PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 1: INTRODUCTION TO ORGANIC CHEMISTRY

SCORE	PERCENTAGE
/230	%

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Q1.

This question is mainly about alkenes.

(a) A few drops of bromine water are added to separate test tubes of propane and propene and the mixtures are shaken.

Describe what is seen at the end of each experiment.

(2)

Propane

.....

Propene

.....

(b) Give the reagents and conditions for each of these conversions.

(i) $CH_2{=}{=}CH_2 \rightarrow CH_3CH_2OH$

(1)

.....

.....

(ii) $CH_2{=}{=}CH_2 \rightarrow CH_2OHCH_2OH$

(1)

.....

.....

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

(1)

(d) Exactly 720 cm^3 of hydrogen gas, measured at room temperature and pressure (r.t.p.), reacted with 0.010 mol of an alkene to form an alkane.

Deduce the number of double bonds in one molecule of the alkene.
You **must** show your working.

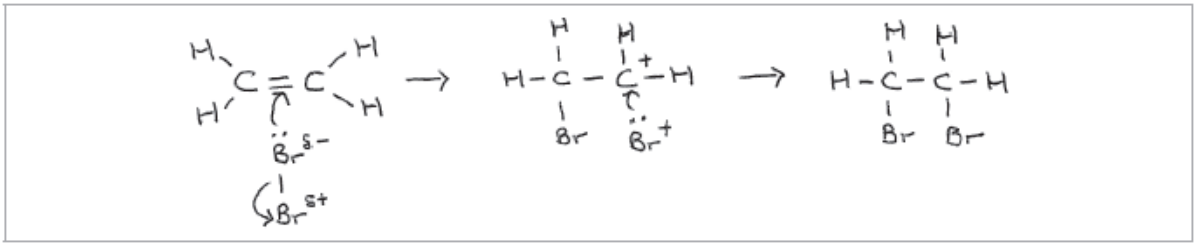
[Molar volume of gas at r.t.p. = 24 000 $cm^3\ mol^{-1}$]

(2)

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.....

(e) A student drew a mechanism for the addition of bromine to ethene.



Describe the three changes needed to correct this student's mechanism.

(3)

Change 1

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Change 2

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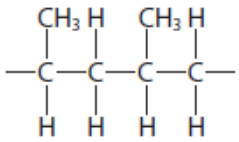
Change 3

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(f) Part of the structure of a polymer is shown.



Draw the structure of the monomer used to make this polymer.

(1)

(Total for question = 11 marks)

Q2.

This question is about the compound ammonium dichromate(VI), $(NH_4)_2Cr_2O_7$.

(a) $(NH_4)_2Cr_2O_7$ breaks down at around 180 °C, producing an oxide of chromium, nitrogen and water as the only products.

(i) Write an equation for the reaction.

State symbols are not required.

(2)

(ii) Give a name for this type of reaction.

(1)

.....

(b) When 0.00100 mol of ammonium dichromate(VI) was heated, 25.2 cm^3 of nitrogen gas, measured at laboratory temperature, was formed.

Calculate the temperature in the laboratory, in degrees Celsius, using the ideal gas equation. Use atmospheric pressure = 101 kPa.

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

(4)

(c) (i) Draw a dot-and-cross diagram of the ammonium ion.

Use dots (●) for the nitrogen electrons and crosses (X) for the hydrogen electrons.

(2)

(ii) Explain the shape of the ammonium ion using electron-pair repulsion theory.

(2)

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(d) Ammonium dichromate(VI) comes with several warnings on its packaging.

- This compound is toxic when inhaled and by passing through the skin.
- Handle with extreme caution.
- Contact can irritate and burn the skin and eyes, with possible eye damage.
- Inhaling can irritate the nose and throat.
- Ammonium dichromate(VI) is a strong oxidiser that enhances the combustion of other substances.

(i) Some of the symbols shown are used for ammonium dichromate(VI).

Identify the symbols for ammonium dichromate(VI) by placing a tick (✓) in the box under each relevant symbol.

(2)

(ii) Suggest why ammonium dichromate(VI) is **not** stored in the same cupboard as alkanes.

(1)

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.....

(Total for question = 14 marks)

Q3.

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.

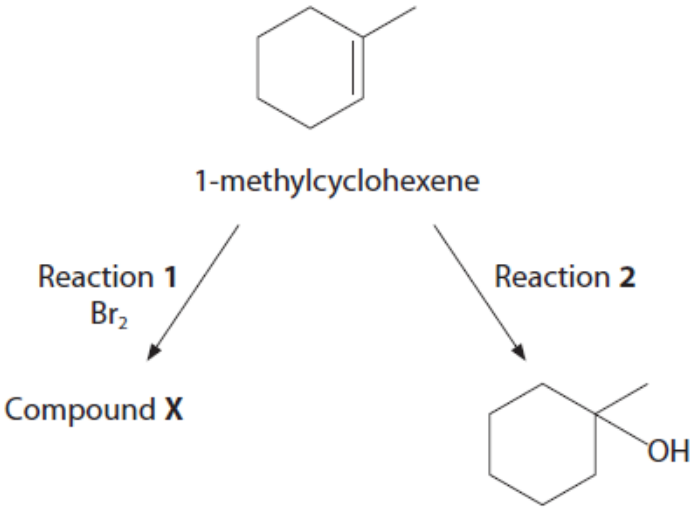
(1)

(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)

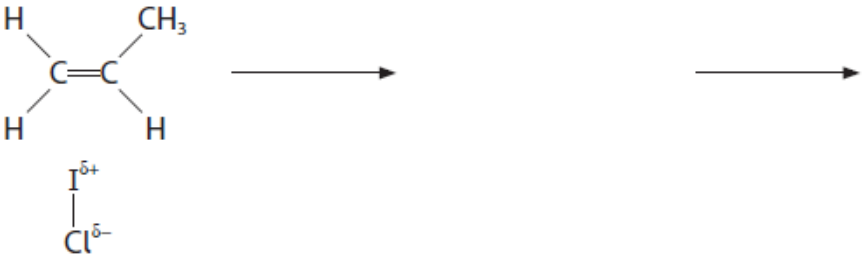
Reagent
.....

Condition
.....

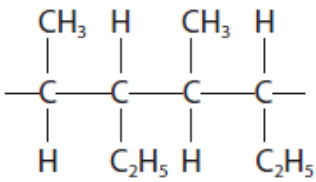
(d) Iodine monochloride, ICl, reacts with alkenes in a similar way to hydrogen bromide.

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)

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)

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(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)

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.....

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.....

(Total for question = 11 marks)

Q5.

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.

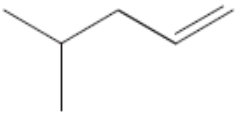
(7)

(Total for question = 15 marks)

Q6.

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 name of the product when this molecule reacts with chlorine gas?



☒ **A** 5,5-dichloro-2-methylpentane

☒ **B** 4,5-dichloro-2-methylpentane

☒ **C** 2,3-dichloro-4-methylpentane

☒ **D** 1,2-dichloro-4-methylpentane

(Total for question = 1 mark)

Q7.

An electrophile

☒ **A** accepts a pair of electrons

☒ **B** always has a negative charge

☒ **C** always has a positive charge

☒ **D** donates a pair of electrons

(Total for question = 1 mark)

Q8.

Members of the homologous series of alkanes have the same

☒ **A** boiling temperature

☒ **B** density

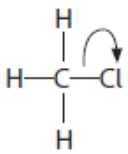
☒ **C** empirical formula

☒ **D** general formula

(Total for question = 1 mark)

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)

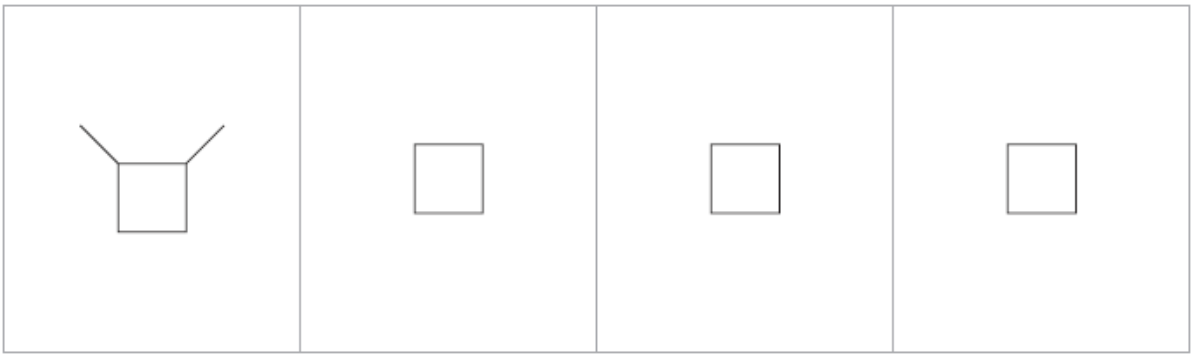
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(c) There are four structural isomers of C_6H_{12} with a ring of four carbon atoms.

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

.....

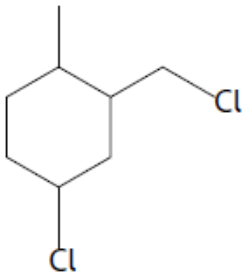
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(Total for question = 18 marks)

Q11.

What is the empirical formula of the following molecule?



(1)

☒ **A** C_4H_4Cl

☒ **B** C_4H_7Cl

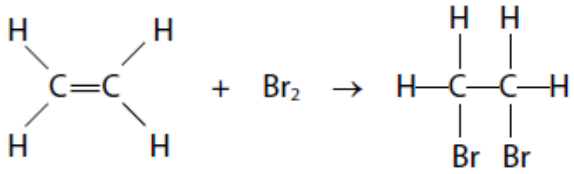
☒ **C** $C_8H_{11}Cl_2$

☒ **D** $C_8H_{14}Cl_2$

(Total for question = 1 mark)

Q12.

Ethene reacts with bromine to form 1,2-dibromoethane.



For the ethene molecule, what is the type of bond broken and the type of bond fission occurring in this reaction?

	Bond broken	Bond fission
☒ **A**	π	heterolytic
☒ **B**	π	homolytic
☒ **C**	σ	heterolytic
☒ **D**	σ	homolytic

(Total for question = 1 mark)

Q13.

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)

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.....

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

(2)

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.....

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(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)

.....

.....

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.....

(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)

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

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

(1)

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.....

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

(1)

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.....

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.....

(Total for question = 15 marks)

Q14.

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 substance is labelled with the hazard symbol shown.



What is the meaning of this symbol?

☒ **A** gloves must be worn

☒ **B** corrosive

☒ **C** do not store with flammable substances

☒ **D** oxidising

(Total for question = 1 mark)

Q15.

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 ☒.

Heterolytic fission produces

☒ **A** free radicals only

☒ **B** ions only

☒ **C** free radicals and positive ions only

☒ **D** free radicals and negative ions only

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(Total for question = 1 mark)

Q16.

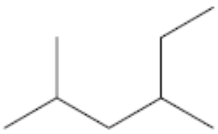
The alkanes are a homologous series of saturated hydrocarbons.

(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)

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.....

(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

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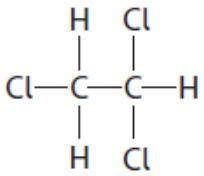
Name

.....

(Total for question = 16 marks)

Q17.

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)

Q18.

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**



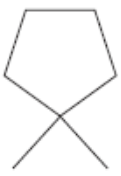
☐ **B**



☐ **C**



☐ **D**



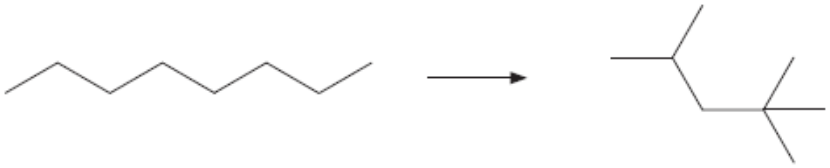
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(Total for question = 1 mark)

Q19.

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)

.....

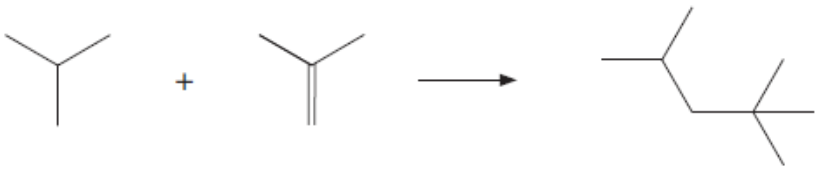
(iii) Give a reason why petrol needs a high proportion of iso-octane.

(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)

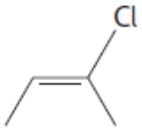
(iii) Deduce the molecular formula of compound **X**, using your answers to (d)(i) and (d)(ii).

(1)

(Total for question = 19 marks)

Q20.

What is the systematic name of compound **X**?



Compound **X**

☒ **A** *E*-2-chlorobut-2-ene

☒ **B** *Z*-2-chlorobut-2-ene

☒ **C** *E*-3-chlorobut-2-ene

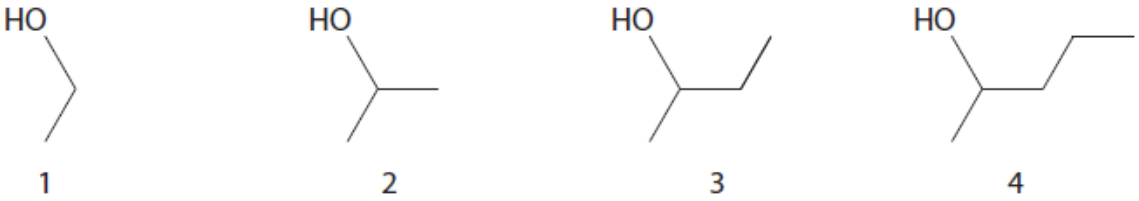
☒ **D** *Z*-3-chlorobut-2-ene

(Total for question = 1 mark)

Q21.

Answer the questions with a cross in the boxes you think are 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 sequence of four molecules is shown.



(a) What is the molecular formula for the fifth molecule in this sequence?

(1)

☒ **A** CH_4O

☒ **B** $C_6H_{11}O$

☒ **C** $C_6H_{14}O$

☒ **D** $C_7H_{16}O$

(b) What is the name of this type of sequence?

(1)

☒ **A** functional group

☒ **B** homologous series

☒ **C** homolytic series

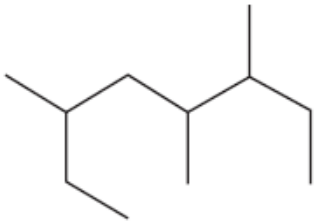
☒ **D** skeletal formulae

(Total for question = 2 marks)

Q22.

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 IUPAC name of this alkane?



☒ **A** 2-ethyl-4,5-dimethylheptane

☒ **B** 6-ethyl-3,4-dimethylheptane

☒ **C** 3,4,6-trimethyloctane

☒ **D** 3,5,6-trimethyloctane

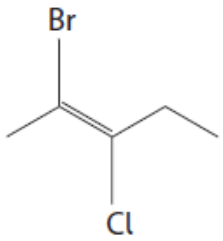
(Total for question = 1 mark)

Q23.

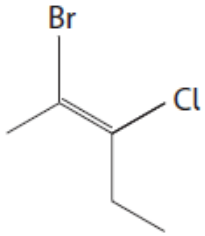
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which structure has the name *E*-2-bromo-3-chloropent-2-ene?

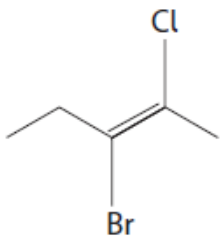
☒ **A**



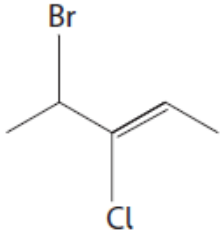
☒ **B**



☒ **C**



☒ **D**



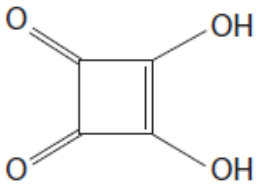
(Total for question = 1 mark)

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

Q24.

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 molecular formula of the compound shown?



☐ **A** C_2HO_2

☐ **B** $C_4H_2O_4$

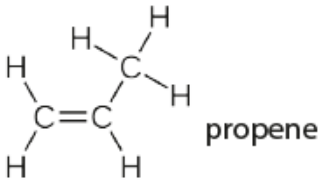
☐ **C** $C_4H_4O_4$

☐ **D** $C_4H_6O_4$

(Total for question = 1 mark)

Q25.

This question is about the reactions of propene.



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)

Br ——— Cl

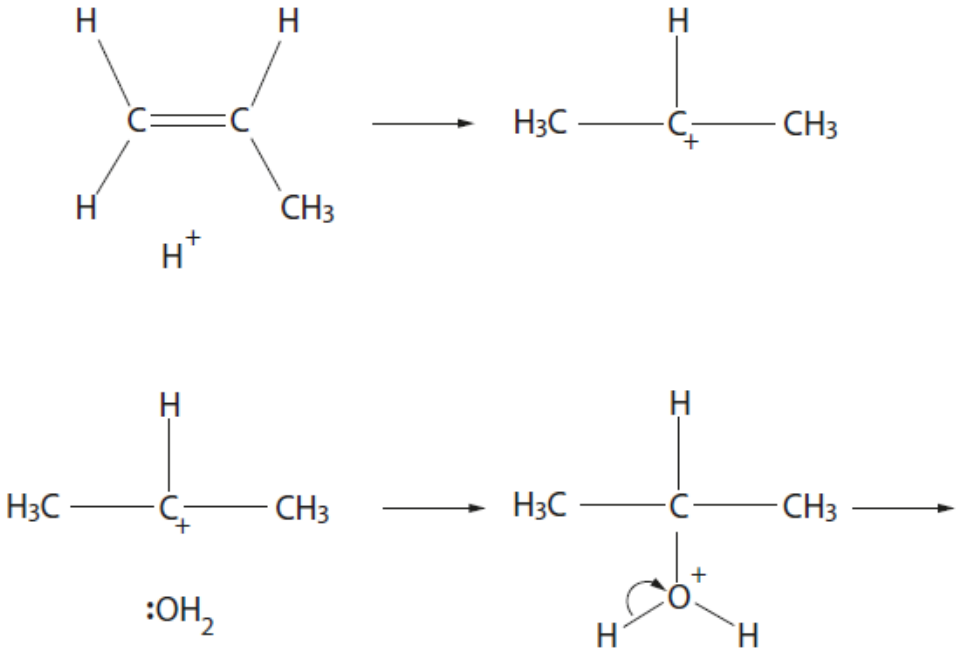
(ii) Draw the mechanism for the formation of 1-bromo-2-chloropropane in this reaction.
Include curly arrows, and relevant lone pairs.

(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)

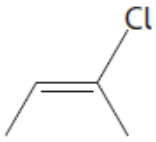
Q26.

Geometric isomerism is shown by 2-chlorobut-2-ene.

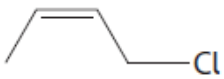
(a) What is the skeletal formula of *E*-2-chlorobut-2-ene?

(1)

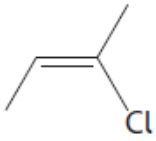
☒ **A**



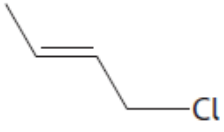
☒ **B**



☒ **C**



☒ **D**



(b) What is the **total** number of sigma bonds in *Z*-2-chlorobut-2-ene?

(1)

☒ **A** 3

☒ **B** 4

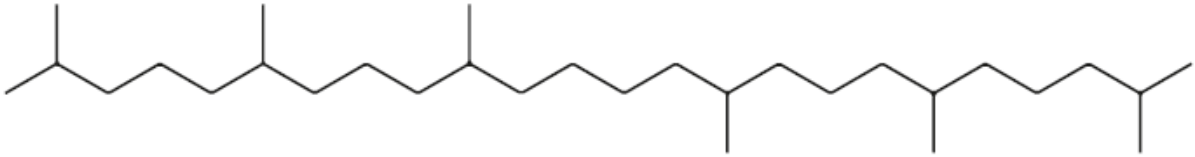
☒ **C** 10

☒ **D** 11

(Total for question = 2 marks)

Q27.

This question is about the production of squalane, a liquid alkane which occurs naturally in human skin and is used in cosmetics.



squalane

(a) Suggest **two** properties that make squalane useful in cosmetics.

(2)

.....

.....

(b) Give the **molecular** formula of squalane.

(1)

.....

(c) Squalane can be produced from squalene, an alkene present in shark liver oil, by reaction with hydrogen gas in the presence of a suitable catalyst.

(i) Give the name of a suitable catalyst for the hydrogenation of squalene.

(1)

.....

(ii) Squalane used in cosmetic products must contain no more than 0.2 ppm by mass of catalyst.

Calculate the maximum permitted mass of catalyst in a product containing 50 g of squalane.

(1)

(iii) A reactor at 200°C contains 8500 mol of liquid squalene, and hydrogen gas at a pressure of 4.0×10^5 Pa.

Under these conditions, the complete hydrogenation of squalene requires 500 m^3 of hydrogen gas.

Calculate the number of C=C bonds in one molecule of squalene.

You **must** show your working.

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

(4)

(iv) Write the equation, using molecular formulae, for the complete hydrogenation of squalene to squalane.
State symbols are **not** required.

(1)

(d) Globally, 2.8 million dm3 of squalene is used each year.
Traditionally squalene was obtained exclusively from shark liver oil, which is a mixture of liquids.

The liver of a shark yields 300 g of squalene.

(i) Suggest the name of a suitable technique to obtain squalene from shark liver oil.

(1)

.....

(ii) Calculate the minimum number of sharks that would be needed to produce 2.8 million dm^3 of squalene.

[Density of squalene = 0.86 g cm^{-3}]

(2)

(iii) Many large corporations now use squalane obtained entirely from plants.

Squalane can be obtained sustainably from corn starch with a yield of 23 % by mass.

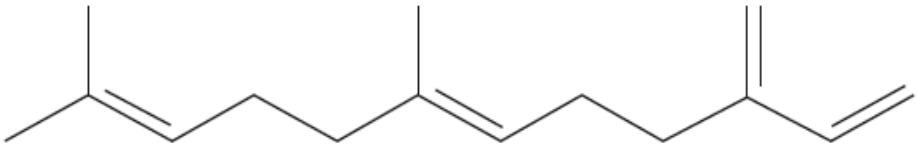
The production of 1 tonne of corn starch requires 0.093 hectares of land.

Calculate the area of land, **in km^2**, required to produce 2500 tonnes of squalane from corn starch.

[1 tonne = 1000kg 1 hectare = 0.01 km^2]

(3)

(e) The *E*-isomer of beta-farnesene can also be obtained from corn starch.



E-beta-farnesene

(i) Explain why beta-farnesene exhibits geometric isomerism and has only two geometric isomers.

You may label the structure and use this in your answer.

(2)

.....

.....

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.....

(ii) Draw the **skeletal** formula of the geometric isomer of *E*-beta-farnesene, giving a reason why this is named the
Z-isomer.

(2)

.....

.....

.....

.....

(f) The compound alpha-farnesene, $C_{15}H_{24}$, is a structural isomer of beta-farnesene.

The structural formula of alpha-farnesene is

$$(CH_3)_2C{=}CHCH_2CH_2C(CH_3){=}CHCH_2CH{=}C(CH_3)CH{=}CH_2$$

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

(2)

.....

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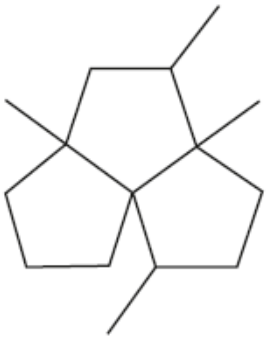
(ii) State the number of **geometric** isomers of alpha-farnesene.

(1)

.....

(iii) Complete the diagram to show another structural isomer of $C_{15}H_{24}$.

(1)



(Total for question = 24 marks)

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 ☒.

How many structural isomers have the formula $C_3H_6Cl_2$?

☒ **A** 2

☒ **B** 3

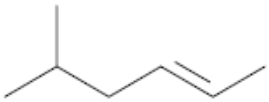
☒ **C** 4

☒ **D** 5

(Total for question = 1 mark)

Q29.

What is the systematic name for this compound?



(1)

☒ **A** *E*-5-methylhex-2-ene

☒ **B** *Z*-5-methylhex-2-ene

☒ **C** *E*-2-methylpent-4-ene

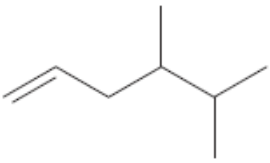
☒ **D** *Z*-2-methylpent-4-ene

(Total for question = 1 mark)

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 ☒.

What is the systematic name of this compound?



☒ **A** 1,1,2-trimethylpent-4-ene

☒ **B** 2,3-dimethylhex-5-ene

☒ **C** 4,5-dimethylhex-1-ene

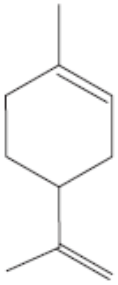
☒ **D** 4,5,5-trimethylpent-1-ene

(Total for question = 1 mark)

Q31.

Limonene is an oil extracted from the skin of citrus fruits such as oranges or lemons.
It is found in some cleaning products such as those used to remove chewing gum.

Limonene has the structure shown.



(a) Deduce the molecular formula of limonene.

(2)

.....

(b) (i) A few drops of acidified potassium manganate(VII) solution are mixed with a sample of limonene.

State the colour change.

(1)

From ..... to .....

(ii) Draw the skeletal formula of the structure of the **organic** product formed when the reaction in (b)(i) is carried out with **excess** acidified potassium manganate(VII).

(1)

(iii) Name the type of reaction that limonene undergoes in (b)(i).

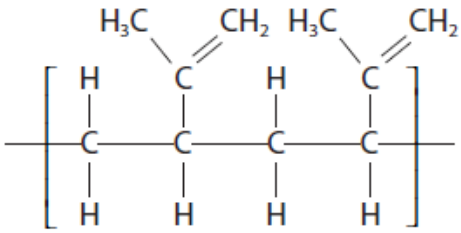
(1)

.....

(c) On heating, limonene reacts to form two molecules of a smaller hydrocarbon, **Q**.

Q can be polymerised to form **R**, a polymer used to improve the grip of car tyres.

A section of **R** is shown.



Section of polymer **R**

Draw the structure of **Q**.

(1)

(d) Give **two** ways in which chemists can help minimise problems caused by the disposal of polymers.

(2)

.....

.....

.....

.....

(e) Limonene is extracted from orange peel using a solvent.

Possible solvents are hexane and liquid carbon dioxide.

Liquid carbon dioxide can be obtained by allowing solid carbon dioxide to melt under high pressure.

(i) Suggest one advantage and one disadvantage of using liquid carbon dioxide rather than hexane to dissolve the limonene. Assume that the carbon dioxide does not escape into the atmosphere.

(2)

Advantage

.....

.....

Disadvantage

.....

.....

(ii) Orange peel contains 1.63 % of limonene by mass.

A chewing gum remover contains 30 cm^3 of limonene per bottle.

Calculate the mass of orange peel, in kg, needed to obtain 30 cm^3 of limonene.

[Density of limonene = 0.841 g cm^{-3}]

(3)

(Total for question = 13 marks)

Q32.

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 type of bond breaking occurs in this process?

$$H_2O \rightarrow H^+ + OH^-$$

☒ **A** electrophilic

☒ **B** heterolytic

☒ **C** homolytic

☒ **D** ionic

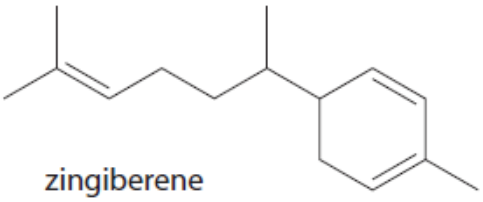
(Total for question = 1 mark)

Q33.

Zingiberene is the compound that gives ginger its characteristic flavour. Its IUPAC name is 2-methyl-5-(6-methylhept-5-en-2-yl)cyclohexa-1,3-diene.

(a) On the structure of zingiberene, draw a circle around the '2-methyl' group referred to in the IUPAC name.

(1)



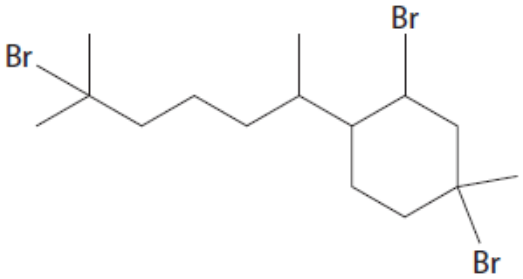
zingiberene

(b) Deduce the molecular formula of zingiberene.

(2)

.....

(c) When zingiberene reacts with excess hydrogen bromide, there are a number of possible products. The structure of the major product is shown.



(i) Name the type and mechanism of the reaction.

(1)

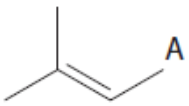
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(ii) The diagram shows a simplified structure of zingiberene, in which part of the molecule is represented by A.

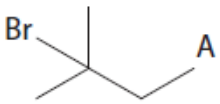
Complete the mechanism for the reaction of zingiberene with **one** molecule of hydrogen bromide.

Include curly arrows, and any relevant dipoles and lone pairs.

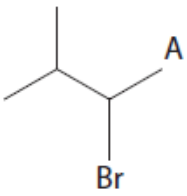
(4)



(iii) For the reaction in (c)(ii) there are two possible products:



I



II

Explain why I is the major product, by referring to your mechanism.

(2)

.....

.....

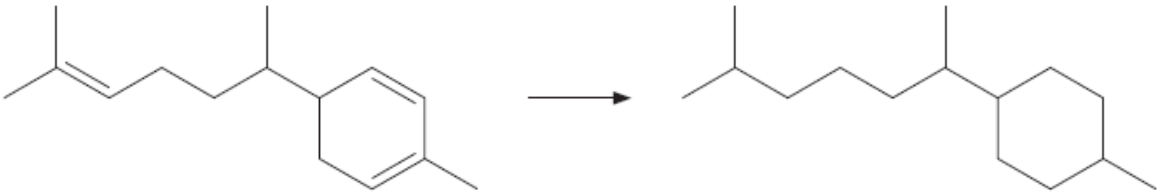
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.....

(d) Zingiberene reacts with hydrogen gas in the presence of a catalyst.



(i) Identify the catalyst, by name or formula.

(1)

.....

(ii) 2.0 mol of zingiberene react completely with hydrogen at 150 °C and a pressure of 120 kPa.

Calculate the minimum volume of hydrogen needed under these conditions, stating your units.

[Ideal gas equation is $pV = nRT$ Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

(Total for question = 15 marks)

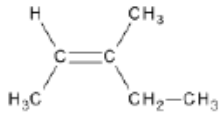
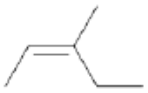
Mark Scheme

Q1.

Question number	Answer	Additional guidance	Mark
(a)	A description that makes reference to the following points:		(2)
	• (propane) yellow (solution) (1)	Allow brown or orange or any combination of yellow, orange and brown Allow no (colour) change / no change in bromine water / remains yellow / turns yellow Allow upper layer / both layers are yellow / orange / brown etc Ignore just 'no reaction' Do not award any mention of red Do not award lower layer is yellow / orange / brown etc	
	• (propene) colourless (solution) (1)	Allow decolorises / colour disappears Allow (both) layers are colourless Ignore initial colour of red in M2 only Do not award remains colourless	

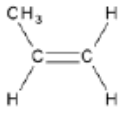
Question number	Answer	Additional guidance	Mark
(b)(i)	• steam / $H_2O(g)$ **and** acid (catalyst) / phosphoric acid / H_3PO_4	In (b)(i) and (ii) allow names or formulae for reagents but if both are given, both must be correct Allow water / H_2O **and** heat for steam Do not award steam **and** room temperature Allow name or formula of any strong acid (catalyst) / H^+ Ignore concentration of acid / pressure	**(1)**

Question number	Answer	Additional guidance	Mark
(b)(ii)	• potassium manganate((VII)) (solution)/ $KMnO_4$ **and** sulfuric acid / H_2SO_4 / acid(ified) / H^+ / sodium hydroxide / NaOH / potassium hydroxide / KOH / alkali(ne) / OH^-	Allow potassium permanganate Do not award K_2MnO_4 Ignore heat / concentration of acid or alkali Allow (1) in (ii) if reagents **and** conditions for (i) and (ii) are interchanged If no other mark is awarded: Allow (1) in (ii) if reagents for both (i) and (ii) are correct but conditions are omitted / incorrect	**(1)**

Question number	Answer	Additional guidance	Mark
(c)	• structure of *Z*-3-methylpent-2-ene	Examples of structure:  or  Allow C_2H_5 / displayed formula Ignore connectivity of methyl and ethyl groups Ignore bond lengths and bond angles on skeletal formula	**(1)**

Question number	Answer	Additional guidance	Mark
(d)	• calculation of number of moles of hydrogen **or** calculation of volume of alkene (1) • deduction of number of double bonds (1)	Example of calculation: $\frac{720}{24000} = 0.030$ or $\frac{0.72}{24} = 0.030$ **or** volume of alkene = 0.01 x 24000 = 240 (cm^3) mole ratio alkene : hydrogen = (0.01 : 0.03 or 720/240) = 1 : 3 so there are 3 double bonds TE on mol hydrogen Correct answer with no working scores (1)	**(2)**

Question number	Answer	Additional guidance	Mark
(e)	• the dipole on the bromine (molecule) should be the other way around (1) • the arrow should go from the double / pi / π bond to the bromine / (pair of) electrons move from the double bond to the bromine **or** the curly arrow should go from C=C to $Br^{\delta+}$ (1) • the Br ion should have a negative charge (1)	Allow the changes in any order and they may be shown on the diagram Ignore references to lone pairs Allow the top bromine should be δ+ / the bottom bromine should be δ− Allow the bromine (atom) should have a negative charge Ignore just 'Br is not positive' Do not award the bromine molecule should have a negative charge Do not award $Br^{\delta-}$	(3)

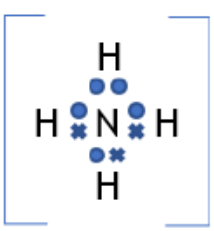
Question number	Answer	Additional guidance	Mark
(f)	• structure of propene	Example of structure:  Allow any unambiguous structure of propene showing the double bond e.g. $CH_3CH{=}CH_2$ Ignore name, even if incorrect Ignore n / brackets Ignore connectivity of CH_3 group	(1)

Q2.

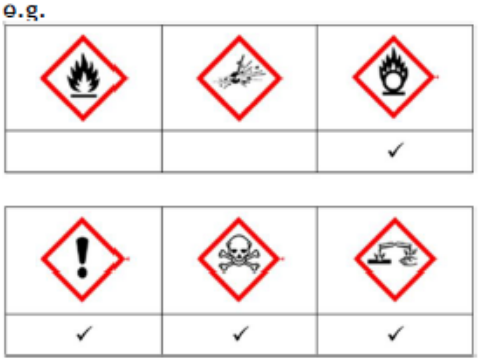
Question Number	Answer	Additional guidance	Mark
(a)(i)	• $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$	1 mark for Cr_2O_3 1 mark for all the rest being correct Allow multiples Marks are standalone	(2)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• (thermal) decomposition **or** redox	Ignore oxidation or reduction on their own	(1)

Question Number	Answer	Additional guidance	Mark
(b)	• conversion of units for *P* and *V* (1) • substitution in equation and rearrange (1) • answer in K (1) • convert to °C (1)	Example of calculation: $P = 101000 / 1.01 \times 10^5$ Pa $V = 0.0000252 / 2.52 \times 10^{-5}$ m^3 Allow incorrect use standard form e.g. 10.1×10^4 Pa $T = \frac{101000 \times 0.0000252}{0.001 \times 8.31}$ T = 306.28 (K) T = 33.3(°C) (33.1°C if 273.15 is used for conversion of kelvin to Celsius) Ignore SF except 1 SF on final answer TE throughout but only award for MP4 if final answer in °C is between 0 and 50°C Units if given must be correct *Comment:* *Correct answer with no working scores 4* *306.28(K) scores 3* *30.85 °C scores 3* *33.7 °C scores 3 as they have used R as 8.3* *33.55 °C scores 3 using 8.3 and 273.15* *306.7K scores 2 as they have used R as 8.3*	(4)

Question Number	Answer	Additional guidance	Mark
(c)(i)	A drawing that shows: • four pairs of electrons and 4 hydrogen atoms around nitrogen (1) • one dative covalent bond **and** plus sign (1)	 Allow answers without brackets Allow use of any symbol for the electrons as long as it is clear which is the dative covalent bond (e.g. by use of an arrow) Ignore placement of positive sign	(2)

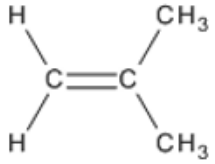
Question Number	Answer	Additional guidance	Mark
(c)(ii)	An explanation that makes reference to: • tetrahedral / tetrahedron (1) • (four) **pairs of electrons** arranged in position of minimum repulsion / maximum separation (1)	MP1 may be scored with a 3D diagram or an answer given in 19(c)(i) Allow phonetic spelling Allow equal repulsion of electron-pairs Allow reference to bonding pairs Ignore reference to bonds Ignore all bond angles Do not award references to lone pairs Marks are standalone	(2)

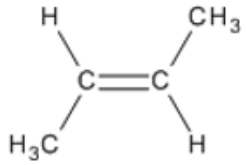
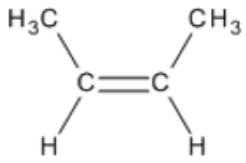
Question Number	Answer	Additional guidance	Mark
(d)(i)	Four correct ticks scores 2 marks, Three correct ticks scores 1 mark Four correct ticks and one incorrect tick scores 1 mark	e.g.  	(2)

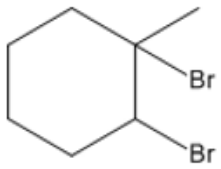
Question Number	Answer	Additional guidance	Mark
(d)(ii)	An answer containing an appropriate suggestion: • dichromate/oxidising agents promote(s) combustion/burning of alkanes/fuels OR alkanes are flammable/combustible **and** dichromate is an oxidising agent	Allow fuels/alkanes would catch fire more easily Ignore dichromate causes alkanes to burn Do not award dichromate catches fire	(1)

Q3.

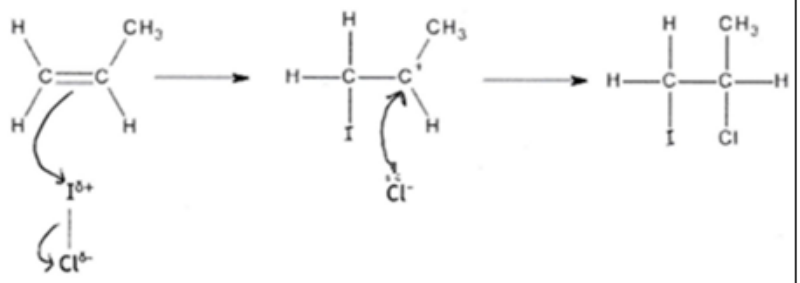
Q	Answer	Additional guidance	Mark
(a)	• (alkene is) C_8H_{16}	Allow $H_{16}C_8$ Allow large numbers e.g. C8H16 Do not award C^8H^{16}	1

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**

Q	Answer	Additional guidance	Mark
(d)	• 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)**	Example of mechanism:  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**

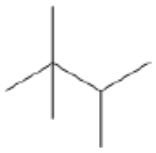
Q	Answer	Additional guidance	Mark
(e)	• pent-2-ene	Allow 2-pentene Ignore *E* / *Z* / *cis* / *trans* Do not award just 'pentene'	**1**

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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)

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)

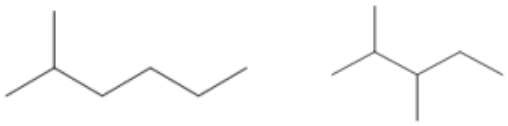
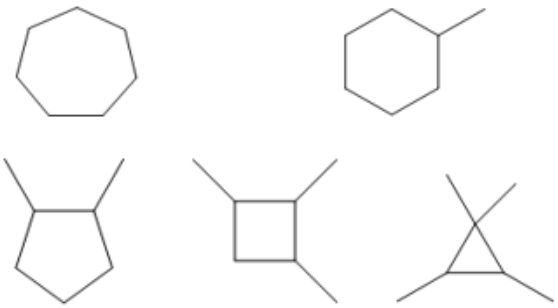
Question number	Answer	Additional guidance	Mark
(b)(iii)	• $C_7H_{15}\bullet + C_7H_{15}\bullet \rightarrow C_{14}H_{30}$	TE on alkyl radical in (b)(ii) Do not award product written as $2C_7H_{15}$ / $C_7H_{15}C_7H_{15}$	(1)

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.

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)			

Q6.

Question Number	Answer	Mark
	The only correct answer is D (1,2-dichloro-4-methylpentane) **A** *is not correct because the chlorine atoms are added to each end of the double bond* **B** *is not correct because the chlorine is numbered lower than the methyl group* **C** *is not correct because the chlorine atoms are added to each end of the double bond*	**(1)**

Q7.

Question number	Answer	Mark
	The only correct answer is A (accepts a pair of electrons) ***B*** *is incorrect because electrophiles never have a negative charge* ***C*** *is incorrect because not all electrophiles have a positive charge* ***D*** *is incorrect because nucleophiles donate a pair of electrons*	**(1)**

Q8.

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)**

Q9.

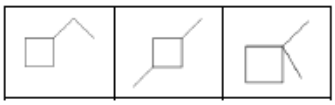
Question number	Answer	Mark
	The only correct answer is D (a pair of electrons from a bond to an atom, forming ions) **A** *is incorrect because movement of an electron is represented by a curly arrow with a half arrow-head and ions are formed when a pair of electrons moves* ***B*** *is incorrect because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

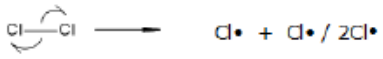
Question Number	Answer	Additional guidance	Mark
(b)(ii)	• C_7H_{14}	Allow $H_{14}C_7$ / C7H14 / H14C7 Ignore any other symbols as working e.g. $CH_2CHCH_3CH_2CH_2CHCH_3$ Do not award superscripts e.g. C^7H^{14}	(1)

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)

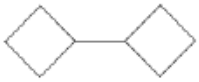
Question number	Answer	Additional guidance	Mark
(d)	• (**E** is) C_9H_{18}	Allow $H_{18}C_9$ Allow large numbers Ignore working Do not award superscripts	(1)

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• / 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 $2C_4H_7$• → C_8H_{14} Allow cyclobutane / hydrocarbon radicals join together Ignore just '(two) radicals join together'	(2)

Q11.

Question number	Answer	Mark
	B (C_4H_7Cl)	1

Q12.

Question number	Answer	Mark
	A π, heterolytic	1

Q13.

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)**

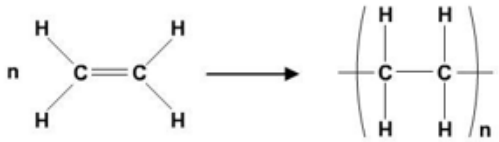
Question Number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • fossil fuels release carbon dioxide (that has been locked up for millions of years) / carbon dioxide is a greenhouse gas **(1)** • increases the greenhouse effect / leads to global warming / 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)

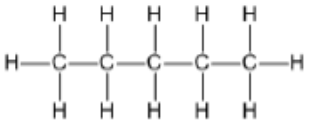
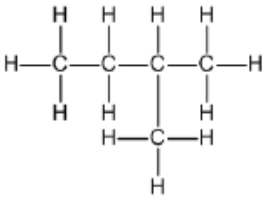
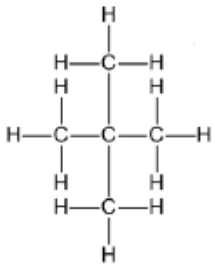
Q14.

Question number	Answer	Mark
	The only correct answer is B (corrosive) ***A*** *is incorrect because this is a precaution and not a hazard* ***C*** *is incorrect because this is a precaution and not a hazard* ***D*** *is incorrect because this is not the symbol for oxidising*	1

Q15.

Question number	Answer	Mark
	The only correct answer is B (ions only) ***A*** *is not correct because heterolytic fission only produces ions* ***C*** *is not correct because heterolytic fission only produces ions* ***D*** *is not correct because heterolytic fission only produces ions*	**1**

Q16.

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

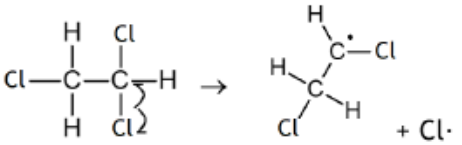
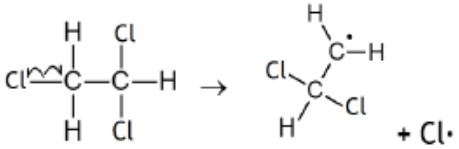
Question number	Answer	Additional guidance	Mark
(e)(iv)	• two propyl (free) radicals react together or • $C_3H_7\bullet + C_3H_7\bullet \rightarrow C_6H_{14}$	Ignore just '(two free) radicals react together' Do not allow molecules/ions	1

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

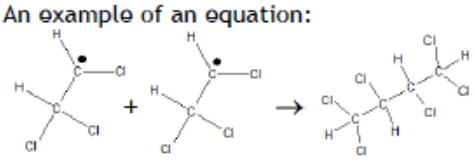
Q17.

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)

Q18.

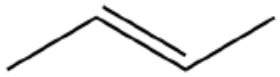
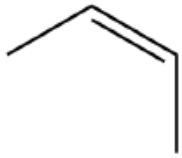
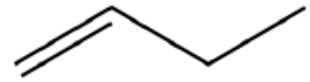
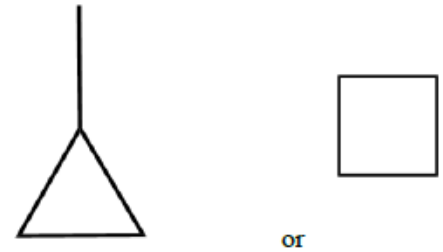
Question number	Answer	Mark
	The only correct answer is D  ***A** is not correct because this compound has a molar mass of 100 g mol^{-1}* ***B** is not correct because this compound has a molar mass of 114 g mol^{-1}* ***C** is not correct because this compound would decolourise bromine water*	1

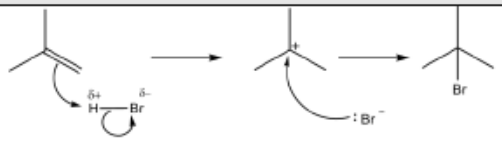
Q19.

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

Q20.

Question number	Answer	Mark
	The only correct answer is A (*E*-2-chlorobut-2-ene) **B** *is incorrect because the two highest priority groups are opposite to each other* **C** *is incorrect because chlorine is on the second carbon atom* **D** *is incorrect because chlorine is on the second carbon atom and the two highest priority groups are opposite to each other*	(1)

Q21.

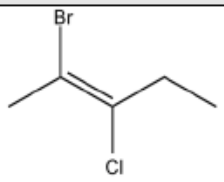
Question number	Answer	Mark
(a)	**The only correct answer is C** ($C_6H_{14}O$) *A* *is incorrect because this precedes the first molecule in the sequence* *B* *is incorrect because this is not in this sequence* *D* *is incorrect because this is the sixth molecule in the sequence*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is B** (homologous series) *A* *is incorrect because this structure is within each of the molecules* *C* *is incorrect because homolytic is a type of bond breaking* *D* *is incorrect because this is the type of structure shown*	(1)

Q22.

Question number	Answer	Mark
	The only correct answer is C (3,4,6-trimethyloctane) ***A*** *is incorrect because the longest chain of carbon atoms is not seven* ***B*** *is incorrect because the longest chain of carbon atoms is not seven* ***D*** *is incorrect because the sum of the locant numbers is not the lowest*	1

Q23.

Question Number	Correct Answer	Mark
	The only correct answer is A  *B is incorrect because it is Z-2-bromo-3-chloropent-2-ene* *C is incorrect because it is E-3-bromo-2-chloropent-2-ene* *D is incorrect because it is E-4-bromo-3-chloropent-2-ene*	**1**

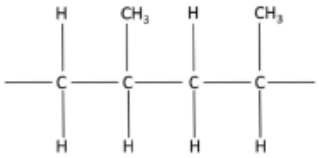
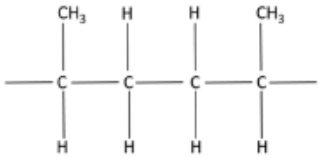
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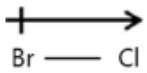
Question number	Answer	Mark
	The only correct answer is B ($C_4H_2O_4$) *A is incorrect because this is the empirical formula* *C is incorrect because there are two extra hydrogens in the formula* *D is incorrect because there are four extra hydrogens in the formula*	**(1)**

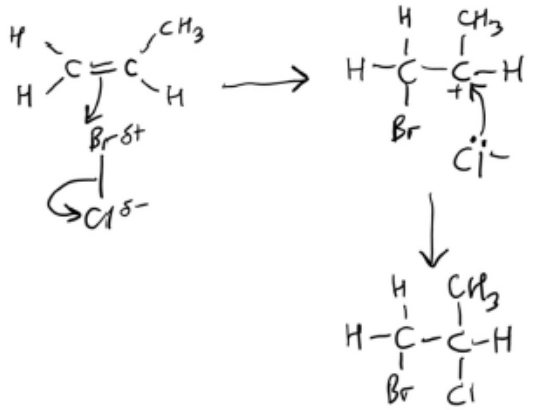
Q25.

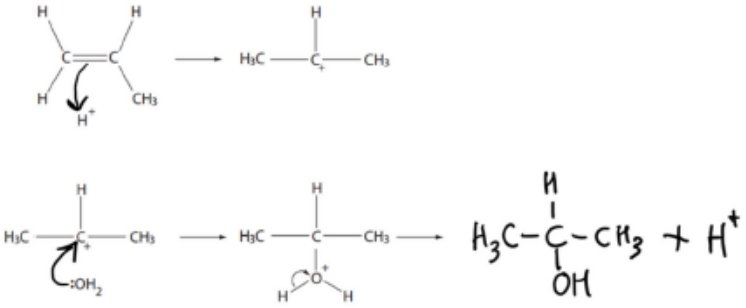
Question Number	Answer	Additional guidance	Mark
(a)	• balanced equation with **1 mol** C_3H_6 and correct products (1) • state symbols (1)	Example of equation: $C_3H_6(g) + 3O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + 3H_2O(l)$ Allow structural, displayed or skeletal formulae Allow $H_2O(g)$ Do not award $H_2O(aq)$ 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**

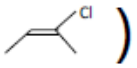
Question Number	Answer	Additional guidance	Mark
(c)	• poly(propene) structure containing two repeat units with extension bonds	Example of diagram:  Accept CH_3 groups on same or opposite sides Allow head-to-head and tail-to-tail configurations eg  Allow displayed, structural, skeletal formulae or any 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

Q26.

Question Number	Answer	Mark
(a)	**The only correct answer is A**  ***B*** *is incorrect because it is Z-1-chlorobut-2-ene* ***C*** *is incorrect because it is Z-2-chlorobut-2-ene* ***D*** *is incorrect because it is E-1-chlorobut-2-ene*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is D** (11) ***A*** *is incorrect because the C-H bonds and the sigma C-C have not been counted* ***B*** *is incorrect because some of the C-H bonds have not been counted* ***C*** *is incorrect because the C-C bond on the alkene bond has not been counted*	(1)

Q27.

Question Number	Answer	Additional guidance	Mark
(a)	Any **two** from the following: • chemically stable / inert / does not (easily) oxidise (1) • colourless (1) • odourless (1) • non-toxic / non-irritant (1) • hydrophobic / immiscible with water (1) • hypoallergenic (1)	Ignore any reference to: carbon chain length intermolecular forces melting/boiling temperature flammability/volatility liquid/moisturising/softening/lubricating/hydrating spreads easily/absorbed easily natural/in human skin cheap Allow unreactive / not very reactive / long shelf life / durable / does not breakdown (easily) Ignore just stable Ignore transparent/clear Allow not harmful / non-hazardous / non-corrosive Ignore safe Allow insoluble Ignore oily	2

Question Number	Answer	Additional guidance	Mark
(b)	• $C_{30}H_{62}$	Accept $H_{62}C_{30}$	1

Question Number	Answer	Additional guidance	Mark
(c)(i)	• nickel	Accept palladium or platinum Allow correct symbol	1

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• 0.00001 / (1 ×) 10^{-5} (g)	Example of calculation: mass = $\frac{50}{10^6} \times 0.2 = 0.00001$ (g) Do not award incorrect unit Accept 10 μg / 0.01 mg Allow answer as fraction eg $\frac{1}{10^5}$ (g) Ignore SF Correct answer with no working scores (1)	1

Question Number	Answer	Additional guidance	Mark
(c)(iii)	• conversion of temperature to K (1) • rearrangement of ideal gas equation (1) • evaluation to give moles of hydrogen (1) • evaluation of mole ratio **and** number of C=C bonds per molecule of squalene (1)	Example of calculation: T = 200 + 273 (= 473 K) $n = \frac{pV}{RT}$ or $n = \frac{4.0 \times 10^5 \times 500}{8.31 \times 473}$ $n(H_2)$ = 50882.429 Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $n(H_2)$: n(squalene) 50882 : 8500 6 : 1 6 (× C=C bonds per molecule) TE on $n(H_2)$ provided $n(H_2)$ > than 8500 and answer is rounded to nearest integer 6 (× C=C bonds per molecule) with no working scores (1) 2 (× C=C bonds per molecule) from use of 24 dm^3 mol^{-1} as molar gas volume scores (2)	4

(c)(iii) cont	**Alternative route to M2, M3 and M4** • rearrangement of ideal gas equation (1) • evaluation to give volume of squalene (1) • evaluation of volume ratio **and** number of C=C bonds per molecule of squalene (1)	<u>Example of calculation:</u> $V = \frac{nRT}{p}$ or $V = \frac{8500 \times 8.31 \times 473}{4.0 \times 10^5}$ V(squalene) = 83.52589 (m^3) Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $V(H_2)$: V(squalene) 500 : 83.52589 6 : 1 6 (× C=C bonds per molecule) TE on V(squalene) provided V(squalene) < 500 (m^3) and answer is rounded to nearest integer	

Question Number	Answer	Additional guidance	Mark
(c)(iv)	• $C_{30}H_{50} + 6H_2 \rightarrow C_{30}H_{62}$	Ignore state symbols TE on (c)(iii) for any C_nH_{2n+2} product formula where $24 \leq n \leq 30$ If the number of C=C bonds is not stated in (c)(iii) then award (1) for an equation of the form: $C_nH_{2n-2y+2} + yH_2 \rightarrow C_nH_{2n+2}$ Where $24 \leq n \leq 30$ and $1 \leq y \leq 14$	**1**

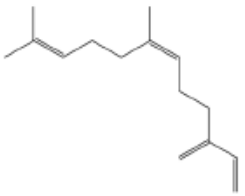
Question Number	Answer	Additional guidance	Mark
(d)(i)	• (fractional) distillation	Ignore solvent extraction Ignore filtration as part of the separation process Do not award just filtration Do not award chromatography	**1**

Question Number	Answer	Additional guidance	Mark
(d)(ii)	• calculation of mass of squalene in 2.8 million dm^3 **or** calculation of volume of squalene per shark (1)	Example of calculation: mass = $2.8 \times 10^9 \times 0.86 = 2.408 \times 10^9$ (g) **or** volume = $\frac{300}{0.86} = 348.8372$ (cm^3)	2
	• calculation of number of sharks required (1)	$\frac{2.408 \times 10^9}{300} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on mass **or** $\frac{2.8 \times 10^9}{348.8372} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on volume Ignore SF Penalise incorrect rounding once only Correct answer with no working scores (2)	

Question Number	Answer	Additional guidance	Mark
(d)(iii)	**Method 1** • calculation of mass of corn starch required (1) • calculation of required land area in hectares (1) • conversion of land area from hectares to km^2 (1) **Method 2** • conversion of land area from hectares to km^2 (1) • calculation of required land area in km^2 to produce 2500 tonnes of corn starch (1) • calculation of required land area in km^2 to produce 2500 tonnes of squalene (1)	Ignore SF and do not penalise correct premature rounding Penalise incorrect rounding once only Penalise incorrect units in final answer only mass = $\frac{2500}{23} \times 100 = 10869.57$ (tonnes) Allow conversion of mass of corn starch to kg / g land area = $10869.57 \times 0.093 = 1010.87$ (hectares) land area = $1010.87 \times 0.01 = 10.1087 = 10$ (km^2) $0.093 \times 0.01 = 0.00093 / 9.3 \times 10^{-4}$ (km^2) land area = $0.00093 \times 2500 = 2.325$ km^2 Allow conversion of mass of corn starch to kg / g land area = $\frac{2.325}{23} \times 100 = 10.1087 = 10$ (km^2)	3

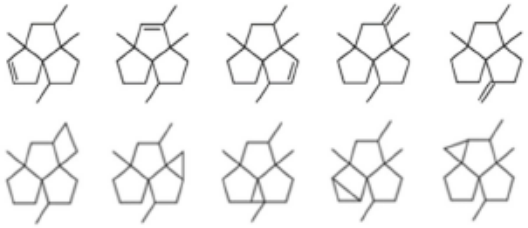
(d)(iii) cont	**Method 3** • calculation of required land area in hectares to produce 2500 tonnes of corn starch (1) • calculation of required land area in hectares to produce 2500 tonnes of squalene (1) • conversion of land area from hectares to km^2 (1)	land area = $2500 \times 0.093 = 232.5$ (hectares) Allow conversion of mass of corn starch to kg / g land area = $\frac{232.5}{23} \times 100 = 1010.87$ (hectares) land area = $1010.87 \times 0.01 = 10.1087 = 10$ (km^2) If no other mark awarded, 1 tonne corn starch yields 230 kg squalane scores (1)	

Question Number	Answer	Additional guidance	Mark
(e)(i)	An explanation that makes reference to the following points: • restricted rotation about/around C=C (1) • (only) central C=C has two different groups attached to each carbon of the C=C (1)	**Mark M1 and M2 independently** Accept pi-bond for C=C Allow just double bond for C=C Allow limited/no rotation about/around C=C Allow C=C restricts rotation Allow C=C cannot rotate Ignore just restricted rotation Do not award molecule cannot rotate Accept C=C from 6th carbon/6-ene for central C=C Allow (only) central C=C has four different groups Allow indication of central C=C on diagram Do not award if any other C=C bond identified as *E*/*Z*	2

Question Number	Answer	Additional guidance	Mark
(e)(ii)	• skeletal formula of *Z*-isomer (1) • (*Z* isomer has highest) priority groups on same side (of C=C) (1)	**Mark M1 and M2 independently** Examples of correct structure:  or  Ignore bond lengths and bond angles Ignore labelling of C=C bonds as *E*/*Z* Ignore any other type of formula Allow lowest priority groups on same side Allow identification of (highest) priority groups on diagram Allow ranking for priority Ignore preference for priority Ignore reference to mass/size of groups Allow top/bottom for same Ignore any reference to cis/trans	2

Question Number	Answer	Additional guidance	Mark
(f)(i)	• (compounds with the) same molecular formula (1) • different structural formula (1)	**Mark M1 and M2 independently** Ignore just same formula Ignore compounds with the same atoms Do not award same molecule Do not award same general formula Allow just different structure Allow different position of the C=C/double bonds Allow different displayed/skeletal formulae Ignore different arrangement of atoms (in space)	2

Question Number	Answer	Additional guidance	Mark
(f)(ii)	• four / 4	Ignore *E*/*Z*	1

Question Number	Answer	Additional guidance	Mark
(f)(iii)	• valid structure containing **one** C=C bond or • valid structure containing **one** bridging carbon-carbon bond	Examples of valid structure:  Ignore bond lengths and bond angles	1

Q28.

Question Number	Answer	Mark
	The only correct answer is C (4) **A** *is not correct because there are 4 isomers* **B** *is not correct because there are 4 isomers* **D** *is not correct because there are 4 isomers*	(1)

Q29.

Question number	Answer	Mark
	A E-5-methylhex-2-ene	1

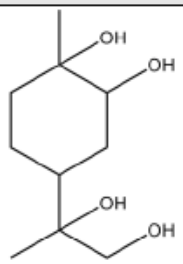
Q30.

Q	Answer	Mark
	The only correct answer is C (4,5-dimethylhex-1-ene) ***A*** *is incorrect because the longest chain has 6 carbon atoms* ***B*** *is incorrect because the double bond starts at the first carbon atom* ***D*** *is incorrect because the longest chain has 6 carbon atoms*	**1**

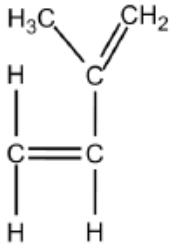
Q31.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • C_{10} **(1)** • H_{16} **(1)**	Allow in either order Allow numerical values not shown as subscripts e.g. C10H16 scores both marks	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following points: • from purple to colourless	Do not award other colours Allow (pale) pink to colourless Ignore references to clear Ignore adjectives before purple e.g. deep purple	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)		Allow displayed formula Ignore connectivity of OH group unless bond shown horizontally, and H connected directly to bond Ignore orientation of OH group	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• oxidation	Allow electrophilic addition	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)		Allow skeletal, structural or displayed or any combination Ignore 'n' before or after structure Ignore connectivity of CH_3 and CH_2 groups	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	An answer that makes reference to any **two** of the following points: • (help develop) biodegradable polymers / polymers from plant material / (polymers that can be) re-used / (polymers that can be easily) recycled (1) • remove (toxic) gases produced by incineration (of polymers) (1) • (develop processes to) convert polymers back into feedstock (for use in chemical industry) (1) • use of IR (spectroscopy) to separate polymers (for recycling) (1)	Allow the term 'plastic' for polymers Ignore biopolymers Ignore reduce use of polymers Allow monomers / smaller molecules / more reactive molecules / more useful molecules for 'feedstock'	2

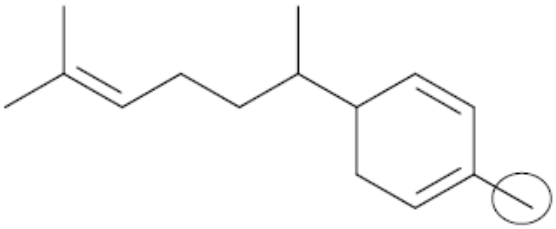
	Acceptable Answers	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following points: advantage of liquid CO_2 • non-flammable / non-toxic / readily available / CO_2 can be reused **(1)** disadvantage of liquid CO_2 • energy needed to generate (high) pressure / (high) pressure is expensive / risk of explosion under pressure / **(1)**	Allow reverse arguments for hexane Allow can be separated (from limonene) easily Allow hexane is non-renewable / finite Ignore 'removes CO_2 from atmosphere' Allow energy needed to maintain pressure Allow strength of vessel needed to withstand (high) pressure Ignore references to temperature Ignore just 'expensive' Do not award greenhouse gas / global warming	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• calculation of mass of limonene required in 30 cm^3 of cleaning product **(1)** • calculation of mass of orange peel needed to produce 1 g of limonene **(1)** • calculation of mass of orange peel needed to produce enough limonene to make 30 cm^3 of cleaning product, in kg **(1)**	<u>Example of calculation</u> $0.841 \times 30 = 25.23$ (g) Ignore units in M1 1 g limonene needs $(100 \div 1.63)$ g of peel = 61.3497 (g) $(100 \div 1.63) \times 25.23 = 1547.9$ (g) = 1.55 (kg) Allow final answer in grams if units quoted Allow TE throughout M2 could be subsumed in M3 Ignore SF except 1 SF Correct answer with no working scores 3 NOTE : if ratio in M2 is inverted mass = 4.11×10^{-4} (kg) and scores M1 and M3	**3**

Q32.

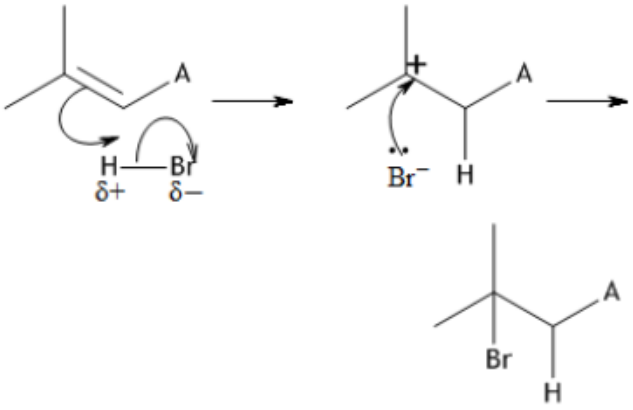
Question Number	Answer	Mark
	The only correct answer is B (heterolytic) **A** *is not correct because this is not a type of bond breaking* **C** *is not correct because this would form radicals* **D** *is not correct because the bond is covalent*	**(1)**

Q33.

Question number	Answer	Additional guidance	Mark
(a)	An answer that shows the following: • any indication of the methyl group on the right-hand side of the structure being selected	Example of diagram:  Allow inclusion of the "2" carbon within the circle Do not award more than one group circled or selected	**1**

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following: • C_{15} (1) • H_{24} (1)	Allow $H_{24}C_{15}$ / C15H24 No TE on incorrect number of carbon atoms	**2**

Question number	Answer	Additional guidance	Mark
(c)(i)	An answer that makes reference to the following: • electrophilic addition	Ignore 'heterolytic' Do not award 'free radical' Do not award substitution	**1**

Question number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to the following: • curly arrow from H—Br bond to Br atom or just beyond **and** dipole on H–Br (1) • curly arrow from C=C to H or close by (1) • structure of tertiary carbocation intermediate (1) • curly arrow from **lone pair** on Br^- to positively charged carbon atom (1)	Example of mechanism shown below  Addition of Br–Br loses M1 only Allow secondary carbocation (should be based on structure from paper) Do not award $Br^{\delta-}$ Do not penalise an incorrect product Allow structural formulae etc. Ignore omission of added hydrogen Ignore omission of A or substitution of A at any stage Ignore connectivity of CH_3 groups Ignore other lone pairs	4

Question number	Answer	Additional guidance	Mark
(c)(iii)	An explanation that makes reference to the following points: • I is formed via a tertiary carbocation **and** II is formed via a secondary carbocation (1) • tertiary (carbocations) are more stable (than secondary) (1)	Assume "it" is I Must have carbocation at least once for M1 "It is a tertiary carbocation" does not score M1 Allow secondary are more stable than primary for M2 Allow tertiary is the most stable Allow reverse argument Marks are independent Ignore "tertiary cations have more alkyl groups' Allow "I is formed via a more stable intermediate" for M2 only	2

Question number	Answer	Additional guidance	Mark
(d)(i)	An answer that makes reference to the following: • nickel / Ni	Accept platinum / Pt / palladium / Pd	1

Question number	Answer	Additional guidance	Mark
(d)(ii)	• rearrangement of ideal gas equation to make volume the subject (1) • changing kPa to Pa **and** °C to K (1) • substitution of values into IGE (including 2 x 3 mol of H_2) (1) • calculation of volume of hydrogen with units (1)	Example of calculation $V = n \times R \times T \div p$ $p = 120 \times 1000 = 1.2 \times 10^5$ (Pa) **and** $T = 150 + 273 = 423$ (K) $V = 6 \times 8.31 \times 423 \div 1.2 \times 10^5 =$ $= 0.17576$ m^3 Accept 175.76 dm^3 / 175760 cm^3 TE at each stage Ignore SF except 1 SF Correct answer **and** units with some working scores (4) Penalise incorrect rounding once only	**4**