curly arrow from bond to Cl Do not award full charges	1

Question Number	Answer	Additional guidance	Mark
(d)(ii)	A mechanism showing:	Example of mechanism:  Allow displayed, structural, skeletal formulae or any combination of these	3
	• curly arrow from C=C bond to (δ+)halogen **and** curly arrow from Br–Cl bond to (δ–)halogen or just beyond (1)	Penalise incorrect propene structure once only Penalise half-headed curly arrows once only	
	• secondary carbocation (1)	Allow primary carbocation for mechanism involving ethene only	
	• curly arrow from lone pair on halide ion to $C^{(+)}$ **and** correct product (1)	Allow curly arrow from lone pair to positive charge Do not award δ– on halide ion	

Question Number	Answer	Additional guidance	Mark
(e)	A mechanism showing: • curly arrow from C=C bond to H^+ (1) • curly arrow from lone pair on water to C^+ (1) • correct structure for propan-2-ol **and** H^+ (catalyst regenerated) (1)	Example of correct mechanism:  Do not award any additional curly arrows from/to/on propene/H^+ Allow curly arrow from lone pair to positive charge Do not award any additional curly arrows shown in this step Allow any combination of displayed/structural/skeletal formulae Ignore atom connectivity except displayed C–H–O Ignore any additional curly arrows added to the central intermediate	3

Q30.

Question number	Answer	Mark
	The only correct answer is B  ***A*** *is not correct because two radicals reacting occurs in termination* ***C*** *is not correct because a methyl radical reacting with methane would re-form the reactants* ***D*** *is not correct because two molecules reacting together directly does not occur*	1