

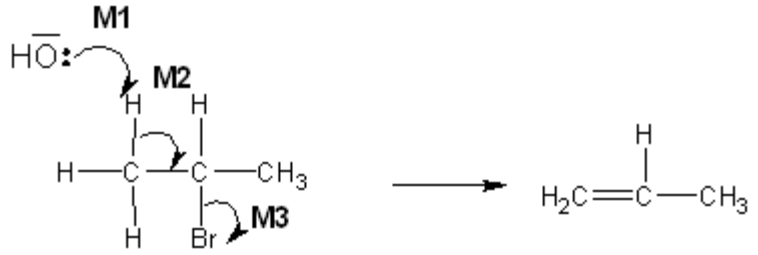
Alkanes and
Halogenoalkanes
Answers

Qu	Part	Sub Part	Marking Guidance	Mark	Comments
4	a		O = 74.1%	1	If atomic numbers or molecular masses are used lose M2 This ratio alone will not score the final mark. (It would get 2) Allow 3 marks for N ₂ O ₅
			$\frac{25.9}{14} \quad \frac{74.1}{16}$	1	
			1.85 4.63 1 2.5 N ₂ O ₅	1	
4	b		Toxic/ poisonous/ <u>forms</u> an acidic gas / forms NO ₂ which is acidic/ respiratory irritant/ forms HNO ₃ when NO reacts with <u>water and oxygen</u> / triggers asthma attacks/ <u>greenhouse gas</u> / photochemical smog/ contributes to global warming /formation of acid rain	1	ignore NO is an acidic gas or NO is acidic in water Not references to ozone layer
4	c		2NO + O ₂ → 2NO ₂	1	Accept multiples or fractions of equation Ignore wrong state symbols
4	d		Nitrogen / N ₂ and oxygen / O ₂ combine/react	1	QWC (not N and O combine) Not nitrogen in fuel Allow N ₂ + O ₂ → 2NO for M1 only
			spark / high temperature / 2500-4000 °C	1	
4	e		2NO + 2CO → N ₂ + 2CO ₂ OR 2NO → N ₂ + O ₂	1	Accept multiples or fractions of equation Ignore wrong state symbols Allow C ₈ H ₁₈ + 25NO → 8CO ₂ + 12.5 N ₂ + 9H ₂ O

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	a	i	<p>M1 Initiation $\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$</p> <p>M2 First propagation $\text{Cl}\cdot + \text{CH}_3\text{CH}_3 \longrightarrow \cdot\text{CH}_2\text{CH}_3 + \text{HCl}$ C_2H_6</p> <p>M3 Second propagation $\text{Cl}_2 + \cdot\text{CH}_2\text{CH}_3 \longrightarrow \text{CH}_3\text{CH}_2\text{Cl} + \text{Cl}\cdot$ $\text{C}_2\text{H}_5\text{Cl}$</p> <p>M4 Termination (must make C₄H₁₀) $2 \cdot\text{CH}_2\text{CH}_3 \longrightarrow \text{C}_4\text{H}_{10} \text{ or } \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$</p>	4	<p>Penalise absence of dot once only.</p> <p>Penalise + or – charges <u>every time</u></p> <p>Penalise incorrect position of dot on ethyl radical once only.</p> <p>Penalise C₂H₅• once only</p> <p>Accept CH₃CH₂• with the radical dot above / below / to the side of <u>the CH₂</u></p> <p>Mark independently</p>
7	a	ii	<p>M1 ultra-violet / uv / sun light OR (very) high temperature OR $500\text{ }^\circ\text{C} \geq T \leq 1000\text{ }^\circ\text{C}$</p> <p>M2 (free-)radical substitution</p>	2	<p>Ignore “heat” for M1</p> <p>Both words needed for M2</p> <p>For M2, ignore the word “mechanism”</p>
7	b	i	<p>$\text{Cl}_2 + \text{H}_2\text{O} \longrightarrow \text{HClO} + \text{HCl}$</p> <p>OR</p> <p>$\text{Cl}_2 + \text{H}_2\text{O} \longrightarrow 2\text{H}^+ + \text{ClO}^- + \text{Cl}^-$</p>	1	<p>Accept HOCl or ClOH</p> <p>Accept other ionic or mixed representations</p> <p>Ignore state symbols</p>

Question	Part	Sub Part	Marking Guidance	Mark	Comments
4	(a)	(i)	single (C-C) bonds <u>only</u> / no double (C=C) bonds	1	Allow all carbon atoms bonded to four other atoms Single C-H bonds only = 0 C=H CE
			C and H (atoms) <u>only/purely/solely/entirely</u>	1	Not consists or comprises Not completely filled with hydrogen CH molecules = CE Element containing C and H = CE
4	(a)	(ii)	C_nH_{2n+2}	1	<i>Formula only</i> C_xH_{2x+2}
4	(b)	(i)	$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$	1	Accept multiples Ignore state symbols
4	(b)	(ii)	gases produced are greenhouse gases/contribute to Global warming/effect of global warming/climate change	1	Allow CO ₂ or water is greenhouse gas/causes global warming Acid rain/ozone CE = 0
4	(c)		carbon	1	Allow C Allow soot
4	(d)	(i)	$C_9H_{20} \rightarrow C_5H_{12} + C_4H_8$	1	Accept multiples
			OR $C_9H_{20} \rightarrow C_5H_{12} + 2C_2H_4$		
4	(d)	(ii)	Plastics, polymers	1	Accept any polyalkene / haloalkanes / alcohols
4	(d)	(iii)	so the <u>bonds</u> break OR because the <u>bonds</u> are strong	1	IMF mentioned = 0
4	(e)	(i)	1,4-dibromo-1-chloropentane / 1-chloro-1,4-dibromopentane	1	Ignore punctuation
4	(e)	(ii)	Chain/position/positional	1	Not structural or branched alone

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	a	i	<p><u>Nucleophilic substitution</u></p> <p>M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.</p> <p>M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.</p> <p>Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.</p>	1 2	<p>Penalise M1 if covalent KOH is used</p> <p>Penalise M2 for formal charge on C or incorrect partial charges</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Max 1 mark for the mechanism for the wrong reactant and/or “sticks”</p> <p>Ignore product</p>
7	a	ii	2-bromopropane ONLY	1	
7	a	iii	<p><u>Polar C–Br</u> OR <u>polar carbon–bromine bond</u> OR <u>dipole on C–Br</u></p> <p>OR C atom of <u>carbon–bromine bond</u> is δ⁺ / electron deficient OR C–Br δ⁺ (δ[–])</p> <p>(Credit <u>carbon–halogen bond</u> as an alternative to <u>carbon–bromine bond</u>.)</p>	1	<p>It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule.</p> <p>Ignore X for halogen</p>

7	b		<p><u>Elimination</u></p>  <p>M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 M3 is independent.</p> <p>Award full marks for an E1 mechanism in which M2 is on the correct carbocation.</p>	1 3	<p>Credit “base elimination” but NOT “nucleophilic elimination” No other prefix.</p> <p><u>Mechanism</u> Penalise M1 if covalent KOH</p> <p>Penalise M3 for formal charge on C or incorrect partial charges</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Max 2 marks for the mechanism for wrong reactant and/or “sticks”</p> <p>Ignore product</p>
7	c		<p><i>Any one condition from this list to favour elimination;</i></p> <ul style="list-style-type: none"> • <u>alcohol(ic) / ethanol(ic)</u> (solvent) • <u>high concentration</u> of KOH / alkali / hydroxide OR <u>concentrated</u> KOH / hydroxide • high temperature or hot or heat under reflux or T = 78 to 100°C 	1	<p>Apply the list principle</p> <p>Ignore “aqueous”</p> <p>Ignore “excess”</p>
7	d	i	<u>Addition</u> (polymerisation) ONLY	1	Penalise “additional”
7	d	ii	<u>But-2-ene</u> ONLY (hyphens not essential)	1	<p>Ignore references to cis and trans or E/Z</p> <p>Ignore butene</p>

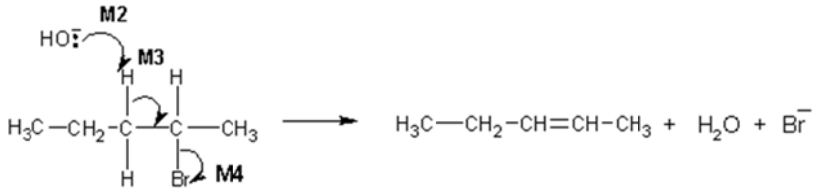
10	c	<p>M1 $2\text{Cl}_2 + 2\text{H}_2\text{O} \longrightarrow 4\text{HCl} + \text{O}_2$</p> <p>M2 <u>silver chloride</u> ONLY</p> <p>M3 The solid / precipitate would dissolve OR is soluble OR (It) forms a (colourless) solution</p>	3	<p>Or multiples</p> <p><u>M2 requires a name</u></p> <p>Mark M3 independently</p> <p>Ignore "disappears"</p>
10	d	<p><u>Electrophilic addition</u></p> <p><i>Mechanism:</i></p> <div style="text-align: center;"> </div> <p>M1 must show an arrow from the double bond towards one of the Cl atoms on a Cl-Cl molecule.</p> <p>M2 must show the breaking of the Cl-Cl bond.</p> <p>M3 is for the structure of the carbocation with Cl substituent.</p> <p>M4 must show an arrow from the lone pair of electrons on a negatively charged chloride ion towards the positively charged carbon atom.</p>	1 4	<p>M2 Penalise partial charges if wrong way around, otherwise ignore</p> <p>Max 3 marks <u>for the mechanism</u> for wrong reactant and/or "sticks" (wrong reactant could be HBr or Br₂ or incorrect alkene)</p>

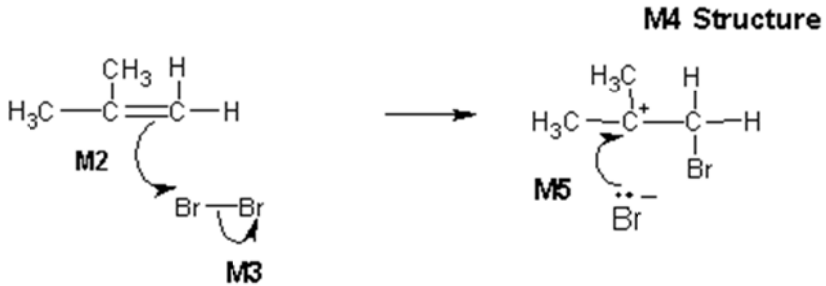
Question	Marking Guidance	Mark	Comments
6(a)	$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ <p>Not enough oxygen / air</p> <p>CMM / methane is a greenhouse gas / contributes to global warming</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Accept multiples</p> <p>Ignore state symbols even if incorrect</p> <p>Do not allow formation of CO_2 / CO_2 is a greenhouse gas</p> <p>Apply list principle, eg</p> <p>CH_4 is a greenhouse gas and toxic = 0</p> <p>CH_4 is a greenhouse gas and damages ozone = 0</p> <p>Allow CH_4 and CO_2 are greenhouses gases</p> <p>Allow collect to use as a fuel so fossil fuels do not run out (as quickly)</p>
6(b)	$\text{CH}_3\text{SH} + 3\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{SO}_2$ <p>Calcium oxide is basic (and SO_2 is acidic) /</p> <p>CaO neutralises SO_2 /</p> <p>CaO reacts with SO_2 to form gypsum / salt / solid / CaSO_4 / CaSO_3</p> <p>Allow $\text{CaO} + \text{SO}_2 \rightarrow \text{CaSO}_3$</p> <p>Acid rain</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Accept multiples</p> <p>Ignore state symbols even if incorrect</p> <p>M2 and M3 can only be scored if SO_2 seen somewhere in the answer</p> <p>Allow consequence of acid rain eg increased rusting of iron / fish in lakes die / problems for asthmatics</p> <p>Apply list principle</p> <p>Ignore air pollution</p>

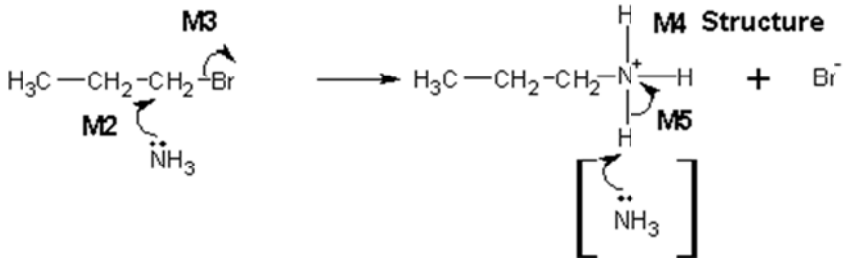
7(e)	$\frac{106.5}{143} \times 100$ 74.48% 3	1 1 1	Allow 74.5% Only
7(f)	<u>2,3-dichloro-3-methylpentane</u> <u>C₃H₆Cl</u>	1 1	Ignore punctuation Only

Question	Marking Guidance	Mark	Comments
7(a)(i)	$\text{CH}_4 + 3\text{F}_2 \longrightarrow \text{CHF}_3 + 3\text{HF}$	1	
7(a)(ii)	<p>M1 Initiation $\text{F}_2 \longrightarrow 2\text{F}\cdot$</p> <p>M2 First propagation $\text{F}\cdot + \text{CHF}_3 \longrightarrow \cdot\text{CF}_3 + \text{HF}$</p> <p>M3 Second propagation $\text{F}_2 + \cdot\text{CF}_3 \longrightarrow \text{CF}_4 + \text{F}\cdot$</p> <p>M4 Termination (must make C₂F₆) $2 \cdot\text{CF}_3 \longrightarrow \text{C}_2\text{F}_6 \text{ or } \text{CF}_3\text{CF}_3$</p>	4	<p>Penalise absence of dot once only.</p> <p>Radical dot on $\cdot\text{CF}_3$ can be anywhere but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only.</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Penalise each of "F" and lower case F, once only in this clip</p>
7(b)(i)	<p><u>Displayed formula</u> e.g.</p> $ \begin{array}{c} \text{Cl} \quad \text{H} \\ \quad \\ \text{Cl}-\text{C}-\text{C}-\text{F} \\ \quad \\ \text{Cl} \quad \text{F} \end{array} $	1	<p><u>All bonds</u> must be drawn out.</p> <p>Ignore bond angles. Penalise "sticks"</p>

<p>7(b)(ii)</p>	<p>M1 <u>C—Cl</u> bond OR <u>carbon-chlorine</u> bond</p> <p>M2 <u>chlorine atom</u> OR <u>chlorine (free) radical</u></p> <p>M3 $2\text{O}_3 \longrightarrow 3\text{O}_2$</p>	<p>3</p>	<p>M1 NOT carbon-halogen</p> <p>Penalise incorrect spelling of chlorine <u>once only</u> in this clip</p> <p>M2 ignore formulae</p> <p>Ignore Cl_2 or $\text{Cl}\cdot$ or $\text{ClO}\cdot$ balanced on <u>both</u> sides of the equation</p> <p>Ignore other equations leading to the overall equation</p>
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Question	Marking Guidance	Mark	Comments
9(a)(i)	<p>M1 Elimination</p>  <p>M2 must show an arrow from the <u>lone pair on the oxygen</u> of a negatively charged hydroxide ion <u>to a correct H</u> atom</p> <p>M3 must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond. Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H</p> <p>M4 is independent provided it is from their <u>original molecule</u></p> <p>Award full marks for an E1 mechanism in which M3 is on the correct carbocation.</p> <p>N.B. These are double-headed arrows</p>	4	<p>For M1, accept “Base elimination” but <u>no other prefix</u>.</p> <p>Penalise M2 if covalent KOH</p> <p>Penalise M4 for formal charge on C of C-Br or incorrect partial charges on C-Br</p> <p>Ignore other partial charges</p> <p>Penalise once only in any part of the mechanism for a line and two dots to show a bond.</p> <p><u>Max any 2 of 3 marks for the mechanism</u> for wrong reactant (or wrong product if shown).</p> <p>Accept the correct use of “sticks” for the molecule except for the C-H being attacked</p>
9(a)(ii)	<p>Structure for pent-1-ene</p> <p>CH₃CH₂CH₂CH=CH₂</p>	1	<p>Penalise C₃H₇</p> <p>Accept correct “sticks”</p>

<p>9 (b)</p>	<p>M1 <u>Electrophilic addition</u></p>  <p>M2 must show an arrow from the double bond towards the Br atom of the Br-Br molecule</p> <p>M3 must show the breaking of the Br-Br bond.</p> <p>M4 is for the structure of the tertiary carbocation with Br on the correct carbon atom.</p> <p>M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom.</p> <p>N.B. These are double-headed arrows</p>	<p>5</p> <p>For M1, both words required.</p> <p>For the mechanism</p> <p>M2 Ignore partial negative charge on the double bond.</p> <p>M3 Penalise partial charges on Br-Br bond if wrong way and penalise formal charges</p> <p>Penalise once only in any part of the mechanism for a line and two dots to show a bond</p> <p><u>Max any 3 of 4 marks for the mechanism</u> for wrong organic reactant or wrong organic product (if shown) or primary carbocation.</p> <p>If HBr is used, max 2 marks for their mechanism</p> <p>Accept the correct use of “sticks”</p>
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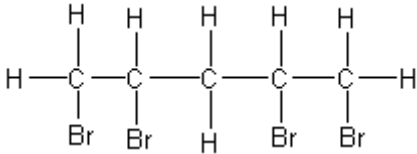
9(c)	<p>M1 <u>Nucleophilic substitution</u></p>  <p>M2 must show an arrow from the lone pair of electrons on the nitrogen atom of an ammonia molecule to the C atom.</p> <p>M3 must show the movement of a pair of electrons from the C-Br bond to the Br atom. M3 is independent provided it is from their <u>original molecule</u></p> <p>M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge must be shown on/or close to, the N atom.</p> <p>M5 is for an arrow from the N-H bond to the N atom.</p> <p>Award full marks for an S_N1 mechanism in which M2 is the attack of the ammonia on the intermediate carbocation.</p> <p>N.B. These are double-headed arrows</p>	5	<p>For M1, both words required.</p> <p>Penalise M2 if NH₃ is negatively charged.</p> <p>Penalise M3 for formal charge on C or incorrect partial charges</p> <p>The second mole of ammonia is not essential for M5; therefore ignore any species here.</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Max any 3 of 4 marks for the mechanism for wrong organic reactant (or wrong organic product if shown)</p> <p>Accept the correct use of “sticks”</p>
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Question	Marking Guidance	Mark	Comments
4(a)	$C_{16}H_{34} + 24.5O_2 \rightarrow 16CO_2 + 17H_2O$	1	Allow multiples Ignore state symbols in equation
4(b)	Solidifies/freezes/goes viscous/waxing occurs	1	Allow does not vapourise/ less volatile Lack of Oxygen = 0 Apply list principle
4(c)(i)	$N_2 + O_2 \rightarrow 2NO$ Spark/ (very) high temp/ 2500 °C – 4000 °C	1 1	Allow multiples/ Ignore state symbols in equation Ignore pressure/catalyst/low % of oxygen Not just heat/hot Apply list principle eg if high temp 150°C = 0
4(c)(ii)	$2CO + 2NO \rightarrow 2CO_2 + N_2$ OR $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5 N_2 + 9H_2O$ OR $C + 2NO \rightarrow CO_2 + N_2$ OR $2NO \rightarrow N_2 + O_2$ Pt/ Pd/ Rh/ Ir	1 1	Allow multiples/ Ignore state symbols in equation Allow other alkane reacting with NO in correctly balanced equation Penalise contradiction of name and symbol
4(c)(iii)	$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$	1	Allow multiples/ Ignore state symbols in equation

4(d)(i)	High temp/ anywhere in range 400 °C – 900 ° C/ anywhere in range 670-1200K / high pressure/ anywhere in range 5000 kPa up to 8000 kPa/	1	Not catalyst/heat
4(d)(ii)	$C_{16}H_{34} \rightarrow C_6H_{14} + 2C_4H_8 + C_2H_4$ Or $C_{16}H_{34} \rightarrow C_6H_{14} + C_4H_8 + 3C_2H_4$	1	Do not allow multiples Ignore state symbols in equation
4(d)(iii)	Polymers/plastics/ named polymer	1	Allow polyesters or polyamides Ignore object made from polymer

Question	Marking Guidance	Mark	Comments
1(a)(i)	chlorotrifluoromethane	1	Spelling must be correct but do not penalise “flouro” Ignore use of 1-
1(a)(ii)	CF ₃ •	1	May be drawn out with dot on C OR if as shown dot may be anywhere
1(a)(iii)	An unpaired / non-bonded / unbonded / free / a single / one / lone <u>electron</u>	1	NOT “bonded electron” and NOT “paired electron” NOT “pair of electrons” NOT “electrons” Ignore “(free) radical”
1(b)	M1 Cl • + O ₃ \longrightarrow ClO• + O ₂ M2 ClO• + O ₃ \longrightarrow 2O ₂ + Cl•	2	Mark independently Equations could gain credit in either position The dot can be anywhere on either radical Penalise the absence of a dot on the first occasion that it is seen and then mark on. Do <u>not</u> make the same penalty in the next equation, but penalise the absence of a dot on the other radical. Apply the list principle for additional equations

Question	Marking Guidance	Mark	Comments
7(a)(i)	(Free-) <u>radical substitution</u>	1	Both words needed
7(a)(ii)	UV light / Ultra-violet light / sunlight OR <u>high</u> temperature / $150^{\circ}\text{C} \leq T \leq 500^{\circ}\text{C}$	1	
7(a)(iii)	Propagation (Step)	1	Ignore “first” or “second” Accept phonetic spelling
7(a)(iv)	M1 Termination (Step) M2 $2\text{CH}_3\text{CH}_2\text{CH}_2\cdot \longrightarrow \text{C}_6\text{H}_{14}$	2	In M2 C_6H_{14} may be drawn out as $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ The dot may be anywhere around the terminal CH_2 on the radical Accept $\text{C}_3\text{H}_7\cdot$ with dot anywhere Penalise the absence of any radical dot
7(a)(v)	$\text{C}_3\text{H}_8 + 8\text{Br}_2 \longrightarrow \text{C}_3\text{Br}_8 + 8\text{HBr}$	1	Or multiples

7(b)(i)	<p>M1 Double bonds are <u>electron-rich</u> OR <u>electron pair donors</u> OR centres of <u>electron density</u>.</p> <p>M2 Bromine <u>becomes polarised</u> / <u>becomes polar</u> OR forms an <u>induced dipole</u> OR <u>becomes $\delta+$ / $\delta-$</u></p>	2	<p>M1 QoL – require <u>one</u> of these terms</p> <p>Ignore “(very) negative” and “nucleophile” as applied to the double bond.</p> <p>Penalise M2 for ion formation from bromine</p> <p>For M2, do not credit dipole formation <u>solely</u> as a consequence of electronegativity</p>
7(b)(ii)	<u>Electrophilic addition</u>	1	<p>Both words needed</p> <p>Accept phonetic spelling</p>
7(b)(iii)	<p>Structure for 1,2,4,5-tetrabromopentane, for example</p> <p style="text-align: center;">$\text{BrCH}_2\text{CHBrCH}_2\text{CHBrCH}_2\text{Br}$</p> <p>OR</p> <div style="text-align: center;">  <pre> H H H H H H - C - C - C - C - C - H Br Br H Br Br </pre> </div>	1	<p>Must be clear that they have drawn 1,2,4,5-tetrabromopentane and does NOT need to be displayed</p> <p>Credit use of “sticks” for each C-H bond</p>

7(c)	<p style="text-align: center;">+</p> <p>M1 Structure of CH₃CHCH₃</p> <p>M2 (Secondary) Carbocation OR (secondary) carbonium ions</p>	2	<p>Mark independently</p> <p>For M1 the positive charge must be on the central carbon atom</p> <p>Penalise bond to positive charge</p> <p>Penalise answers which show more than the correct carbocation e.g. the mechanism, unless the intermediate is clearly identified</p> <p>Credit use of “sticks” for each C-H bond</p> <p>For M2, penalise “primary” or “tertiary”</p>
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Question	Marking Guidance	Mark	Comments
8(a)(i)	<u>Electron pair donor</u> OR Species which uses a <u>pair of electrons</u> to <u>form a co-ordinate / covalent bond</u> .	1	Credit “lone pair” as alternative wording Credit “electron pair donator”
8(a)(ii)	<u>Replacement of the halogen</u> (atom) (by the nucleophile) OR The <u>carbon-halogen bond / C-X</u> breaks and a bond forms with the nucleophile or between the carbon and the nucleophile	1	They must describe the idea of substitution in a haloalkane. Accept the idea that a nucleophile replaces the halogen which becomes a halide ion Penalise reference to “halogen molecule” and penalise the idea that the haloalkane contains a halide
8(a)(iii)	<u>Splitting molecules using / by water</u> OR <u>breaking / splitting / dissociating (C–X) bond(s) / using / by water</u>	1	NOT simply the reaction with water or simply the addition of water. Ignore “compound”
8(a)(iv)	(Heat) <u>energy / enthalpy required / needed / absorbed</u> (at constant pressure) <u>to break / split it / the</u> (carbon-halogen) <u>bond</u> OR (Heat) <u>energy / enthalpy required / needed / absorbed</u> (at constant pressure) for <u>homolysis of the</u> (C–X / the carbon-halogen) <u>bond</u>	1	Ignore bond formation Ignore “average”

8(b)	<p> M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation. </p>	2	<p> Penalise M1 if covalent KOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark for the wrong reactant Accept the correct use of “sticks” </p>
8(c)(i)	<p> M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to the correct</u> H atom M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 M3 is independent provided it is from the <u>original molecule</u> Award full marks for an E1 mechanism in which M2 is on the correct carbocation. </p>	3	<p> Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks for wrong reactant Accept the correct use of “sticks” for the molecule except for the C-H being attacked </p>

<p>8(c)(ii)</p>	<p>M1 <u>Stated</u> that the spectrum has an <u>absorption / absorbance / peak in the range 1620 cm⁻¹ to 1680 (cm⁻¹) or specified correctly in this range</u> from the spectrum</p> <p>M2 depends on correct <u>range or wavenumber being specified</u></p> <p>M2 (Infrared absorption) <u>due to C=C OR carbon-carbon double bond</u></p>	<p>2</p>	<p>QoL for correct M1 statement which includes both the word absorption (or alternative) and the correct range or wavenumber</p> <p>Allow “peak” OR “dip” OR “spike” OR “trough” OR “low transmittance” as alternatives for absorption.</p> <p>For M2 it is not sufficient simply to state that an alkene has C=C</p> <p>M2 could be on the spectrum</p> <p>Ignore reference to other absorptions</p>
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Question	Marking Guidance	Mark	Comments
2(a)(i)	C_nH_{2n} / C_xH_{2x}	1	
2(a)(ii)	<u>Fractional distillation</u> / GLC / gas liquid chromatography / fractionation	1	Do not allow cracking / distillation
2(b)(i)	But-1-ene / but1ene	1	Ignore hyphens and commas Do not allow butene-1 / but-2-ene / butane / butane /alkene / C_4H_8 / propene / straight-chain alkene
2(b)(ii)	A structure of cyclobutane or methyl-cyclopropane	1	Allow skeletal formula.
2(c)(i)	$C_{15}H_{32} \rightarrow 2C_4H_8 + C_7H_{16}$	1	Do not accept multiples.
2(c)(ii)	Thermal cracking	1	Not catalytic cracking or cracking.
	To produce products that are in greater demand / more valuable / more expensive / more profitable	1	The (unsaturated) alkene or the (unsaturated) molecule or X produced can be polymerised or can be made into plastics. Ignore more useful products.
2(c)(iii)	Break (C-C or C-H) bonds	1	Allow to overcome the activation energy. Allow to break the carbon chain. Penalise breaking wrong bonds.
2(d)(i)	<u>H₂</u>	1	Only.

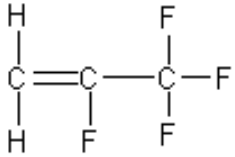
2(d)(ii)	Fuel / LPG	1	Allow camping gas, lighter fuel, propellant, refrigerant, cordless appliances. Do not allow petrol or motor fuel. Ignore natural gas.
2(d)(iii)	$C_4H_{10} + 2.5O_2 \rightarrow 4C + 5H_2O$	1	Accept multiples.
2(d)(iv)	SO ₂ / sulfur dioxide	1	If other sulfur oxides, mark on.
	Calcium oxide / CaO / lime / quicklime	1	Allow CaCO ₃ / allow Ca(OH) ₂ or names. Allow any solid base. M2 dependent on M1. Do not allow limewater.
2(d)(v)	Neutralisation	1	Allow acid-base reaction. Allow flue gas desulfurisation / FGD
2(e)	(Molecules) are similar sizes / have similar M_r / have similar number of electrons	1	Chemical error CE = 0/2 if breaking bonds. Allow similar number of carbon and hydrogen atoms / similar surface area / similar chain length. Can accept same number of carbon atoms. Do not accept same number of H atoms / same number of bonds. Ignore similar amount of bonds.
	Similar van der Waals forces <u>between molecules</u> / similar <u>intermolecular</u> forces (IMF)	1	Not similar incorrect IMF eg dipole-dipole

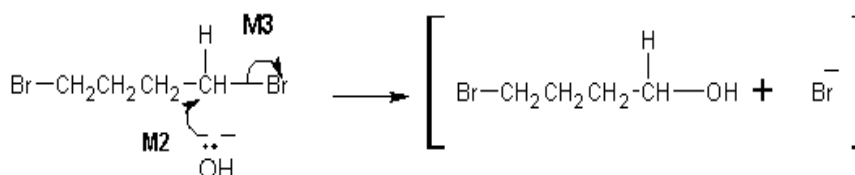
2(c)	<p>M1 Yield increases / goes up</p> <p>M2 The (forward) reaction / to the right is <u>endothermic</u> OR <u>takes in / absorbs heat</u></p> <p>OR</p> <p>The reverse reaction / to the left is <u>exothermic</u> OR <u>gives out / releases heat</u></p> <p>Can only score M3 if M2 is correct</p> <p>M3 The (position of) <u>equilibrium shifts / moves</u> (from left to right) <u>to oppose the increase in temperature (QoL)</u></p>	3	<p>If M1 is given as “decrease” / “no effect” / “no change” then CE= 0 for clip, but mark on only M2 and M3 from a blank M1</p> <p>For M3, <u>not</u> simply “to oppose the change”</p> <p>For M3, credit the (position of) <u>equilibrium shifts / moves (QoL)</u></p> <p>to <u>absorb the heat</u> OR</p> <p>to <u>cool the reaction</u> OR</p> <p>to <u>lower the temperature</u></p> <p>(There must be a <u>specific</u> reference to the change that is opposed)</p>
2(d)(i)	<p>An activity which has no <u>net / overall</u> (annual) carbon emissions <u>to the atmosphere</u></p> <p>OR</p> <p>An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions <u>to the atmosphere</u>.</p> <p>OR</p> <p>There is no change in the <u>total amount / level</u> of carbon dioxide / CO₂ carbon /greenhouse gas present <u>in the atmosphere</u>.</p>	1	<p>The idea that the carbon / CO₂ given out equals the carbon / CO₂ that was taken in from <u>the atmosphere</u></p>
2(d)(ii)	$\text{CH}_3\text{OH} + 1\frac{1}{2}\text{O}_2 \longrightarrow \text{CO}_2 + 2\text{H}_2\text{O}$	1	<p>Ignore state symbols</p> <p>Accept multiples</p>

2(d)(iii)	$3\text{H}_2 + 1\frac{1}{2}\text{O}_2 \longrightarrow 3\text{H}_2\text{O}$ <p>OR</p> $2\text{H}_2 + \text{O}_2 \longrightarrow 2\text{H}_2\text{O}$	1	Ignore state symbols Accept multiples Extra species must be crossed through
2(e)	<p>M1 $q = m c \Delta T$ OR $q = 140 \times 4.18 \times 7.5$</p> <p>M2 = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ) (also scores M1)</p> <p>M3 Using 0.0110 mol therefore $\Delta H = -\underline{399}$ (kJmol^{-1}) OR $-\underline{400}$</p> <p>+399 or +400 gains 2 marks</p>	3	Award full marks for <u>correct answer</u> Ignore the case for each letter Penalise M3 ONLY if correct numerical answer but sign is incorrect; +399 gains 2 marks Penalise M2 for arithmetic error and mark on In M1 , do not penalise incorrect cases in the formula If $\Delta T = 280.5$; score $q = m c \Delta T$ only If $c = 4.81$ (leads to 5050.5) penalise M2 ONLY and mark on for M3 = - 459 Ignore incorrect units

Question	Marking Guidance	Mark	Comments
6(a)(i)	<p>M1 Initiation $\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$</p> <p>M2 First propagation $\text{Cl}\cdot + \text{CH}_2\text{Cl}_2 \longrightarrow \cdot\text{CHCl}_2 + \text{HCl}$</p> <p>M3 Second propagation $\text{Cl}_2 + \cdot\text{CHCl}_2 \longrightarrow \text{CHCl}_3 + \text{Cl}\cdot$</p>	3	Penalise absence of dot once only. Penalise + or – charges every time Accept dot anywhere on CHCl_2 radical but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only Penalise once only for a line and two dots to show a bond. Penalise once only for double headed curly arrows Mark independently
6(a)(ii)	<p>M1 Condition ultra-violet / uv / sun light OR <u>high</u> temperature OR $400^\circ\text{C} \leq T \leq 900^\circ\text{C}$</p> <p>M2 Type of mechanism (free-) <u>radical substitution</u> (mechanism)</p>	2	
6(b)(i)	$\text{CHCl}_3 + \text{Cl}_2 \longrightarrow \text{CCl}_4 + \text{HCl}$	1	Allow X as alternative to CCl_4 only if X is clearly identified as CCl_4

6(c)	<p>M1 a statement about bond breakage / formation of Cl• <u>C-Cl / carbon-chlorine bond breakage</u> occurs OR Cl• / chlorine (free) radical <u>forms</u> OR correct equation $\text{CHClF}_2 \longrightarrow \text{Cl}\cdot + \cdot\text{CHF}_2$</p> <p>M2 $\text{Cl}\cdot + \text{O}_3 \longrightarrow \text{ClO}\cdot + \text{O}_2$ M3 $\text{ClO}\cdot + \text{O}_3 \longrightarrow \text{Cl}\cdot + 2\text{O}_2$ M4 CHClF₂ / chlorine-containing compounds/ CFCs <u>damage / react with / decrease</u> the ozone layer OR this overall decomposition occurs; $2\text{O}_3 \longrightarrow 3\text{O}_2$ OR without an ozone layer or with a decreased ozone layer, uv radiation is not being “filtered” / prevented from passing through the atmosphere or there is a concern about an increase in skin cancer etc. OR Cl• catalyses the decomposition of ozone / a single Cl• causes (chain) reaction / decomposition of many ozone molecules / ozone layer</p>	4	<p>Penalise M1, if Cl• is formed from Cl₂ as the only reaction or an additional reaction</p> <p>Do not penalise an incorrect equation using CHClF₂ if correct reference is made to Cl• formation or C-Cl / carbon-chlorine bond breakage</p> <p>M2 and M3 either order</p> <p>Penalise absence of dot once only. Accept dot anywhere on ClO radical</p> <p>Award M4 for the general idea behind the EU justification for banning the use of CFCs as refrigerants</p> <p>Penalise M4 if overall ozone decomposition equation is incorrect</p> <p>Ignore “greenhouse effect”, “global warming” etc.</p>
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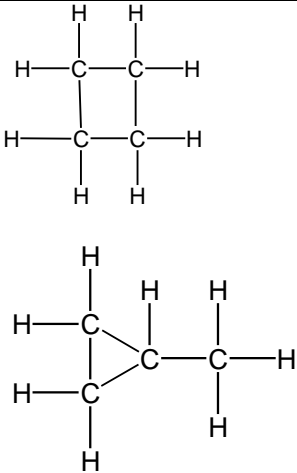
6(d)(i)		1	All bonds must be drawn out
6(d)(ii)	<p>2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / C-Cl (bonds)</p> <p>OR</p> <p>It does not produce Cl• / does not produce chlorine (free) radical(s)</p> <p>OR</p> <p>chlorodifluoromethane does contain chlorine / does produce Cl• / does produce chlorine (free) radical(s)</p> <p>OR</p> <p>C-F is too strong and does not break / create radicals</p> <p>OR</p> <p>C-F is stronger than C-Cl</p>	1	Ignore “chlorine molecules”

8(b)(i)	<p>M1 <u>nucleophilic substitution</u></p>  <p>M2 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom.</p> <p>M3 must show the movement of a pair of electrons from the C—Br bond to the Br atom. Mark M3 independently provided it is from the <u>original molecule</u></p> <p>For M2 and M3 award full marks for an S_N1 mechanism</p> <p>NB The arrows here are double-headed</p>	3	<p>For M1, both words required</p> <p>Penalise M2 if covalent NaOH / KOH is used</p> <p>Penalise one mark from M2 or M3 if half-headed arrows are used</p> <p>Penalise M3 for formal charge on C of the C-Br or incorrect partial charges on C-Br</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>For M2 and M3, maximum 1 of 2 marks for the mechanism if wrong reactant is used.</p> <p>Penalise M3 if an extra arrow is drawn from the Br of the C-Br bond to, for example, K⁺</p> <p>Accept the correct use of “sticks”</p>
8(b)(ii)	<p>M1 B</p> <p>M2 C</p> <p>M3 A</p>	3	

Question	Marking Guidance	Mark	Comments
3(a)(i)	Crude oil / oil / petroleum	1	Do not allow 'petrol'
3(a)(ii)	Fractional distillation / fractionation / fractionating	1	Not distillation alone
3(b)(i)	5	1	Allow five / V
3(b)(ii)	Chain (isomerism)	1	Allow branched chain / chain branched / side chain (isomerism) Ignore position (isomerism) Do not allow straight chain / geometric / branched / function
3(c)(i)	$C_{12}H_{26}$ / $H_{26}C_{12}$	1	Only
3(c)(ii)	<u>Thermal</u> cracking High temperature ($400^{\circ}C \leq T \leq 900^{\circ}C$) or ($650 K \leq T \leq 1200 K$) and High pressure ($\geq 10 \text{ atm}$, $\geq 1 \text{ MPa}$, $\geq 1000 \text{ kPa}$)	1 1	If not thermal cracking, CE = 0/2 If blank mark on Allow 'high heat' for 'high temperature' Not 'heat' alone If no T, units must be 650 - 900
3(c)(iii)	To produce substances which are (more) in demand / produce products with a high value / products worth more	1	Ignore 'to make more useful substances'

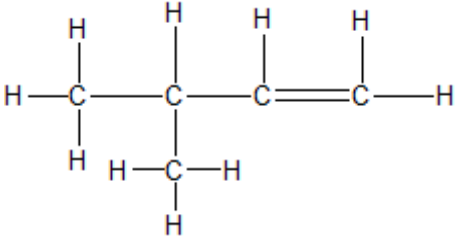
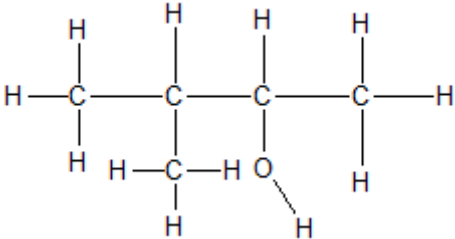
3(d)(i)	Corrosive or diagram to show this hazard symbol	1	Ignore irritant, acidic, toxic, harmful
3(d)(ii)	$\left(\frac{120.5}{86 + 71} \times 100 \right)$ =76.75(%) or 76.8(%)	1	Allow answers > 3 sig figs
3(e)	2,2-dichloro-3-methylpentane C ₃ H ₆ Cl	1 1	Ignore punctuation Any order

Question	Marking Guidance	Mark	Comments
4(a)(i)	$C_8H_{18} + 8\frac{1}{2} O_2 \rightarrow 8CO + 9H_2O$	1	Accept multiples
4(a)(ii)	Not enough oxygen or air (available for complete combustion) /lack of oxygen or air / too much octane	1	Ignore poor ventilation, low temp, poor mixing, incomplete combustion
4(b)(i)	$2CO + 2NO \rightarrow 2CO_2 + N_2$	1	Allow multiples
4(b)(ii)	Pt / Pd / Rh / Ir or names Big(ger) surface area / increased reaction rate / removes more of the gases / ensures complete reaction	1	Apply list principle
		1	Allow (ceramic) withstands high temperatures
4(c)(i)	Acid rain	1	Allow consequence of acid rain Ignore greenhouse gas / global warming / ozone
4(c)(ii)	CaO/ lime / CaCO ₃ /limestone Neutralises the gas or words to that effect/it is basic/ SO ₂ is acidic	1	Allow chemical names
		1	Allow 'reacts with it' or 'it is alkaline' Ignore 'absorb'

Question	Marking Guidance	Mark	Comments
2(a)(i)	(Compounds with the) same molecular formula But different structural formula / different displayed formula/different structures / different skeletal formula	1 1	Allow same number and type of atom for M1 Ignore same general formula. M2 dependent on M1 Not different positions of atoms/bonds in space.
2(a)(ii)	But-2-ene	1	Allow but-2-ene. Allow but 2 ene. Ignore punctuation.
2(a)(iii)	(2)-methylprop-(1)-ene	1	Do not allow 2-methyleprop-1-ene.
2(a)(iv)		1	Do not allow skeletal formulae. Penalise missing H and missing C
2(b)(i)	$C_4H_8 + 2O_2 \rightarrow 4C + 4H_2O$	1	Accept multiples.

2(b)(ii)	Exacerbates asthma / breathing problems / damages lungs / smog / smoke / global dimming	1	Ignore toxic / pollutant / soot / carcinogen. Do not allow greenhouse effect / global warming / acid rain / ozone.
2(c)(i)	$C_{16}H_{34}$	1	Allow $H_{34}C_{16}$ C and H must be upper case.
2(c)(ii)	Jet fuel / diesel / (motor) fuel / lubricant / petrochemicals / kerosene / paraffin / central heating fuel / fuel oil	1	Ignore oil alone. Not petrol / bitumen / wax / LPG / camping fuel.
2(d)(i)	$C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5 N_2 + 9H_2O$	1	Accept multiples.
2(d)(ii)	Ir / iridium OR Pt / platinum OR Pd / palladium OR Rh / rhodium	1	

Question	Marking Guidance	Mark	Comments
5(a)(i)	<p>M1 Elimination</p> <p>M2 must show an arrow from the <u>lone pair on the oxygen</u> of a negatively charged hydroxide ion <u>to a correct H atom</u></p> <p>M3 must show an arrow from a correct C–H bond adjacent to the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in M2</p> <p>M4 is independent provided it is from their <u>original molecule</u>, BUT CE=0 for the mechanism (penalise M2, M3 and M4 only) if nucleophilic substitution mechanism is shown</p> <p>Award full marks for an E1 mechanism in which M4 is on the correct carbocation</p> <p>NB These are double-headed arrows</p>	4	<p>M1 Credit “base elimination” but no other prefix.</p> <p>Penalise M2 if covalent KOH</p> <p>Penalise M4 for formal charge on C or Br of C–Br or incorrect partial charges on C–Br</p> <p>Ignore other partial charges.</p> <p>Penalise once only in any part of the mechanism for a line and two dots to show a bond.</p> <p>Maximum any 2 of 3 marks for the mechanism for wrong organic reactant or wrong organic product (if shown).</p> <p>Credit the correct use of “sticks” for the molecule except for the C–H being attacked.</p> <p>Penalise M4, if an additional arrow is drawn from Br eg to K+</p>

5(a)(ii)	<p><u>Displayed formula</u> for 3-methylbut-1-ene</p> 	1	All bonds and atoms must be drawn out, but ignore bond angles.
5(a)(iii)	<u>Position(al)</u> (isomerism or isomer)	1	Penalise any other words that are written in addition to these.
5(b)(i)	<p><u>Displayed formula</u> for 3-methylbutan-2-ol</p> 	1	All bonds and atoms must be drawn out, but ignore bond angles.
5(b)(ii)	<p>Any one from</p> <ul style="list-style-type: none"> • <u>Lower / decreased</u> temperature OR <u>cold</u> • <u>Less concentrated (comparative)</u> OR <u>dilute</u> KOH • <u>Water (as a solvent) / (aqueous conditions)</u> 	1	Ignore “pressure”.
5(b)(iii)	<u>Nucleophilic substitution</u>	1	Both words needed – credit phonetic spelling.

5(b)(iv)	(Strong / broad) absorption / peak in the range 3230 to 3550 cm ⁻¹ or specified value <u>in this range</u> or <u>marked correctly</u> on spectrum	1	Allow the words “dip” OR “spike” OR “trough” OR “low transmittance” as alternatives for absorption.
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Question	Marking Guidance	Mark	Comments
7(a)	<p>Initiation $\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$</p> <p>First propagation $\text{Cl}\cdot + \text{CH}_3\text{Cl} \longrightarrow \cdot\text{CH}_2\text{Cl} + \text{HCl}$</p> <p>Second propagation $\text{Cl}_2 + \cdot\text{CH}_2\text{Cl} \longrightarrow \text{CH}_2\text{Cl}_2 + \text{Cl}\cdot$</p> <p>Termination (must make 1,2-dichloroethane) $2 \cdot\text{CH}_2\text{Cl} \longrightarrow \text{CH}_2\text{ClCH}_2\text{Cl}$</p>	4	Penalise absence of dot once only. Credit the dot anywhere on the radical. Penalise $\text{C}_2\text{H}_4\text{Cl}_2$
7(b)(i)	(chlorine free) <u>radical</u>	1	Ignore formula.
7(b)(ii)	<p>M1 $\text{Cl}\cdot + \text{O}_3 \longrightarrow \text{ClO}\cdot + \text{O}_2$</p> <p>M2 $\text{ClO}\cdot + \text{O}_3 \longrightarrow \text{Cl}\cdot + 2\text{O}_2$</p>	2	<p>M1 and M2 could be in either order.</p> <p>Credit the dot anywhere on the radical.</p> <p>Penalise absence of dot once only.</p> <p>Individual multiples acceptable but both need to be doubled if two marks are to be awarded.</p>

Question	Marking Guidance	Mark	Comments
8(a)	Structure for 3-methylbut-1-ene $\text{H}_2\text{C}=\text{CHCH}(\text{CH}_3)_2$	1	Any correct structural representation. Credit “sticks” and require the double bond.
8(b)	Structure for 2-methylpropan-2-ol $(\text{CH}_3)_3\text{COH}$	1	Any correct structural representation. Credit “sticks”.
8(c)	Structure for propene $\text{H}_2\text{C}=\text{CHCH}_3$	1	Any correct structural representation. Credit “sticks” and require the double bond.
8(d)	Structure for 2-aminobutane $\text{CH}_3\text{CH}_2\text{CH}(\text{NH}_2)\text{CH}_3$	1	Any correct structural representation. Credit “sticks”.

Question	Marking Guidance	Mark	Comments
4(a)	Fractional distillation / fractionation / GLC / gas liquid chromatography	1	
4(b)	C ₄ H ₁₀ Because it has a higher bp / has stronger IMF / larger molecule / longer chain / larger surface (area)	1	Need C ₄ H ₁₀ and the reason for the mark
4(c)	C ₄ H ₁₀ + 6½ O ₂ → 4CO ₂ + 5H ₂ O	1	Accept multiples Ignore state symbols
4(d)	CO ₂ or H ₂ O evolved is a greenhouse gas / CO ₂ or H ₂ O evolved contribute to global warming / the products are greenhouse gases	1	Ignore climate change
4(e)	CH ₃ CH ₂ CH ₂ CH ₃ + 3.5O ₂ → C ₂ H ₂ (CO) ₂ O + 4H ₂ O	1	Accept multiples Allow with or without a number 1 before the organic molecules
4(f)(i)	C ₂ H ₅ SH + 4.5O ₂ → 2CO ₂ + 3H ₂ O + SO ₂	1	Accept multiples
4(f)(ii)	Calcium oxide / calcium carbonate Neutralises the SO ₂ / acid base reaction / it is a base	1 1	Allow any base or alkali Allow correct formulae Can only score M2 if base or alkali used in M1 Allow M2 if blank in M1

4(f)(iii)	Ethanol contains Hydrogen bonding Which is stronger than IMF (VDW / dipole-dipole forces) in ethanethiol/ (H bonding) is the strongest IMF	1 1	Breaking covalent bonds CE = 0/2 Only award M2 if M1 given, but allow IMF in ethanol are stronger than in ethanethiol for maximum 1 mark
4(g)(i)	(2,2-)dimethylpropane	1	Ignore punctuation
4(g)(ii)	Because molecule is smaller / less polarisable / has less surface (area)/ is more spherical / molecules can't get as close to one another (to feel the vdW forces) <u>vdW intermolecular forces or vdW force between molecules are weaker or fewer</u>	1 1	Allow converse answers referring to straight chain isomers CE = 0/2 if breaking bonds Need vdW rather than just IMF
4(g)(iii)	1 or one	1	
4(h)(i)	C ₉ H ₂₀	1	H ₂₀ C ₉
4(h)(ii)	Thermal (cracking) High pressure AND high temperature OR Pressure of ≥ 10 atm, ≥ 1 MPa ≥ 1000 kPa AND temp of $400\text{ }^{\circ}\text{C} \leq T \leq 1000\text{ }^{\circ}\text{C}$ or $650\text{ K} \leq T \leq 1300\text{ K}$	1 1	If not thermal cracking CE = 0/2 If blank mark on Allow high P and T Do not allow high heat If no units for T, then range must be 650-1000

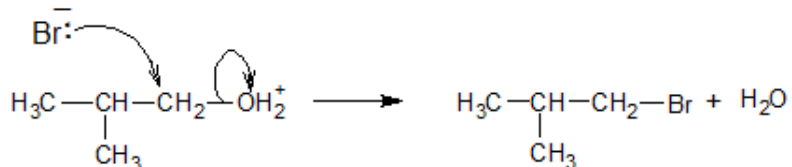
7(c)(i)	$2\text{O}_3 \longrightarrow 3\text{O}_2$	1	<p>ONLY this equation or a multiple Ignore NO over the arrow Other species must be cancelled</p>
7(c)(ii)	$\text{O} + \text{NO}_2 \longrightarrow \text{NO} + \text{O}_2$	1	<p>ONLY this answer and NOT multiples Ignore any radical dot on the O atom</p>

Question	Marking Guidance	Mark	Comments
5(a)	Crude oil OR petroleum Fractional distillation / fractionation	1 1	Not petrol. Not distillation alone.
5(b)	$C_{12}H_{26} + 12.5O_2 \longrightarrow 12CO + 13H_2O$	1	Allow balanced equations that produce CO_2 in addition to CO Accept multiples.
5(c)(i)	M1 Nitrogen and oxygen (from air) <u>react / combine</u> / allow a correct equation M2 at high temperatures	1 1	If nitrogen from petrol / paraffin / impurities CE=0/2 Allow temperatures above 1000 °C or spark. Not just heat or hot. M2 dependent on M1 But allow 1 mark for nitrogen and oxygen together at high temperatures.
5(c)(ii)	$2NO + O_2 \longrightarrow 2NO_2$	1	Allow multiples.
5(c)(iii)	$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$	1	Allow multiples.
5(d)(i)	C_nH_{2n+2} C_nH_{2n+2}	1	Allow C_xH_{2x+2} Allow C_xH_{2x+2}

5(d)(ii)	$C_{12}H_{26} \longrightarrow C_6H_{14} + C_6H_{12}$	1	Only.
	C_3H_7	1	Only.
	Zeolite / aluminosilicate(s)	1	Ignore aluminium oxide.
5(d)(iii)	Larger molecule / longer carbon chain / more electrons / larger surface area	1	Allow dispersion forces / London forces / temporary induced dipole-dipole forces <u>between molecules</u> . If breaking bonds, CE = 0/2
	More / stronger <u>van der Waals' forces between molecules</u>	1	
5(e)	2,2,3,3,4,4-hexamethylhexane	1	Only.
	Chain	1	Ignore punctuation. Ignore branch(ed).
5(f)	Cl_2	1	Only. Not CL_2 or $Cl2$ or $CL2$ or Cl^2 or CL^2 Ignore Chlorine.
	Cl-Cl		

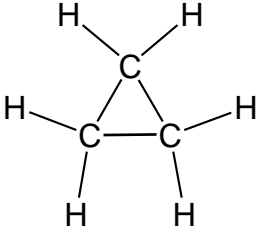
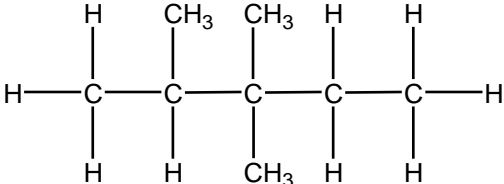
Question	Marking Guidance	Mark	Comments
5(a)(i)	<p>M1 Initiation $\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$</p> <p>M2 First propagation $\text{Cl}\cdot + \text{CHF}_3 \longrightarrow \text{CF}_3\cdot + \text{HCl}$</p> <p>M3 Second propagation $\text{Cl}_2 + \text{CF}_3\cdot \longrightarrow \text{CClF}_3 + \text{Cl}\cdot$</p> <p>M4 Termination (must make C₂F₆) $2 \text{CF}_3\cdot \longrightarrow \text{C}_2\text{F}_6 \text{ or } \text{CF}_3\text{CF}_3$</p>	4	<p>Penalise absence of dot once only.</p> <p>Penalise + or – charges <u>every time</u></p> <p>Credit $\text{CF}_3\cdot$ with the radical dot above / below / to either side.</p> <p>Mark independently.</p>
5(a)(ii)	<p>ultra-violet / uv / sun light</p> <p>OR (very) high temperature</p> <p>OR $500\text{ }^\circ\text{C} \leq T \leq 1000\text{ }^\circ\text{C}$</p> <p>OR $773\text{ K} \leq T \leq 1273\text{ K}$</p>	1	

5(b)(i)	Cl• OR chlorine atom / chlorine (free-) radical / Cl (atom)	1	Not 'chlorine' alone. Credit 'Cl' alone on this occasion.
5(b)(ii)	$2\text{O}_3 \longrightarrow 3\text{O}_2$	1	Or multiples. Ignore state symbols. If the correct answer is on the line OR clearly identified below some working, then ignore any working.

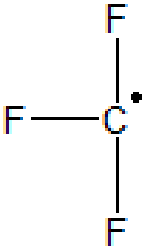
Question	Marking Guidance	Mark	Comments
8(a)(i)	<p>M1 double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH₂</p> <p>M2 double-headed arrow from the bond to the O atom</p> <p>As follows</p> 	2	Penalise additional arrows.
8(a)(ii)	<p>M1 <u>nucleophilic substitution</u></p> <p>M2 1-bromo(-2-)methylpropane</p>	2	<p>M1 both words needed (allow phonetic spelling).</p> <p>M2 Require correct spelling in the name but ignore any hyphens or commas.</p>

8(b)	<p>M1 hydrolysis</p> <p>M2 <u>C≡N</u> with absorption range <u>2220–2260</u> (cm^{-1})</p> <p>M3 <u>O–H(acids)</u> with absorption range <u>2500–3000</u> (cm^{-1}) OR <u>C=O</u> with absorption range <u>1680–1750</u> (cm^{-1}) OR <u>C–O</u> with absorption range <u>1000–1300</u> (cm^{-1})</p>	3	<p>For M1 give credit for 'hydration' on this occasion only.</p> <p>Credit 1 mark from M2 and M3 for identifying C≡N and either O–H(acids) or C=O or C–O without reference to wavenumbers or with incorrect wavenumbers.</p> <p>Apply the list principle to M3</p>
8(c)(i)	<p>M1 Yield / product OR ester increases / goes up / gets more</p> <p>M2 (By Le Chatelier's principle) the position of <u>equilibrium is driven / shifts / moves to the right / L to R / in the forward direction / to the product(s)</u></p> <p>M3 – requires a correct statement in M2 (The position of equilibrium moves) to <u>oppose the increased concentration of ethanol</u> to <u>oppose the increased moles of ethanol</u> to <u>lower the concentration of ethanol</u> to <u>oppose the change and decrease the ethanol</u></p>	3	<p>If no reference to M1, marks M2 and M3 can still score BUT if M1 is incorrect CE=0</p> <p>If there is reference to 'pressure' award M1 ONLY.</p>

Question	Marking Guidance	Mark	Comments
6(a)	Saturated – single bonds only / no double bonds	1	
	Hydrocarbon – contains carbon and hydrogen (atoms) <u>only</u>	1	
6(b)	$C_{16}H_{34} + 16.5O_2 \longrightarrow 16CO + 17H_2O$	1	Allow multiples
6(c)	(On combustion) SO_2 produced	1	Allow equation to produce SO_2 . Ignore sulfur oxides. If formula shown it must be correct M2 is dependent on M1. But if M1 is sulfur oxides, allow M2. For M2 allow consequence of acid rain or SO_2 . Ignore greenhouse effect and toxic
	Which causes acid rain	1	
6(d)(i)	$C_{16}H_{34} \longrightarrow C_8H_{18} + C_2H_4 + 2C_3H_6$	1	Allow multiples

6(d)(ii)	polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal	1	Accept alternative names Ignore plastic and polymer
6(d)(iii)		1	
6(e)		1	Allow any unambiguous representation
6(f)	2,4-dichloro-2,4-dimethylhexane	1	Only but ignore punctuation

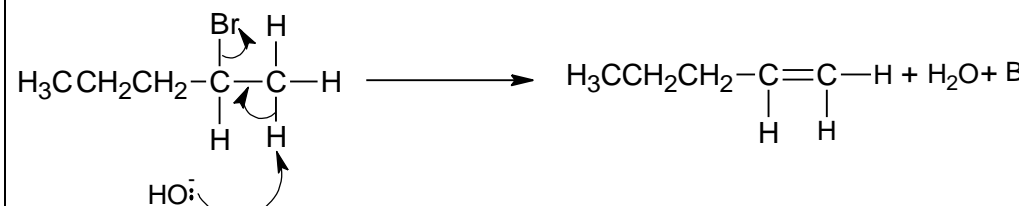
Question	Marking Guidance	Mark	Comments
5(a)(i)	<p>Initiation $\text{Br}_2 \longrightarrow 2\text{Br}\cdot$</p> <p>First propagation $\text{Br}\cdot + \text{CHF}_3 \longrightarrow \cdot\text{CF}_3 + \text{HBr}$</p> <p>Second propagation $\text{Br}_2 + \cdot\text{CF}_3 \longrightarrow \text{CBrF}_3 + \text{Br}\cdot$</p> <p>Termination $2\cdot\text{CF}_3 \longrightarrow \text{C}_2\text{F}_6$ OR CF_3CF_3 OR $2\text{Br}\cdot \longrightarrow \text{Br}_2$ OR $\text{Br}\cdot + \cdot\text{CF}_3 \longrightarrow \text{CBrF}_3$</p>	4	<p>Penalise absence of dot once only</p> <p>Credit the dot anywhere on the radical</p>

5(a)(ii)	Ultra-violet / uv / sunlight OR T > 100°C OR <u>high</u> temperature	1	
5(b)(i)		1	Displayed formula required with the radical dot on carbon
5(b)(ii)	(The) <u>C—Br</u> (bond) breaks more readily / is weaker than (the) <u>C—Cl</u> (bond) (or converse) OR The <u>C—Br bond enthalpy / bond strength</u> is less than that for <u>C—Cl</u> (or converse)	1	Requires a comparison between the two bonds Give credit for an answer that suggests that the UV frequency / energy may favour <u>C—Br</u> bond breakage rather than <u>C—Cl</u> bond breakage Ignore correct references either to size, polarity or electronegativity Credit correct answers that refer to, for example “the bond between carbon and bromine requires less energy to break than the bond between carbon and chlorine”

5(b)(iii)	<p>M1 $\text{Br}\cdot + \text{O}_3 \longrightarrow \text{BrO}\cdot + \text{O}_2$</p> <p>M2 $\text{BrO}\cdot + \text{O}_3 \longrightarrow \text{Br}\cdot + 2\text{O}_2$</p> <p>M3 One of the following They / it / the bromine (atom)</p> <ul style="list-style-type: none">• does not appear in the overall equation• is regenerated• is unchanged <u>at the end</u>• has <u>not been used up</u>• provides an alternative route / mechanism	3	<p>M1 and M2 could be in either order Credit the dot anywhere on the radical Penalise absence of dot once only Penalise the use of multiples once only</p>
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Question	Marking Guidance	Mark	Comments
4(a)(i)	Alk <u>a</u> ne(s)	1	Ignore C _n H _{2n+2}
4(a)(ii)	C ₈ H ₁₈ + 12.5O ₂ → 8CO ₂ + 9H ₂ O	1	Allow multiples
4(a)(iii)	<u>2, 2, 4-trimethylpentane</u>	1	
4(b)(i)	<u>But-1-ene</u>	1	Ignore (E or Z)
4(b)(ii)	C ₁₄ H ₃₀	1	
4(b)(iii)	Thermal High pressure / 7000kPa / 70 atms <u>and</u> High temperature/temperature in range 400-1000°C (673–1273K)	1 1	If catalytic CE = 0 (allow ≥1000 kPa or ≥10 atms – no upper value) Allow high temperature and pressure or high pressure and temperature If no units for temperature allow 673-1000

Question	Answers	Mark	Additional Comments/Guidance
3a) i.	$\text{CH}_3\text{Cl} + 2\text{Cl}_2 \rightarrow \text{CHCl}_3 + 2\text{HCl}$	1	IGNORE state symbols ALLOW multiples
3a) ii.	(Free-)radical substitution	1	This answer only
3a) iii.	Initiation: $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ 1 st Propagation step $\text{Cl}\cdot + \text{CH}_2\text{Cl}_2 \rightarrow \cdot\text{CHCl}_2 + \text{HCl}$ 2 nd Propagation step $\cdot\text{CHCl}_2 + \text{Cl}_2 \rightarrow \text{CHCl}_3 + \text{Cl}\cdot$ Termination $2 \cdot\text{CHCl}_2 \rightarrow \text{C}_2\text{H}_2\text{Cl}_4$	1 1 1 1	Penalise absence of dot once only Penalise + and/or – charges every time ALLOW \cdot anywhere on $\cdot\text{CHCl}_2$ but, if drawn out as a structure, then \cdot must be on C Mark independently ALLOW $\cdot\text{CH}_2\text{Cl} + \cdot\text{CCl}_3 \rightarrow \text{C}_2\text{H}_2\text{Cl}_4$ IGNORE state symbols throughout
3b) i.	$\text{CClF}_3 \rightarrow \cdot\text{CF}_3 + \text{Cl}\cdot$	1	ALLOW \cdot anywhere on $\cdot\text{CF}_3$ unless displayed
3b) ii.	$\text{Cl}\cdot + \text{O}_3 \rightarrow \text{ClO}\cdot + \text{O}_2$ $\text{ClO}\cdot + \text{O}_3 \rightarrow 2\text{O}_2 + \text{Cl}\cdot$	1 1	Equations can be in either order Penalise absence of \cdot once only ALLOW \cdot anywhere on $\cdot\text{ClO}$ NOT $\cdot\text{O}_3$
Total		9	

Question	Answers	Mark	Additional Comments/Guidance
8(a)	<p>NaOH/KOH</p> <p><i>reaction 1</i> = ethanolic/alcoholic AND <i>reaction 2</i> = aqueous</p> <p>rxn 1 = base/proton acceptor</p> <p>rxn 2 = nucleophile/lone pair donor/electron pair donor</p> <p>(Base) Elimination</p>  <p>M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom</p> <p>M7 must show an arrow from a correct C–H bond on C adjacent to the C of the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in M6</p> <p>M8 is independent provided it is from their original molecule and shows curly arrow from C-Br to Br</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>IGNORE OH⁻</p> <p>NOT M1 if any mention of acidified/H⁺ in reagents or conditions</p> <p>IGNORE temp</p> <p>NOT ethanoic</p> <p>NOT nucleophilic</p> <p>ALLOW correct E1 mechanism</p> <p>IGNORE incorrect inorganic products</p> <p>If forming pent-2-ene can award M8 only even if arrows in mechanism correct</p> <p>If C chain length or halogen wrong in reactant or product max 2/3</p>