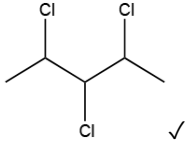
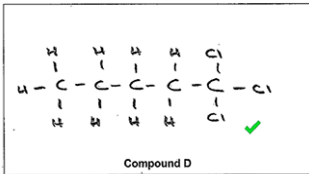


Mark scheme - Alkanes

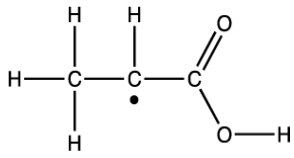
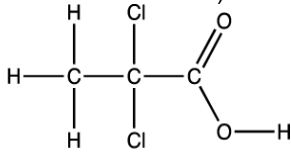
Question	Answer/Indicative content	Marks	Guidance
1	<p>i</p> <p>Initiation</p> $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot \text{ AND UV } \checkmark$ <p>Propagation</p> $\text{C}_4\text{H}_{10} + \text{Cl}\cdot \rightarrow \text{C}_4\text{H}_9\cdot + \text{HCl } \checkmark$ $\text{C}_4\text{H}_9\cdot + \text{Cl}_2 \rightarrow \text{C}_4\text{H}_9\text{Cl} + \text{Cl}\cdot \checkmark$	<p>3 (AO1.1)</p> <p>(AO2.5)</p> <p>(AO2.5)</p>	<p>Dots NOT required for initiation IGNORE temperature OR pressure</p> <p>Dots required in each propagation equation</p> <p>ALLOW 1 mark for BOTH propagation equations with any dots missing or extra dots</p> <p>e.g. $\text{C}_4\text{H}_{10} + \text{Cl} \rightarrow \text{C}_4\text{H}_9 + \text{HCl}$ $\text{C}_4\text{H}_9\cdot + \text{Cl}_2 \rightarrow \text{C}_4\text{H}_9\text{Cl} + \text{Cl}$</p> <p>DO NOT ALLOW charges</p> <p>Examiner's Comments</p> <p>A minority of Many candidates scored all 3 marks for this part, showing that most had thoroughly learnt the mechanism for radical substitution. The equation and conditions for the initiation step were well-known but the equations for the propagation steps often included errors. It was common for dots to be omitted for some radicals and $\text{C}_4\text{H}_9\text{Cl}\cdot$, rather than $\text{C}_4\text{H}_9\cdot$, was often shown for one of the products in the first propagation stage. $\text{H}\cdot$ was then shown as the other product.</p>
	<p>ii</p> $\text{C}_4\text{H}_{10} + 10 \text{Cl}_2 \rightarrow \text{C}_4\text{Cl}_{10} + 10 \text{HCl } \checkmark$	<p>1 (AO2.6)</p>	<p>ALLOW structural formulae, e.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 + 10\text{Cl}_2$ $\rightarrow \text{CCl}_3\text{CCl}_2\text{CCl}_2\text{CCl}_3 + 10\text{HCl}$</p> <p>Examiner's Comments</p> <p>Only the highest attaining candidates were able to write the correct equation. Although most candidates did identify the organic product as C_4Cl_{10}, the other product was usually seen as 5H_2 rather than 10HCl.</p>
	<p>iii</p> $n(\text{E}) = \frac{78.0}{32500} = 2.4(0) \times 10^{-3} \text{ (mol) } \checkmark$ $M(\text{E}) = \frac{0.636}{2.4(0) \times 10^{-3}} \text{ OR } 265 \checkmark$ <p>Molecular formula = $\text{C}_4\text{H}_4\text{Cl}_6 \checkmark$</p>	<p>3 (AO3.1×2)</p> <p>(AO3.2)</p>	<p>ALLOW ECF from incorrect $n(\text{E})$ ALLOW ECF from incorrect $M(\text{E})$ from $n(\text{E})$</p>

					<p>-----</p> <p>COMMON ERROR</p> $n(\text{E}) = \frac{78.0}{24000} = 3.25 \times 10^{-3} \text{ (mol)} \quad \times$ $M(\text{E}) = \frac{0.636}{3.25 \times 10^{-3}} = 195.69 \text{ OR } 196 \quad \checkmark$ <p style="text-align: right;">(3SF or more)</p> <p>Molecular formula = C⁴H⁶Cl⁴ ✓</p> <p>ALLOW ECF for molecular formula but must be derived from a calculated value for <i>M</i>(E)</p> <p>Examiner's Comments</p> <p>A minority of This question discriminated very well. It was encouraging to see the number of candidates who used 32.5 dm³ mol⁻¹ as the molar gas volume under the experimental conditions to obtain 2.40 × 10⁻³ mol of gas. Many though used 24.0 dm³ mol⁻¹ for RTP and obtained 3.25 × 10⁻³ mol. Error carried forward allowed such candidates to still secure the final 2 of the 3 marks available.</p> <p>Lower attaining candidates were unsure where to start and tried to do anything with the number provided. The result was often n unusable number.</p>
			Total	7	
2	a		<p>Structural isomers: 1 mark</p> <p>Different structural formulae AND same molecular formula ✓</p> <p>Common molecular formula: 1 mark</p> <p>C₅H₁₂ for all 3 hydrocarbons ✓</p>	5	<p>For 'structural': ALLOW different structure OR different displayed/ skeletal formula</p> <p>DO NOT ALLOW any reference to spatial/space/3D</p> <p>Same formula is not sufficient (no 'molecular')</p> <p>Different arrangement of atoms is not sufficient (no 'structure'/'structural')</p> <p>ALLOW 5 carbons and 12 hydrogens</p> <p>ALLOW for 2 marks: Different structural formulae AND same molecular formula ✓ of C₅H₁₂ ✓</p>

			<p>Boiling point and branching:</p> <p>1 mark</p> <p>Boiling point decreases with</p> <p>more branching</p> <p>OR more methyl/alkyl groups/side chains</p> <p>OR shorter carbon chain ✓</p> <p>Branching and London forces: 1 mark</p> <p><i>Could be seen anywhere within response</i></p> <p>More branching gives less (surface) contact</p> <p>AND</p> <p>fewer/weaker London forces ✓</p> <p>Energy and intermolecular forces: 1 mark</p> <p>Less energy to break London forces/intermolecular forces/intermolecular bonds/ ✓</p>	<p>Comparisons needed throughout ORA throughout</p> <p>ALLOW comparison between any alcohols, e.g. A is least branched and has highest b pt C is most branched and has lowest b pt</p> <p>ALLOW induced dipole(-dipole) interactions IGNORE van der Waals'/vdw forces ALLOW SA for surface area</p> <p>ALLOW 'harder to overcome intermolecular forces' ALLOW more energy to separate the molecules</p> <p>IGNORE just 'bonds' <i>intermolecular/London forces required</i></p> <p>Examiner's Comments</p> <p>This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C₅H₁₂. Candidates were expected to link the amount of surface contact between molecules with induced dipole-dipole forces or London forces. 'Contact' or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.</p>
b	i	Radical substitution ✓	1	<p>ALLOW Free radical substitution</p> <p>Examiner's Comments</p> <p>Most candidates identified this reaction as radical substitution.</p>

		ii	<table border="1" data-bbox="300 241 753 338"> <thead> <tr> <th>A</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>3 ✓</td> <td>2 ✓</td> </tr> </tbody> </table>	A	B	3 ✓	2 ✓	2	<p>Examiner's Comments</p> <p>Most candidates achieved at least one mark, particularly for isomer A. Successful candidates often drew structures of the isomers alongside the table to help with their response.</p>
A	B								
3 ✓	2 ✓								
		iii	<p>Structure of D</p> <p>Structure of a trichloro isomer of A, e.g.</p>  <p>ALLOW any trichloro isomer of A CHECK carefully</p> <p>Equation</p> $\text{C}_5\text{H}_{12} + 3\text{Cl}_2 \rightarrow \text{C}_5\text{H}_9\text{Cl}_3 + 3\text{HCl} \checkmark$ <p>Molecular formulae required</p> <p>NO ECF from incorrect structure of D</p>	2	<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>IGNORE molecular formula</p> <p>ALLOW multiples, e.g. $2\text{C}_5\text{H}_{12} + 6\text{Cl}_2 \rightarrow 2\text{C}_5\text{H}_9\text{Cl}_3 + 6\text{HCl}$</p> <p>Examiner's Comments</p> <p>Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a correct equation for its formation. Many attempts at this equation showed H_2 as the second product rather than HCl.</p> <p>Exemplar 6</p> <p>(iii) The reaction of compound A with excess chlorine forms a compound D, which has a molar mass of 175.5 g mol^{-1}.</p> <p>Draw a possible structure for compound D and write the equation for its formation from compound A. Use molecular formulae in the equation.</p>  <p>Equation $\text{C}_5\text{H}_{12} + 3\text{Cl}_2 \rightarrow \text{C}_5\text{H}_9\text{Cl}_3 + 3\text{HCl}$ [2]</p>				

			Total	10	
3		i	Ultraviolet (radiation)/UV ✓	1	<p>ALLOW sunlight IGNORE temperature</p> <p>Examiner's Comments</p> <p>Most candidates scored this mark.</p>
		ii	$\text{CH}_3\text{CH}_2\text{COOH} + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{HCl}$ ✓	1	<p>ALLOW $\text{C}_2\text{H}_5\text{COOH} + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{ClCOOH} + \text{HCl}$ ALLOW $\text{C}_3\text{H}_6\text{O}_2 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{HCl}$</p> <p>Examiner's Comments</p> <p>Many candidates could write the overall equation but there was some confusion with propagation steps and some equations contained radicals or missed out HCl as a product.</p>
		iii	one electron from the bond (pair) goes to each atom / chlorine/radical ✓	1	<p>ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron from the bond goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations</p> <p>Examiner's Comments</p> <p>Homolytic fission is described in the specification in terms of each bonding atom receiving one electron from the bonded pair forming two radicals. A large proportion of candidates failed to match the essential points in this definition.</p>
		iv	<p><i>Propagation step 1</i> $\text{Cl}\cdot + \text{CH}_3\text{CH}_2\text{COOH} \rightarrow \text{CH}_3\text{CHCOOH}\cdot + \text{HCl}$ ✓</p> <p><i>Propagation step 2</i> $\text{CH}_3\text{CHCOOH}\cdot + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{Cl}\cdot$ ✓</p>	2	<p>ALLOW</p> <p>1. $\text{Cl}\cdot + \text{C}_3\text{H}_6\text{O}_2 \rightarrow \text{C}_3\text{H}_5\text{O}_2\cdot + \text{HCl}$ 2. $\text{C}_3\text{H}_5\text{O}_2\cdot + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{Cl}\cdot$</p> <p>ALLOW dot at any position on the radical ALLOW 1 mark if both equations correct but any dots omitted from radicals</p> <p>Examiner's Comments</p> <p>Generally well answered. Candidates took note of the instruction in the question and it was very rare to see radicals without their unpaired electron.</p>

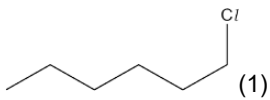
		v	<p>✓</p> 	1	<p>Dot shown in correct position</p> <p>ALLOW –OH</p> <p>Examiner's Comments</p> <p>Unfortunately, candidates who were not able to attempt equations for the propagation steps in part (iv) were then unable to suggest the structure of the radical formed in the first step. Many candidates did not present a fully displayed formula. However, formulae showing –OH were given credit in this question.</p>
		vi	<p>Any structure with two or more Cl atoms on alkyl chain (provided that one Cl is at C-2)</p>  <p>e.g. ✓</p>	1	<p>ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above</p> <p>DO NOT ALLOW C₃H₄Cl₂O₂</p> <p>ALLOW further substitution into any or all of the 4 positions occupied by H atoms in the alkyl group, provided that at least one Cl is at C-2</p> <p>Examiner's Comment:</p> <p>Generally well answered but it was clear from some of the structures drawn that some candidates did not understand what is meant by further substitution.</p>
		Total		7	
4			<p>Alcohols have hydrogen bonds (and van der Waals' forces) ✓</p> <p>Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW reference to specific compounds e.g. comparing methane and methanol</p> <p>Second marking point requires BOTH types of intermolecular forces in response i.e comparison of hydrogen bonds AND van der Waals is essential</p> <p>DO NOT ALLOW the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water</p> <p>ALLOW more energy required to break hydrogen bonds than van der Waals' forces</p>

					<p>ALLOW it is harder to overcome the hydrogen bonds than van der Waals' forces</p> <p>IGNORE more energy is needed to break bonds</p> <p>Examiner's Comments</p> <p>Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.</p>
			Total	2	
5		i	$\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O} \checkmark$	1	<p>ALLOW multiples e.g. $2\text{C}_8\text{H}_{18} + 25\text{O}_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O}$</p> <p>IGNORE state symbols</p> <p>Examiner's Comments</p> <p>Almost all candidates could provide a correctly balanced equation for the complete combustion of octane.</p>
		ii	<p>$(n(\text{C}_8\text{H}_{18}) \text{ burned}) = 0.32 \text{ (mol)} \checkmark$</p> <p>$(n(\text{CO}_2) \text{ from complete combustion}) = 2.56$ or 2.6 mol</p> <p>OR</p> <p>$(\text{ratio } n\text{CO}_2 / n\text{C}_8\text{H}_{18}) = 7.8(125)$</p> <p>OR</p> <p>$(n \text{ C}_8\text{H}_{18} \text{ produce } 2.5 \text{ mol CO}_2) = 0.31(25)$ \checkmark</p>	2	<p>DO NOT ALLOW ECF from an incorrect moles of octane</p> <p>DO NOT ALLOW ECF from incorrect ratio from equation in (i)</p> <p>ALLOW the following alternate methods</p> <hr/> <p>Method 1</p> <p>$(\text{mass CO}_2 \text{ produced}) = 110 \text{ g} \checkmark$</p> <p>$(\text{mass CO}_2 \text{ from complete combustion}) = 8 \times 0.32 \times 44 = 112.64 \text{ or } 112.6 \text{ or } 113 \text{ g} \checkmark$</p> <hr/> <p>Method 2</p> <p>$(n \text{ C}_8\text{H}_{18} \text{ to produce } 2.5 \text{ mol CO}_2) = 0.31(25)$ \checkmark</p>

					<p>(mass of octane required to produce 2.50 mol CO₂) = 35.6 OR 35.63 OR 35.625 g ✓</p> <p>Examiner's Comments</p> <p>Candidates coped well with this unfamiliar question. Almost all candidates recognised the need to calculate the number of moles of octane combusted and received the first mark. The majority of candidates were able to process this to show that 2.56 moles of carbon dioxide should have been produced. It was encouraging to see a range of alternative approaches adopted by candidates. For example, some used the calculated moles of octane and the amount of CO₂ given in the question to show that the reacting ratio was less than 8. The mark scheme allowed full marks for all valid responses.</p>
			Total	3	
6	a	i	<p>(series of compounds with the) same functional group OR same / similar chemical properties OR same / similar chemical reactions ✓</p> <p>each successive/subsequent member differing by CH₂ ✓</p>	2	<p>IGNORE references to physical properties IGNORE has same general formula (in question) DO NOT ALLOW have the same empirical formula OR have the same molecular formula</p> <p>Examiner's Comments</p> <p>Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH₂ group. Some responses were imprecise and referred to just members differing by CH₂ group.</p>
		ii	C _n H _{2n} ✓	1	<p>Examiner's Comments</p> <p>Most candidates were able to state the general formula for the cycloalkanes.</p>
		iii	<p>More carbons (in ring) OR more (surface area of) contact</p> <p>AND</p>	2	<p>Both answers need to be comparisons ALLOW ORA throughout</p> <p>ALLOW has more electrons OR larger (carbon) ring OR higher molecular mass IGNORE bigger molecule IGNORE chain instead of ring DO NOT ALLOW 'more contact between</p>

			<p>more van der Waals forces OR stronger van der Waals forces ✓</p> <p>More energy needed to break the intermolecular forces ✓</p>		<p>atoms'</p> <p>ALLOW 'VDW' for van der Waals 'More intermolecular forces' is not sufficient</p> <p>ALLOW it is harder to overcome the intermolecular forces ALLOW intermolecular bonds / van der Waals bonds ALLOW more energy is needed to separate molecules IGNORE more energy is needed to break bonds</p> <p>Examiner's Comments</p> <p>This was a well answered question and many candidates could relate the difference in boiling point to the increase in points of contact and stronger van derWaals' forces. A significant number of candidates referred to the breaking of bonds rather than intermolecular forces.</p>								
	b		<p>tetrahedral ✓</p> <p>four bonding pairs repel OR four bonds repel ✓</p>	2	<p>Mark each point independently</p> <p>IGNORE surrounded by four atoms IGNORE four areas of electron charge repel IGNORE four electron pairs repel (<i>one could be lp</i>) DO NOT ALLOW atoms repel</p> <p>Examiner's Comments</p> <p>Most candidates were able to state the shape required. Explanations for the bond angle often focused on the four bond pairs around the carbon atom, however candidates did not always refer to repulsion between these electron pairs.</p>								
	c	i	<table border="1"> <thead> <tr> <th>Step</th> <th>Equation</th> </tr> </thead> <tbody> <tr> <td>Initiation (1 mark)</td> <td>$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓</td> </tr> <tr> <td>Propagation (2 marks)</td> <td>$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓</td> </tr> <tr> <td>Termination (2 marks)</td> <td>$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$</td> </tr> </tbody> </table>	Step	Equation	Initiation (1 mark)	$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓	Propagation (2 marks)	$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓	Termination (2 marks)	$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$	5	<p>IGNORE state symbols</p> <p>IGNORE dots</p> <p>If an incorrect hydrocarbon with six C atoms is used: DO NOT ALLOW any marks for the propagation steps but ALLOW ECF for termination steps (<i>i.e.</i> 3 <i>max</i>)</p> <p>Examiner's Comments</p>
Step	Equation												
Initiation (1 mark)	$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓												
Propagation (2 marks)	$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓												
Termination (2 marks)	$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$												

			<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: auto;"> <p style="text-align: center;">Two correct ✓ All three correct ✓✓</p> </div>		<p>This question required candidates to apply their knowledge of the radical substitution mechanism and those who had prepared well scored full marks. A common misconception was to have hydrogen radicals being formed and reacted in propagation and termination steps.</p>
		ii	<p>The breaking of a (Br-Br) bond AND forms (two) radicals OR the breaking of a (Br-Br) bond AND one electron (from the bond pair) goes to each atom / bromine ✓</p>	1	<p>ALLOW 'the breaking of a covalent bond' ALLOW the splitting of the bond in bromine</p> <p>ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations</p> <p>Examiner's Comments</p> <p>This question was better attempted than in previous sessions. Although many candidates were able to identify that radicals were formed, a significant number did not refer to the breaking of the covalent bond in Br₂.</p>
	d	i	$\text{C}_6\text{H}_{12} + 2\text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + 2\text{HBr} \checkmark$	1	<p>ALLOW molecular formula only.</p> <p>Examiner's Comments</p> <p>This question proved quite difficult for the vast majority of candidates who failed to apply their knowledge of radical substitution to an unfamiliar example. The most common incorrect answer was $\text{C}_6\text{H}_{12} + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + \text{H}_2$.</p>
		ii	<p>1,1-dibromocyclohexane OR 1,2-dibromocyclohexane OR 1,3-dibromocyclohexane OR 1,4-dibromocyclohexane ✓</p>	1	<p>Locant numbers MUST lowest possible e.g. DO NOT ALLOW 2,4-dibromocyclohexane etc.</p> <p>IGNORE structures</p> <p>Examiner's Comments</p> <p>Candidates were required to name one of the dibromocyclohexane compounds that could be formed from cyclohexane and the more able candidates were able to apply their understanding of nomenclature successfully. Common incorrect responses included straight chain dibromo compounds e.g. 1,2—dibromohexane and incorrect use</p>

					of locant numbers e.g. 2,3— dibromocyclohexane.
			Total	15	
7		i	any mono or multiple substituted chlorohexane – e.g.  (1)	1	
		ii	(because) substitution can replace any H atom / multiple substitution <i>owtte</i> (1)	1	ignore vague statements about free radical reactions being random allow termination can join alkyl radicals to form larger hydrocarbons <i>owtte</i>
			Total	2	
8		i	CO is toxic	1	allow responses linked to effect of CO in blood
		ii	<i>Calculation:</i> $n(\text{butane}) = 600/58.0 = 10.34$ (mol) AND $n(\text{O}_2)$ required = $6.5 \times 10.34 = 67.2$ (mol) (1) $n(\text{O}_2)$ consumed = $1.50 \times 10^3 / 24.0 = 62.5$ (mol) OR volume O_2 required for complete combustion = $67.2 \times 24.0/1000 = 1.61 \text{ m}^3$ (1) <i>Conclusion:</i> incomplete combustion / stove not safe to use AND $62.5 < 67.2$ OR $1.61 > 1.50$ (1)	3	using 1 : 6.5 ratio allow number rounding to 67
			Total	4	
9		i	Overlap of orbitals directly between the bonding atoms	1	allow a correct diagram
		ii	120° AND trigonal planar	1	allow planar triangle
			Total	2	
10			Initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ (1) Propagation $\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\cdot + \text{HCl}$ (1) $\text{C}_2\text{H}_5\cdot + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$ (1) Termination $\text{Cl}\cdot + \text{Cl}\cdot \rightarrow \text{Cl}_2$	5	If the structure of the ethyl radical is drawn, the lone electron must be attached to a C atom

		OR $C_2H_5\cdot + Cl\cdot \rightarrow C_2H_5Cl$ OR $C_2H_5\cdot + C_2H_5\cdot \rightarrow C_4H_{10}$ (1) Initiation, propagation, termination used in correct context (1)		
		Total	5	