Questions

Q1.

This is a question about alkanes.

Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation.

(2)

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(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

(1)

C_8H_{18} → ..... + ...

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

(1)

(Total for question = 4 marks)

Q2.

This question is about alkanes and their reactions.

A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.

$$C_3H_8(g) + Br_2(l) \rightarrow C_3H_7Br(l) + HBr(g)$$

(i) The first step of the reaction involves

(1)

- ☒ **A** heterolytic bond fission to form free radicals
- ☒ **B** heterolytic bond fission to form ions
- ☒ **C** homolytic bond fission to form free radicals
- ☒ **D** homolytic bond fission to form ions

(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (i).

(2)

(iii) A source from the internet gave the percentage yield for this reaction as 31.0%.

The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

- ☒ **A** bromine is very unreactive
- ☒ **B** a gaseous reactant always gives a low yield
- ☒ **C** the reaction is very slow
- ☒ **D** the reaction produces a mixture of organic products

(iv) Calculate the volume of propane, in dm^3, measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.
Give your answer to an appropriate number of significant figures.
[Molar gas volume at r.t.p. = 24.0 dm^3 mol^{-1}]

(3)

(Total for question = 7 marks)

Q3.

Catalytic converters in cars remove unwanted substances such as nitrogen monoxide, carbon monoxide and unreacted hydrocarbons from the exhaust fumes.

The formula of the nitrogen monoxide free radical can be written as NO•

(i) Which is true for the NO• free radical ?

(1)

- ☒ **A** NO• is formed during thermal decomposition of LiNO3
- ☒ **B** NO• has a total of 15 protons, 15 neutrons and 16 electrons
- ☒ **C** NO• is a species with an unpaired electron
- ☒ **D** NO• is formed by heterolytic fission

(ii) It has been suggested that unreacted hydrocarbons and nitrogen monoxide are removed in a catalytic converter by reacting them together.

The reaction between decane and nitrogen monoxide produces carbon dioxide, water and nitrogen as the only products.
Complete the balanced equation for this reaction.
State symbols are not required.

(2)

..... $C_{10}H_{22}$ + ... NO →

(iii) Give a possible reason why this reaction might not proceed according to the equation in (ii).

(1)

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(Total for question = 4 marks)

Q4.

This question is about organic compounds.

Organic compounds can be grouped together in homologous series.

(i) Describe **two** characteristics of a homologous series.

(2)

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(ii) Name the homologous series to which propene belongs.

(1)

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(Total for question = 3 marks)

Q5.

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

This question is about hydrocarbons.

When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

All gas volumes are measured at the same temperature and pressure when water is a gas.
What is the **increase** in the total volume when 100 cm^3 of ethane is burned in excess oxygen?

(1)

- ☒ **A** 50 cm^3
- ☒ **B** 100 cm^3
- ☒ **C** 200 cm^3
- ☒ **D** 500 cm^3

(ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, C_xH_y, was mixed with excess oxygen and ignited.
Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 cm^3.
The equation for the complete combustion of C_xH_y is

$$C_xH_y(g) + (x + \frac{y}{4})O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

The total gas volume **decreased** by 75 cm^3.
The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 cm^3.
All gas volumes were measured at the same temperature and pressure.
Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of C_xH_y.
Include the **skeletal formula** of the cyclic hydrocarbon.

(3)

(Total for question = 4 marks)

Q6.

This question concerns the combustion of fossil fuels in power stations.

One of the problems associated with the combustion of some fossil fuels is the production of acidic gases, including the oxides of nitrogen and sulfur.

(i) Explain how oxides of sulfur and nitrogen can be formed from the combustion of fossil fuels.

(2)

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(ii) Some power stations use a process of flue gas desulfurisation (FGD) to remove sulfur oxides from the gaseous combustion products.

One such process, known as wet scrubbing, uses a mixture of calcium carbonate and water to react with sulfur dioxide.

Two relevant equations are

$$SO_2(g) + CaCO_3(s) \rightarrow CaSO_3(s) + CO_2(g)$$

$$CaSO_3(s) + 2H_2O(l) + \tfrac{1}{2}O_2(g) \rightarrow CaSO_4 \cdot 2H_2O(s)$$

Explain why this process is an incomplete solution to the problem of burning fossil fuels. Use the equations provided to illustrate your answer.

(2)

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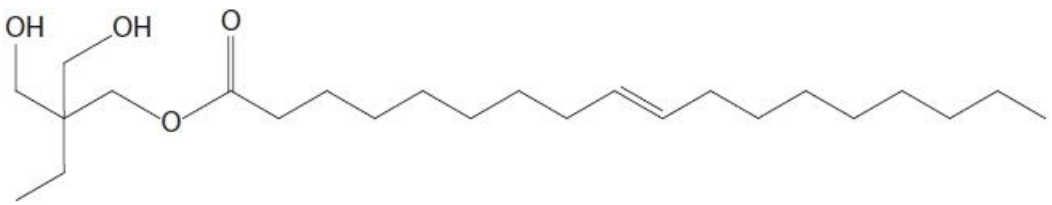
(Total for question = 4 marks)

Q7.

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 ☒ .

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

An alternative to synthetic oil is known as mineral oil and consists solely of hydrocarbons separated from crude oil.

(i) What is the name of the process used to separate different hydrocarbons from crude oil?

(1)

- ☒ **A** cracking
- ☒ **B** reforming
- ☒ **C** fractional distillation
- ☒ **D** heating under reflux

(ii) Explain why compound **X** is likely to have a higher boiling temperature than hydrocarbons of a similar molecular mass and shape.

A detailed description of how the intermolecular forces arise is not required.

(2)

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(Total for question = 3 marks)

Q8.

During cracking, carbon to carbon bonds are broken.

Explain the **two** major reasons for cracking hydrocarbons.

(3)

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(Total for question = 3 marks)

Q9.

Some alkanes are used as fuels for transport. Crude oil, which is a mixture of hydrocarbons, is the major source of these alkanes. Crude oil is processed by fractional distillation, cracking and reforming.

Fractional distillation produces fractions which contain molecules of a similar boiling temperature. Molecules containing six carbon atoms are found in both the petrol fraction and the higher boiling kerosene fraction.

(i) Identify, by name or structural formula, the unbranched alkane with six carbon atoms found in kerosene.

(1)

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(ii) Explain why **isomers** of the alkane in (i) have lower boiling temperatures and so are found in the petrol fraction.

(3)

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(Total for question = 4 marks)

Q10.

Ethane reacts with chlorine in the presence of ultraviolet light to form a mixture of products.

(i) In the initiation step, chlorine molecules are converted into radicals.

$$Cl_2 \rightarrow 2Cl^{\bullet}$$

Identify the type of bond broken and the type of bond fission occurring in this step.

(1)

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

(ii) Write the propagation steps to show the formation of C_2H_5Cl.

(2)

(iii) State how some butane, C_4H_{10}, is formed in the reaction.

(1)

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(Total for question = 4 marks)

Q11.

This is a question about hydrocarbons.

State what is meant by the term **hydrocarbon**.

(1)

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(Total for question = 1 mark)

Q12.

This is a question about catalytic converters in car exhaust systems.

When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

(1)

(ii) Describe the stages by which the reaction in (i) occurs in a catalytic converter.

(3)

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(Total for question = 4 marks)

Q13.

Write the equation for reforming heptane into cycloheptane, showing the **skeletal** formulae of the organic molecules.

(2)

(Total for question = 2 marks)

Q14.

Ethane can also be converted into chloroethane.

(i) Give the reagent and condition required to convert ethane into chloroethane.

(1)

Reagent

.....

Condition

.....

(ii) What is the mechanism and type of reaction by which ethane is converted into chloroethane?

(1)

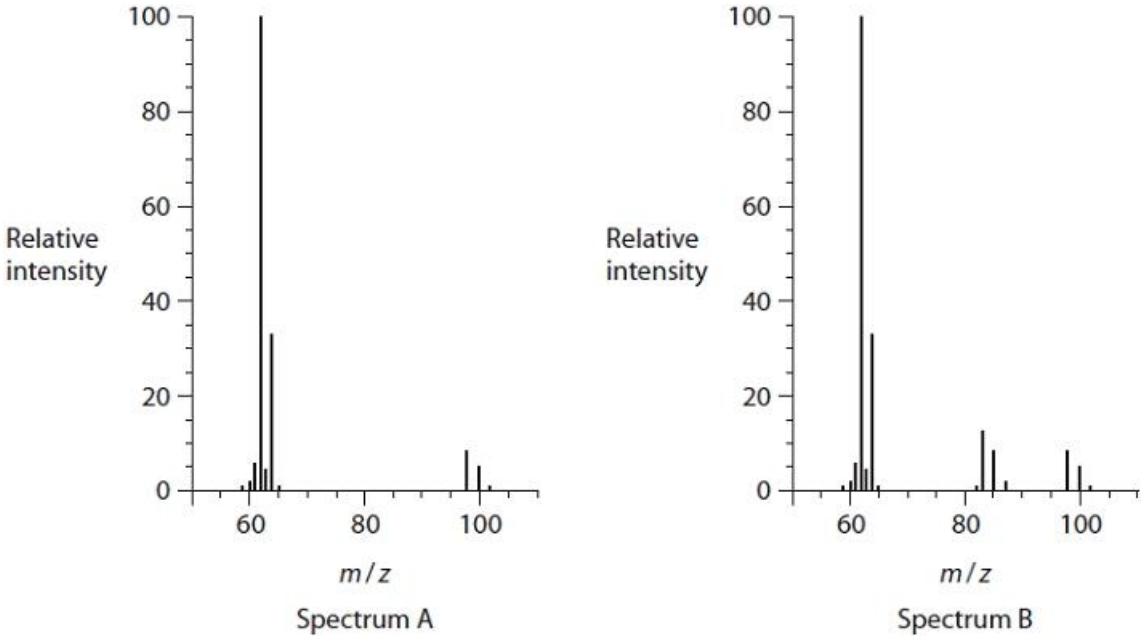
- ☒ **A** electrophilic addition
- ☒ **B** free radical addition
- ☒ **C** free radical substitution
- ☒ **D** nucleophilic substitution

(iii) Further reactions of chloroethane result in the formation of small amounts of the isomers 1,1-dichloroethane and 1,2-dichloroethane.

Write equations to show the formation of these products.
Curly arrows are not required.

(3)

(iv) The mass spectra of the two isomers of dichloroethane are shown.



Deduce the molecular formulae of the species responsible for the molecular ion peaks at *m* / *z* 98, 100 and 102.
The molecular formulae for the species producing these peaks are the same in both spectra.

(2)

(v) State why in both spectra the peaks at 98, 100 and 102 have different relative intensities.

(1)

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(vi) Explain how the presence of the peaks at 83, 85 and 87 in Spectrum B allows the identification of the isomer responsible for this spectrum.

(2)

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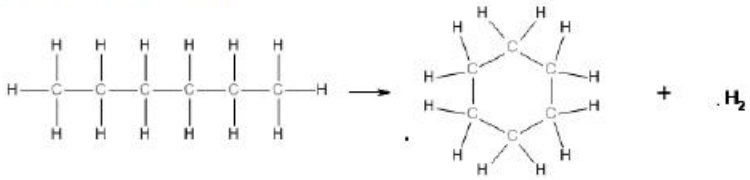
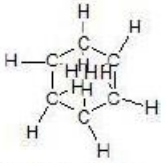
(Total for question = 10 marks)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • different alkanes have different boiling temperatures/points **(1)** • because of (different) chain length/molar mass /strength of intermolecular forces/ number of electrons **(1)**	 Allow Volatility for boiling temperature Allow Different alkanes condense at different temperatures Ignore melting temperatures if given with boiling temperatures Ignore densities Accept London /dispersion /van der Waals forces Allow reference to size A comparison such as 'longer alkanes have higher boiling points' scores 2 Ignore any reference to surface area Do not award references to cracking Do not award reference to just weight/mass Do not award incorrect trend	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	Correct equation	<u>Example of equation:</u> $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$ OR $C_8H_{18} \rightarrow 2C_2H_4 + C_4H_{10}$ OR $C_8H_{18} \rightarrow 3C_2H_4 + C_2H_6$ Allow $CH_2=CH_2$ for C_2H_4 Products can be given in either order Do not award equations forming H_2	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	Correct equation	Example of equation:  $+ \ H_2$ Accept bonds to hydrogen atoms inside the ring, e.g.  Allow skeletal or structural formulae for hexane  or $CH_3(CH_2)_4CH_3$ and for cyclohexane  or $(CH_2)_6$ Ignore $C_6H_{14} \rightarrow C_6H_{12} + H_2$	(1)

Q2.

Question Number	Answer	Mark
(i)	**The only correct answer is C (homolytic bond fission to form free radicals)** *A is incorrect because such bond fission would produce ions* *B is incorrect because the first step of the reaction produces free radicals by homolytic fission* *D is incorrect because the first step of the reaction produces free radicals*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	122.9 æ(122.9 + 80.9) x 100 **or** 122.9 æ(44.0 + (2 x 79.9)) x 100 **or** (122.9æ203.8) x 100 (1) = 60.304% (1)	Allow 123 æ (123+81) = 60.29% Award M1 only if final answer given as decimal 0.603 rather than % Allow TE for M2 for only one incorrect A_r value Ignore SF Correct answer with or without working scores (2)	**(2)**

Question Number	Answer	Mark
(iii)	**The only correct answer is D** (the reaction produces a mixture of organic products) *A is incorrect because bromine is very reactive* *B is incorrect because gaseous reactants do not necessarily give a poor yield* *C is incorrect because the kinetics of the reaction do not affect the yield*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	Amount of 1-bromopropane (1) So moles of propane required (1) So volume of propane required to 2 or 3 SF (1) **Alternative route** Target mass of 1-bromopropane required to produce 14.7 g (with a 31.0% yield) (1) Moles of propane required to produce the required mass of 1-bromopropane (1) So volume of propane required to 2 or 3 SF (1)	14.7/122.9 = 0.11961 (mol) (0.11961/31) x 100 = 0.38584 (mol) = 0.38584 x 24.0 = 9.2601 (dm^3) = 9.3 / 9.26 (dm^3) Allow 14.7/123 = 0.11951 (mol) (0.11951/31) x 100 = 0.38552 (mol) = 0.38552 x 24.0 = 9.2526 (dm^3) = 9.3 / 9.25 (dm^3) 14.7 x $\frac{100}{31.0}$ = 47.4 g $\frac{47.4}{122.9}$ = 0.3857 (mol) 0.3857 x 24.0 = 9.3 / 9.26 (dm^3) Award (2) for a final answer of 0.890 / 0.89 (dm^3) (incorrect use of 31.0%) Answer assuming 100% yield scores (2) for final answer of 2.87 / 2.9 (dm^3) Penalise incorrect units in M3 Do not award M3 if Ideal Gas Eqtn used for propane volume Penalise incorrect rounding once only **Correct answer to 2 or 3 SF with or without working scores (3)**	**(3)**

Q3.

Question Number	Answer	Mark
(i)	The only correct answer is **C** (NO• is a species with an unpaired electron) ***A*** *is not correct because nitrogen dioxide, NO_2, is formed during this reaction* ***B*** *is not correct because this would be NO^-. NO• has 15 protons, 15 neutrons and 15 electrons* ***D*** *is not correct because radicals such as this are made by homolytic fission*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct substances **(1)** • correct balancing **(1)**	Example of equation $2C_{10}H_{22} + 62NO \rightarrow 20CO_2 + 22H_2O + 31N_2$ Ignore a dot on NO ALLOW multiples	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • oxygen is present and so $C_{10}H_{22}$ / intermediate compounds might react with oxygen Or NO might react with CO	Allow there is (enough) oxygen for complete combustion Allow the reaction must occur in a series of steps as there are too many particles reacting in the equation Allow it is unlikely for the reactants to be in the correct ratio Allow it is unlikely there will be enough NO / decane Allow reactants can react in other ways giving formation of other named products (such as CO, C, NO_x) Allow NO may react with other substances / air / oxygen to form NO_x / oxides of nitrogen / other nitrogen containing products	**(1)**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	Award any **two** from the following: • they have the same general formula **(1)** • they / neighbouring compounds differ from each other by a $-CH_2-$ group **(1)** • they have the same functional group / display similar chemical properties **(1)** • they show a gradual change / trend in physical properties **(1)**	 Allow example of general formula, e.g alkanes are C_nH_{2n+2} Do not award 'the same formula / molecular formula / structural formula' Allow 'the same chemical properties' Ignore 'the same physical properties' or 'similar physical properties'. Trend must be stated or implied. Allow a stated property such as boiling temperature	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• alkene(s)	Do not award alkanes	(1)

Q5.

Question Number	Answer	Mark
(i)	**The only correct answer is A** (50 cm^3) ***B*** *is incorrect because this is the increase in volume from 200 cm^3 of ethane* ***C*** *is incorrect because this is the volume of CO_2 formed* ***D*** *is incorrect because this is the total volume of CO_2 and H_2O formed*	(1)

Question number	Answer	Additional Guidance	Mark
(ii)	• calculation of x **(1)** • calculation of y **(1)** • structure of cyclopentene **(1)**	Example of calculation (volume of CO_2 = 125 (cm^3) so x = 125/25) = 5 (25 + 25(5 + (y/4)) − 75 = 125) y = 8  Allow the skeletal formula of any cyclic C_5H_8 compound with C=C e.g. a methylcyclobutene TE on x and y for a cyclic hydrocarbon	**(3)**

Q6.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • because sulfur compounds/impurities in fuel **and** react with oxygen (from air) (1) • because nitrogen in the air **and** reacts with oxygen (from air) (1)	Penalise omission of oxygen (from air) once only Allow nitrogen compounds in the fuel	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (because although sulfur dioxide is removed) carbon dioxide is produced. (1) • carbon dioxide is a greenhouse gas (and must therefore be removed/stored) (1)	Do not award more energy/fossil fuel burned to heat the reaction Allow carbon dioxide adds to/causes global warming	(2)

Q7.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (fractional distillation) *A is incorrect because the process is used to produce smaller hydrocarbons* *B is incorrect because the process is used to produce branched and cyclic hydrocarbons* *D is incorrect because the process is used to heat reaction mixtures*	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to one of the following pairs of points Either • the OH groups (in compound **X**) can form hydrogen bonds (1) • so more energy is needed to vaporise compound **X** / break intermolecular forces in compound X (1) Or • hydrocarbons have only London forces, but compound **X** has hydrogen bonds (as well) (1) • hydrogen bonds are stronger (than London forces) (1)	Ignore references to dipole-dipole interactions Allow 'the oxygen (in compound X) can form hydrogen bonds') Allow 'more energy is needed to break bonds in compound X' if H bonds discussed Any reference to the breaking of **covalent** bonds loses M2 only	(2)

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • shorter chain alkanes **and** alkenes formed **(1)** • Alkenes are useful starting materials in organic synthesis / used for making polymers / plastics **(1)** • Shorter chain alkanes are more in demand / higher value / can be used as fuel **(1)**	Answers only referring to hydrocarbons and not alkanes and / or alkenes can only score M3. Allow shorter chain hydrocarbons **and** alkenes formed Allow for a named product of synthesis, e.g. ethanol / alcohol / dihaloalkane etc.. Ignore just 'are more useful' Allow 'Shorter chain hydrocarbons are more in demand / higher value / are better fuels than longer chain hydrocarbons If M2 and M3 are not scored award 1 mark for 'to make polymers / plastics and fuels / higher value compounds' OWTTE.	**(3)**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• hexane / $CH_3CH_2CH_2CH_2CH_2CH_3$	Allow displayed formula / skeletal formula Do not award hexene Ignore C_6H_{14}	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • isomers in petrol fraction have branched chains **(1)** • branched chains have a lower surface area / do not pack so closely together **(1)** • intermolecular forces / van der Waals' forces / London forces / dispersion forces / instantaneous dipole-induced dipole forces are weaker (so boiling temperature is lower) **(1)**	Unambiguous mention of breaking bonds within molecules can only score M1 Allow isomers can be secondary or tertiary Allow branched chains have lower boiling temperatures Ignore smaller molecule / smaller chain / shorter chain Do not award cyclic / geometric isomers / alkenes Allow branched chains have less points of contact Do not award unless clearly forces / bonds between molecules or 'intermolecular' is seen	**(3)**

Q10.

Question Number	Answer	Mark
(i)	**D** (σ, homolytic)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• $C_2H_6 + Cl\cdot \rightarrow C_2H_5\cdot + HCl$ **(1)** • $C_2H_5\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$ **(1)**	Equations can be in either order Allow correct structural / displayed / skeletal formulae Allow dots / circles anywhere on formula Allow 1 mark for two correct steps but using the incorrect alkane / bromine Allow 1 mark if both propagation steps correct but initiation / termination steps also written and not labelled as such or additional incorrect propagation step(s) Ignore state symbols and curly arrows, even if incorrect Penalise missing dots once only **Comment:** If $C_2H_5^+$ appears in both equations but equations are otherwise correct, allow 1 as TE	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• (two) ethyl/ $C_2H_5^{(\cdot)}$ radicals react together **or** $C_2H_5\cdot + C_2H_5\cdot \rightarrow C_4H_{10}$	Allow $C_2H_5 + C_2H_5 \rightarrow C_4H_{10}$ Ignore termination Ignore just '(two) radicals react together' Ignore ethane radicals / ethyl groups Do not allow molecules / ions Do not allow incorrect radicals or product Do not allow initiation / propagation / elimination / substitution	**(1)**

Q11.

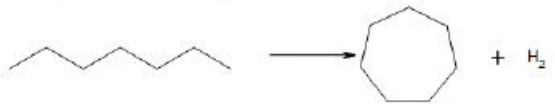
Question Number	Answer	Additional Guidance	Mark
	An answer which makes reference to: • a compound of hydrogen and carbon only	Allow absence of 'only' Allow substance/molecule/chain/species for compound Do not award reference to a carbon and/or a hydrogen Do not award 'an element made of carbon and hydrogen' Do not award a mixture of carbon and hydrogen Do not award contains carbon and hydrogen molecules	**(1)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	Correct equation	$2NO + 2CO \rightarrow N_2 + 2CO_2$ Accept multiples Ignore catalysts and conditions if stated	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	A description that makes reference to the following points:	Absence of reference to the catalytic surface results in a deduction of one mark	**(3)**
	• **adsorption** of gases to catalytic surface **(1)**	Do not award absorption or "stick"	
	• weakening of bonds (and chemical reaction) on catalytic surface **(1)**	Allow bonds break (and reaction occurs) on catalytic surface Ignore the type of interaction referred to between the reactants and the catalytic surface	
	• desorption of products from catalytic surface **(1)**	Allow 'release' of products from catalytic surface Allow de-adsorbed	

Q13.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• correct <u>skeletal</u> formulae for heptane and cycloheptane **(1)** • formula for hydrogen **(1)**	Mark independently but max 1 if additional reactants and/or products or more than 1 mole/molecule of hydrogen  Do not allow just structural or displayed formulae for the organic reactant or product, or any combination of formulae, for M1 Ignore additional formulae written as working Ignore shape of heptagon, provided it has 7 sides Ignore any conditions, even if incorrect	**(2)**

Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • chlorine / Cl_2 **and** ultraviolet / uv (light)	Allow sunlight Ignore chlorine radicals Ignore temperatures Do not award presence of an additional catalyst Do not award hydrogen chloride / HCl / hydrochloric acid / HCl(aq)	**(1)**

Question Number	Answer	Mark
(ii)	The only correct answer is **C** (free radical substitution) ***A*** *is not correct because as ethane is saturated the reaction is a substitution* ***B*** *is not correct because as ethane is saturated the reaction is a substitution* ***D*** *is not correct because as ethane has no bonds with significant polarity the reaction is not nucleophilic*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)		Allow radical dots anywhere on the radical species throughout	**(3)**
	• chloroethane reacts with a chlorine radical OR	$CH_3CH_2Cl + Cl\bullet \rightarrow \bullet CH_2CH_2Cl + HCl$ or $CH_3CH_2Cl + Cl\bullet \rightarrow CH_3CHCl\bullet + HCl$ Allow $C_2H_5Cl + Cl\bullet \rightarrow C_2H_4Cl\bullet + HCl$	
	both correct structure formulae of the products **including** identification of which is which **(1)**	CH_3CHCl_2 1,1-dichloroethane CH_2ClCH_2Cl 1,2-dichloroethane	
	• formation of 1,1-dichloroethane via radical mechanism OR	$CH_3CHCl\bullet + Cl\bullet \rightarrow CH_3CHCl_2$ or $CH_3CHCl\bullet + Cl_2 \rightarrow CH_3CHCl_2 + Cl\bullet$ Ignore reactions of $C_2H_4Cl\bullet$	

	overall equation for the formation of 1,1-dichloroethane **(1)** • formation of 1,2-dichloroethane via radical mechanism OR equation for the formation of 1,2-dichloroethane **(1)**	$CH_3CH_2Cl + Cl_2 \rightarrow CH_3CH_2Cl_2 + HCl$ $\bullet CH_2CH_2Cl + Cl\bullet \rightarrow CH_2ClCH_2Cl$ or $\bullet CH_2CH_2Cl + Cl_2 \rightarrow CH_2ClCH_2Cl + Cl\bullet$ Ignore reactions of $C_2H_4Cl\bullet$ $CH_3CH_2Cl + Cl_2 \rightarrow CH_2ClCH_2Cl + HCl$ If M2 and M3 are not scored allow (1) for a balanced equation for the reaction of $C_2H_4Cl\bullet$ with $Cl\bullet$ or Cl_2 to form $C_2H_4Cl_2$ (examples shown) $C_2H_4Cl\bullet + Cl\bullet \rightarrow C_2H_4Cl_2$ or $C_2H_4Cl\bullet + Cl_2 \rightarrow C_2H_4Cl_2 + Cl\bullet$	

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that makes reference to the following points: • 98 peak is due to $C_2H_4{}^{35}Cl_2^+$ **and** 102 peak is due to $C_2H_4{}^{37}Cl_2^+$ **(1)** • 100 peak is due to $C_2H_4{}^{35}Cl{}^{37}Cl^+$ **(1)**	Allow $C_2H_4{}^{35}Cl{}^{35}Cl^+$ Allow $C_2H_4{}^{37}Cl{}^{37}Cl^+$ Allow structural formulae of the molecular ions of either 1,1- or 1,2-dichloroethane or both Allow structures with the positive charge anywhere including outside of brackets of any type. Penalise omission of + once only	**(2)**

Question Number	Answer	Additional Guidance	Mark
(v)	An answer that makes reference to the following point • ^{35}Cl and ^{37}Cl atoms are in a 3:1 ratio	Answer must refer to the isotopes of chlorine. Ignore comments about isotopes of carbon or hydrogen or just isotopes Allow a larger proportion of chlorine atoms are chlorine-35 than chlorine-37 Allow the ratio of the peak heights to be 9:6:1 Allow the abundance of chlorine- 35 and chlorine-37 are different Allow there are two isotopes of chlorine	**(1)**

Question Number	Answer	Additional Guidance	Mark
(vi)	An answer that makes reference to the following points: Either • the peaks are formed by fragments containing both chlorine atoms attached to one carbon atom or the fragments are $CH^{35}Cl^{37}Cl^{+}$, $CH^{35}Cl_2^{+}$ and $CH^{37}Cl_2^{+}$ **(1)** • this fragmentation / configuration is only possible from 1,1-dichloroethane / is not possible from 1,2-dichloroethane **(1)** Or • the peaks at 83, 85 and 87 represent the loss of a CH_3 group **(1)** • only 1,1-dichloroethane has a methyl group **(1)**	Allow a diagram showing the fragmentation of 1,1- dichloromethane to form a fragment containing one carbon and two chlorine atoms Allow the use of molecule instead of fragment Do not award fragments where the number of hydrogens on the carbon changes Allow just $CHCl_2^{+}$ Do not penalise the absence of the positive charge Do not award fragments where the number of hydrogens changes to allow for the different masses Allow only 1,1-dichloroethane has two chlorines on the same carbon / 1,2-dichlorethane does not have two chlorines on the same carbon Allow the peaks are 15 below the molecular ion values so they represent the loss of a CH_3 group	**(2)**