

Mark scheme

Question	Answer/Indicative content	Marks	Guidance
1	<p data-bbox="280 913 408 947">Equation</p> <div data-bbox="338 987 730 1061" style="text-align: center;"> </div> <p data-bbox="280 1144 360 1178">Name</p> <p data-bbox="331 1227 616 1261">Radical substitution ✓</p> <p data-bbox="280 1346 456 1379">Bond fission</p> <p data-bbox="331 1429 600 1462">homolytic (fission) ✓</p>	3	<p data-bbox="951 331 1422 432">ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p data-bbox="951 477 1401 544">IGNORE mechanism, need overall equation</p> <p data-bbox="951 584 1265 618"><u>Examiner's Comments</u></p> <p data-bbox="951 656 1433 757">This question differentiated well, with a wide mix of responses given. Just over 40% scored all 3 marks.</p> <p data-bbox="951 797 1445 1440">Equation: The most common error was to omit HBr as a product. Some gave H₂ or just Br as a product. Some misunderstood the question and attempted to give either a partial mechanism, such as the propagation step or a complete mechanism, rather than the overall equation. Some gave molecular formula rather than structures as asked for. Those using structural or displayed formula were more prone to errors, such as missing hydrogens or incorrect chain length, than those that were confident using skeletal formula. Candidate should avoid giving equations in two formats, e.g. skeletal and structural because slips in one will lose marks.</p> <p data-bbox="951 1480 1445 1760">Mechanism: Many candidates were able to identify the radical substitution mechanism, but a significant number did not score here. Most common incorrect responses were electrophilic or nucleophilic substitution but there were also those that thought it was an addition reaction.</p> <p data-bbox="951 1800 1414 2013">Bond fission: A significant number identified this as heterolytic, even if the recognised mechanism was radical. Some struggled with the spelling or even suggested homogeneous or heterogenous.</p>

				<p style="text-align: center;">  Misconception </p> <p>Many struggled to identify the mechanism and then to link to bond fission. Try to introduce key terminology early on in teaching organic chemistry so that it can then be revisited with each topic. Relevant mechanism terminology:</p> <ul style="list-style-type: none"> - substitution / addition / elimination - electrophile / nucleophile / radical - homolytic / heterolytic
	ii	<p>Further substitution/s OR Different termination products OR More than one termination step</p> <p>Substitution at different positions along (carbon) chain ✓</p>	2	<p>ALLOW dibromo/multibromo compounds formed OR example of further substitution product e.g. $\text{CH}_2\text{BrCBr}(\text{CH}_3)_2$ / $\text{C}_4\text{H}_8\text{Br}_2$ / 1,2-dibromo-2-methylpropane OR example of different organic termination product e.g. C_8H_{18}</p> <p>ALLOW more than one H (atom) can be replaced ALLOW radicals react with each other to form other products</p> <p>ALLOW a hydrogen (atom) on a different carbon (atom) can be replaced ALLOW Substitutions can occur at other carbons (along the chain) ALLOW example of substitution at different position on chain e.g. $\text{CH}_2\text{BrCH}(\text{CH}_3)_2$ / 1-bromo-2-methylpropane</p> <p>IGNORE references to separation of products IGNORE references to atom economy or yield</p> <p><u>Examiner's Comments</u></p> <p>Most candidates scored one mark here, with approximately a third of candidates scoring both marks. Most recognised that further or multiple substitution would occur or that there</p>

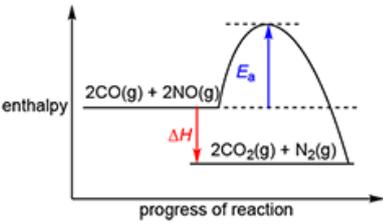
					<p>would be a variety of termination products. The second mark was harder to achieve as although many responses suggested a different position, it was not always clearly conveyed that a hydrogen on a different carbon along the chain was being substituted, e.g. 'substitution can occur anywhere in the molecule'. The best responses gave examples to clarify their point, e.g. 'the bromine radical can be substituted anywhere along the hydrocarbon chain making other products such as 1-bromo-2-methylpropane'.</p> <p>However, many gave vague answers such as poor yield or mixture of products, without explanation of how or what they might be. Some focused on HBr being formed as a product, suggesting it is toxic, or lowers the atom economy. Others highlighted ultraviolet radiation as being a limitation due to it being 'expensive', 'hard to achieve', 'lack of sources' or 'hazardous'. Others suggested that the reaction needed 'high temperatures'.</p>
			Total	5	
2			C	1	<p><u>Examiner's Comments</u></p> <p>Approximately two thirds of candidates gave the correct answer C. The most common incorrect response seen was D, confusing the strength of the σ and π bonds, possibly as a C=C bond is stronger than C-C. Some gave D assuming alkenes are polar due to their reactivity and showing a misunderstanding of the term 'polar'.</p>
			Total	1	
3			B	1	<p><u>Examiner's Comments</u></p> <p>A large majority of candidates were able to correctly identify shape at x as being trigonal planar and y as being</p>

					tetrahedral. The most common incorrect responses seen were for getting one of these incorrect i.e. D incorrect for x or C incorrect for y.
			Total	1	
4			C	1	<p><u>Examiner's Comments</u></p> <p>Some candidates chose B as the correct option. The other options were chosen randomly, suggesting that many had not learnt this specification content and had guessed.</p>
			Total	1	
5	a		<p>CHECK FOR RESPONSES ON TABLE</p> <p>Trend</p> <p>Boiling point decreases with more branching OR fewer methyl/alkyl groups/side chains ✓</p> <p>Branching and surface contact</p> <p><i>Could be seen anywhere within response</i></p> <p>Branching linked to the amount of (surface) contact / interaction/overlap (between molecules) ✓</p> <p>Type and strength of intermolecular force</p> <p><i>Could be seen anywhere within response</i></p> <p>Branching/ boiling points/contact linked to strength of London forces OR induced dipole(-dipole) interactions OR extent of surface contact ✓</p> <p>Energy and intermolecular forces</p>	4	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>Comparisons needed throughout ORA throughout</p> <p>ALLOW comparison between 2 alkanes, e.g. C has greatest branching AND lowest boiling point A has no branching AND highest boiling point</p> <p>IGNORE Chain length</p> <p>Surface area alone is not sufficient <i>must have idea of contact.</i></p> <p>DO NOT ALLOW responses comparing different numbers of electrons (as all have the same number).</p> <p>ALLOW more branching results in fewer London forces ORA</p> <p>IGNORE van der Waals'/vdW forces. OR IDID OR IDD</p> <p>ALLOW more energy to break/overcome London forces OR induced dipole(-dipole)</p>

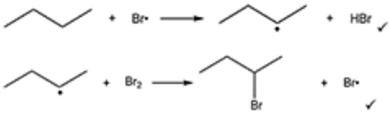
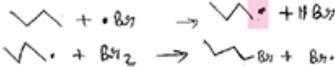
		<p><i>Linked to energy seen anywhere</i></p> <p>More energy to break intermolecular forces with less branching ✓</p> <p>IGNORE just 'bonds' <i>intermolecular or type of forces required</i></p>	<p>interactions OR vdW forces</p> <p>IGNORE harder to overcome/break intermolecular forces (no reference to energy)</p> <p>Examiner's Comments</p> <p>Most candidates were given 3 or 4 marks. The most common omission was the idea of surface contact. Most candidates identified London forces or induced dipole interactions as the relevant intermolecular force. A few candidates gave a general comment in terms of 'intermolecular' forces without specifying the type of intermolecular forces.</p> <p>There has been a general improvement in candidate responses to this type of question with fewer candidates than in previous exams suggesting the breaking of hydrogen bonds or covalent bonds.</p> <p>Exemplar 2</p> <p><small>Refer to the isomers A, B and C in your answer.</small></p> <p><small>I isomers A, B and C have the same molecular formulae but different structural formulae. Boiling point decreases down from A to C because there is more branching so fewer surface points of contact. This results in fewer London forces between the molecules so less energy is required to overcome these London forces. (All going down the table from A to C)</small></p> <p>Exemplar 2 shows an excellent response. The explanation is clear and the candidate is aware of the main factors responsible for the trend in boiling points. This response was given the full 4 marks.</p>
b	<p>CORRECT DOTS REQUIRED FOR ALL MARKS</p> <p>Initiation</p> <p>ultraviolet / UV</p> <p>AND</p> <p>$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ OR $\text{Br}_2 \rightarrow \text{Br}\cdot + \text{Br}\cdot$</p>	5	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>DO NOT ALLOW charged formulae</p> <p>IGNORE position of dots within a formula</p> <p>DO NOT ALLOW if reagents also present, e.g..steam</p>

		<p style="text-align: center;">OR $\text{Br}-\text{Br} \rightarrow 2\text{Br}\cdot$, etc ✓</p> <p>Propagation</p> <p>1 $\text{C}_2\text{H}_6 + \text{Br}\cdot \rightarrow \text{C}_2\text{H}_5\cdot + \text{HBr} \checkmark$ 2 $\text{C}_2\text{H}_5\cdot + \text{Br}_2 \rightarrow \text{C}_2\text{H}_5\text{Br} + \text{Br}\cdot \checkmark$</p> <p>Termination In either order:</p> <p>$\text{C}_2\text{H}_5\cdot + \text{C}_2\text{H}_5\cdot \rightarrow \text{C}_4\text{H}_{10}$ OR $2\text{C}_2\text{H}_5\cdot \rightarrow \text{C}_4\text{H}_{10} \checkmark$ $\text{C}_2\text{H}_5\cdot + \text{Br}\cdot \rightarrow \text{C}_2\text{H}_5\text{Br} \checkmark$</p>		<p>ALLOW $\cdot\text{CCH}_5$ for $\text{C}_2\text{H}_5\cdot$</p> <p>ALLOW $\text{C}_2\text{H}_5\text{C}_2\text{H}_5$ for $\text{C}_4\text{H}_{10} \checkmark$</p> <p><u>Examiner's Comments</u></p> <p>This question was answered extremely well with most candidates obtaining the full 5 marks. It was encouraging to see the widespread correct use of dots to indicate radicals, with relatively few omissions. Of the three steps, initiation and termination were answered better than the equations for propagation.</p>									
c		<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Carbon atom</th> <th>Bond angle</th> <th>Name of shape</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">109.5</td> <td style="text-align: center;">tetrahedral</td> </tr> <tr> <td style="text-align: center;">2</td> <td style="text-align: center;">120</td> <td style="text-align: center;">trigonal planar</td> </tr> </tbody> </table> <p style="text-align: center;">2 OR 3 correct ✓ 4 correct ✓</p> <p>Number of electron pairs</p> <p>In C1/109.5°, 4 bonded pairs/bonding regions/bonds ✓ In C2/120°, 3 bonded regions/bonds ✓</p> <p>Electron pair repulsion</p> <p>Electron pairs/bonded pairs repel (as far apart as possible) ✓</p> <p><i>Electron pairs/bonded pairs essential</i></p>	Carbon atom	Bond angle	Name of shape	1	109.5	tetrahedral	2	120	trigonal planar	5	<p>ALLOW 109–110 for C1</p> <p>ALLOW 118–122 for C2 ALLOW planar triangle</p> <p>ALLOW table responses if in wrong columns</p> <p>IGNORE areas of electron density</p> <p>For bonded pairs</p> <p>ALLOW bp, bonded groups, bonded atoms <i>Bonded/bonding essential</i></p> <p>For C2, ALLOW</p> <ul style="list-style-type: none"> • 3 bonded areas/environments • 3 bonded pairs/groups/atoms • 2 bonded pairs and 1 double bond • 2 bonded pairs and 1 bonded region <p>DO NOT ALLOW 'atoms repel'</p> <p>IGNORE</p> <ul style="list-style-type: none"> • electrons repel • bonds repel
Carbon atom	Bond angle	Name of shape											
1	109.5	tetrahedral											
2	120	trigonal planar											

			<i>DO NOT ALLOW 'bonded atoms' for this mark</i>		<ul style="list-style-type: none"> • electron region OR electron density • lone pairs repel more <i>irrelevant here</i> • shapes, even if wrong <p><u>Examiner's Comments</u></p> <p>The bond angles and shapes rewarded the well-prepared candidates, with many being given both available marks for this part of the question. This part discriminated very well.</p> <p>For the explanation, most candidates identified 4 and 3 for C1 and C2, but candidates often linked 4 and 3 to atoms, rather than to electron pairs or bonded pairs for C1 and to bonding regions for C2.</p> <p>A mark was available for stating that 'electron pairs repel', but this important fact was often omitted despite being the main principle that determines molecular shapes.</p> <p>The question discriminated well, giving a good spread of marks across the five available.</p> <p> Misconception</p> <p>Many students think that molecular shapes are determined solely by lone pairs or by repulsion between bonded atoms. The principle behind molecular shapes is called electron pair repulsion theory because it is based on repulsion between electron pairs, which may be bonded pairs or lone pairs, but not atoms.</p>
			Total	14	
6		i	$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$	2 (AO2.6 ×2)	ALLOW multiples IGNORE state symbols

		<p>Correct species ✓ Balanced ✓</p>	<p>For heptane formula, ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW 1 mark for balanced combustion equation for a different alkane (ECF) e.g. $C_6H_{14} + 9\frac{1}{2}O_2 \rightarrow 6CO_2 + 7H_2O$</p> <p>Examiner's Comments</p> <p>Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.</p>
ii		 <p>Reactants, products and ΔH</p> <p>2CO + 2NO on LHS AND 2CO₂ + N₂ on RHS AND ΔH labelled with products below reactants AND Arrow downwards ✓</p> <p>E_a (independent of ΔH)</p> <p>curve with arrow from reactants to top of curve AND E_a labelled ✓</p>	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IGNORE state symbols</p> <p>ΔH DO NOT ALLOW $-\Delta H$ DO NOT ALLOW double headed arrow on ΔH ALLOW ΔH arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.</p> <p>ALLOW -746 for ΔH</p> <p>E_a ALLOW AE OR A_E ALLOW 2 arrowheads at each end of E_a line OR no arrowhead BUT DO NOT ALLOW arrowhead down</p> <p>2 (AO2.1) (AO1.2)</p>

			<p>IF endothermic diagram shown,</p> <p>ALLOW ECF for E_a using MS criteria</p>		<p>E_a line must reach maximum (or near to maximum) on curve</p> <p>Examiner's Comments</p> <p>Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a doubleheaded arrow for ΔH or a $-\Delta H$ label.</p> <p>Some candidates showed endothermic profiles and these could create issues with positioning of the ΔH and E_a arrows.</p> <p>Generally, positioning of ΔH and E_a arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.</p>
		iii	<p>Catalyst lowers activation energy OR Catalyst increases rate without itself changing ✓</p> <p>Reaction proceeds via a different route/pathway OR More molecules/particles exceed activation energy ✓</p>	<p>2 (AO1.2 ×2)</p>	<p>ALLOW 2nd labelled curve on profile diagram in 23(a)(ii) with lower activation energy/E_c with catalyst</p> <p>ALLOW E_c needs less energy to start reaction</p> <p>ALLOW E_c curve is lower than E_a curve</p> <p>IGNORE 'shorter route' for alternative route</p> <p>IGNORE more successful collisions</p> <p>Examiner's Comments</p> <p>Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.</p>
			Total	6	
7			Skeletal formulae required	<p>2 (AO3.1 ×2)</p>	<p>ALLOW 1 mark (ECF) for 2 'correct' equations with dot omitted or incorrectly positioned</p> <p>ALLOW 1 mark for forming 1-bromobutane with dots correct for 1-</p>

				<p>bromobutane e.g.</p>  <p>No credit for responses using molecular formulae for organic structures</p> <p>Examiner's Comments</p> <p>This question discriminated very well at the top end of the ability range, but many ignored the instruction to use skeletal formula and obtained no marks as a result.</p> <p>Of those that did use skeletal formula, many placed the dot on the wrong carbon atom or produced 1-bromobutane, rather than 2-bromobutane, stated in the question. A mark was still available by ECF for misplaced or absent dots or formation of 1-bromobutane with dots.</p> <p>This question was aimed to be demanding and so it proved to be.</p>
		Total	2	
8	a	<p>Trend for all 3 hydrocarbons (1 mark): Boiling point increases with less branching OR less methyl/alkyl groups/side chains ✓</p> <p>Explanation with comparison (3 marks):</p> <p>Branching and surface contact (Less branching gives) more (surface) contact / interaction (between molecules) ✓</p>	<p>4 (AO1.1) (AO1.2 X3)</p>	<p>ANNOTATE WITH TICKS AND CROSSES Comparisons needed throughout ORA throughout</p> <p>Must have link between rank order of branching and boiling point for all 3. ALLOW Hexane is least branched/straight chain and has highest bp AND 2,2-dimethylbutane is most branched and has lowest bp. IGNORE Chain length</p> <p>Surface area alone is not sufficient, must have idea of contact.</p> <p>DO NOT ALLOW arguments comparing different numbers of electrons (as all have the same number).</p>

			<p>Surface contact and London forces (More surface contact) gives more /stronger induced dipole(–dipole) interactions/ London forces ✓</p> <p>Energy and intermolecular forces More energy to break induced dipole(–dipole) interactions/ London forces/intermolecular forces/intermolecular bonds (with less branching) ✓</p>	<p>IGNORE van der Waals'/vdW forces OR IDID OR IDD</p> <p>ALLOW 'more energy to break intermolecular forces' if intermolecular forces are not identified or incorrect. IGNORE harder to overcome/break intermolecular forces (no reference to energy) IGNORE just 'bonds' intermolecular/London forces required</p> <p><u>Examiner's Comments</u></p> <p>Most candidates attempted this question, gaining at least 1 mark, with over half scoring 3 or more marks. Responses often lacked clarity as many candidates struggled to articulate their ideas. It was common to see lengthy responses often with unnecessary repetition and sometimes even contradictions. A good strategy adopted by some was to draw skeletal formulae for the compounds next to the data provided. This enabled them to focus their response more easily on the extent of branching.</p> <p>Many candidates were unable to give a clear trend for the first marking point, as asked for in the question, but were able gain credit by a lengthier comparison of all three as indicated in the extra guidance. However, this mark was often lost through incomplete explanation, not referring to boiling point at all or an attempt to compare just chain length. The most common error for the second mark was omission of 'contact' or 'interaction' with reference only to surface area or 'packing' of molecules. Some lost this mark for a change in number of electrons. The third marking point was the most frequently awarded. Some candidates lost the mark for not explicitly naming the intermolecular forces as London forces/induced dipole-dipole interactions or for incorrectly using</p>
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van der Waals. Some lost the mark for not explicitly indicating how increased or decreased contact would affect the strength or magnitude of London forces, e.g. 'less contact to form London forces'. The final mark was harder to obtain as it needed to be clear that **energy** was required to break **intermolecular** forces. For example, 'less energy to break bonds' or 'easier to separate the molecules' or 'more energy to boil' were not sufficient.



Misconception

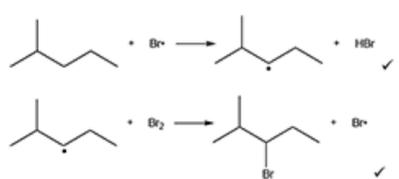
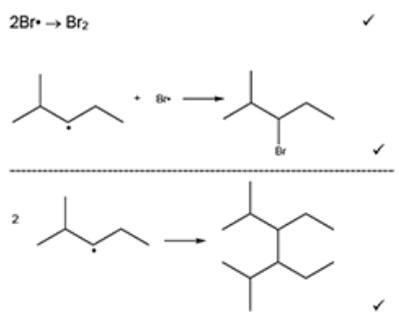
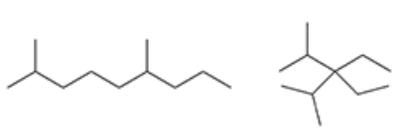
Responses often highlighted that candidates lacked understanding about what London forces are, e.g. indicating that they form 'between atoms' or referring to induced dipole-dipole forces as something else. Intermolecular forces are difficult to fully comprehend as they can't be visualised making this a challenging topic to teach.

OCR have produced a '[Bonding](#)' [teaching guide](#) with lots of useful suggestions and resources. This includes a link to this [Salters A Level chemistry revision activity on intermolecular bonding](#)

Exemplar 1

* increasing boiling point with fewer branches and longer carbon chains
 * fewer branches = more points of contact between molecules
 * stronger London forces
 * more energy required to break stronger London force and separate molecules.

This exemplar shows a clear, concise response. The candidate has drawn skeletal structures next to the table. The trend is stated first followed by a detailed explanation, presented as a bullet point list, with all 4 marking points awarded.

			<p>Initiation $\text{Br}_2 \rightarrow 2\text{Br}\cdot$ AND ultraviolet / UV ✓</p> <p>Propagation</p>  <p>Termination</p> 	<p>b</p> <p>i</p> <p>6 (AO1.1) (AO2.5) (AO2.5) (AO2.5) (AO3.1)</p>	<p>DOT REQUIRED throughout IGNORE temperature and pressure</p> <p>ALLOW ECF for use of $\text{Cl}\cdot$ (from Cl_2) in subsequent propagation and termination steps</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position</p> <p>DO NOT ALLOW ECF from incorrect radical intermediate for termination steps</p> <p>Examiner's Comments</p> <p>Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.</p>  <p>Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect positioning of the radical dot, most typically on the terminal carbon, addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the</p>
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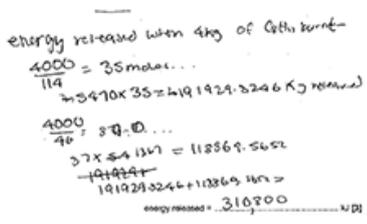
					<p>termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.</p>
		ii	<p>C_6Br_{14} ✓</p> <p>Correct balanced equation</p> <p>$C_6H_{14} + 14 Br_2 \rightarrow C_6Br_{14} + 14 HBr$ ✓</p>	<p>2 (AO2.6 ×2)</p>	<p>ALLOW 1 mark for correct balanced equation using any combination of skeletal OR structural OR displayed formula</p> <p>Examiner's Comments</p> <p>Most responses gained at least 1 mark for this question giving the correct molecular formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.</p>
		iii	<p>$n(B) = \frac{72.0}{40000}$ OR $\frac{0.072}{40}$ OR $1.8(0) \times 10^{-3}$ (mol) ✓</p> <p>$M(B) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓</p> <p>Molecular formula = $C_6H_9Br_5$ ✓</p>	<p>3 (AO2.2 ×2) (AO3.2)</p>	<p>ALLOW 2SF up to calculator value</p> <p>ALLOW ECF from incorrect $n(B)$</p> <p>ALLOW ECF from incorrect $M(B)$ from $n(B)$</p> <p>-----</p> <p>COMMON ERROR</p> <p>$n(B) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) ✗</p> <p>$M(B) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$</p> <p>Molecular formula = $C_6H_{12}Br_2$ OR $C_6H_{11}Br_3$ ✓</p> <p>ALLOW ECF for viable molecular formula with C_6 but must be derived from a calculated value for $M(B)$</p>

					<p><u>Examiner's Comments</u></p> <p>Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use $PV=nRT$ or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.</p>
			Total	15	
9			B	1 (AO2.2)	<p><u>Examiner's Comments</u></p> <p>This was a demanding question. Candidates needed to calculate the moles of oxygen and then determine the ratio of alkane to oxygen to find the correct response. The majority of successful candidates clearly showed their working to help them to arrive at the correct answer. The most common incorrect answer was C.</p>
			Total	1	
10			D	1 (AO1.1)	<p><u>Examiner's Comments</u></p> <p>Most candidates identified D (only 1) for an equation that could be part of a propagation step.</p>
			Total	1	
11			D	1 (AO1.2)	<p>ALLOW 15 (correct number of sigma bonds)</p> <p><u>Examiner's Comments</u></p> <p>This question discriminated well, with higher ability candidates correctly identifying D. Often students overlooked the sigma bonds in the aromatic ring and selected B.</p>
			Total	1	

12			D	1(AO1.2)	<p>ALLOW 9</p> <p><u>Examiner's Comments</u></p> <p>Candidates found this question difficult with very many choosing option B rather than the correct option D. Candidates are advised to draw out all bonds displayed when tackling such as question as the answer of B (3) results from considering just the three bonds shown in the skeletal formula and omitting the other 6 C–H bonds.</p>
			Total	1	
13			D	1(AO2.6)	<p><u>Examiner's Comments</u></p> <p>This question discriminated extremely well with most candidates choosing the correct option. Most candidates showed some working. The key to success was to identify the balanced equation that produced CO₂ and H₂O in a 3 : 4 molar ratio.</p>
			Total	1	
14	a	i	UV OR ultraviolet ✓	1 (AO1.1)	<p>ALLOW Sunlight IGNORE Temperature</p> <p><u>Examiner's Comments</u></p> <p>Most candidates gave the correct response to this question. Incorrect responses included use of high temperatures and/or catalyst.</p>
		ii	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 + \text{Br}\cdot \rightarrow \text{CH}_3\text{CH}_2\dot{\text{C}}\text{HCH}_3 + \text{HBr} \checkmark$ $\text{CH}_3\text{CH}_2\dot{\text{C}}\text{HCH}_3 + \text{Br}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CHBrCH}_3 + \text{Br}\cdot \checkmark$	2 (AO 2.5 × 2)	<p>ALLOW Displayed or Skeletal formulae ALLOW 1 mark if BOTH equations are 'correct' using molecular formulae, i.e. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 + \text{Br}\cdot \rightarrow \text{C}_4\text{H}_9\cdot + \text{HBr}$ $\text{C}_4\text{H}_9\cdot + \text{Br}_2 \rightarrow \text{C}_4\text{H}_9\text{Br} + \text{Br}\cdot \checkmark$</p> <p>IGNORE position of • within CH₃CH₂CHCH₃ •</p> <p>ALLOW 1 mark if incorrect structure of</p>

				<p>intermediate radical is used, e.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\cdot$ for $\text{CH}_3\text{CH}_2\text{CHCH}_3\cdot$ ✓</p> <p>Examiner's Comments</p> <p>Candidates always find radical mechanisms tricky and this one had the added complexity of forming 2-bromo isomer. However, a majority of students still gained marks. Many candidates formed the incorrect radical removing H from C-1 i.e. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\cdot$ therefore scoring only 1 mark. Some responses were a little messy making it very easy to miss off a dot or H or Br. Many candidates reacted with $\text{Br}\cdot$ in the first step but added Br to the radical intermediate (as well as forming HBr). Candidates should always check equations so that they balance in terms of atoms.</p>
	iii	<p>Further substitution OR formation of di/ tri / etc. bromobutanes OR produces different termination products OR more than one termination step ✓</p> <p>Formation of 1-bromobutane OR (Br) substitution in a different position ✓</p>	<p>2 (AO 3.2 × 2)</p>	<p>ALLOW multisubstitution, including examples ALLOW an example of a different termination product ALLOW more than one hydrogen (atom) can be replaced ALLOW radicals react with each other to form other products</p> <p>Examiner's Comments</p> <p>Candidates found this question very challenging and few scored both marks. Many responses considered only the formation of HBr (other product) and/or general statements about other products with no indication of how they were formed. Some described losses due to the purification method or incomplete reaction (due to conditions such as T and P) or low atom economy. Some referred to the stability of the radical intermediate, showing possible confusion with electrophilic addition.</p>

					Candidates who understood the mechanism were more confident in answering this question, at least recognising that further substitution was possible.
	b		<p>% atom economy for butane and bromine (5.1)</p> $= \frac{136.9}{217.8} \times 100 = 62.9\% \checkmark$ <p>atom economy for but-2-ene and HBr (5.2) is 100% \checkmark</p>	2 (AO 2.2) (AO1.2)	<p>Calculator: 62.85583104</p> <p>ALLOW calculation for 5.2</p> <p>ALLOW Calculations not expressed as a % i.e. 0.629 and 1.</p> <p>Examiner's Comments</p> <p>Despite the question asking for calculations to be included, many candidates didn't include them and so lost both marks. Some gained one mark as recognised that 5.1 has 100% atom economy but either didn't or incorrectly calculated for 5.2 (30% was seen frequently). Care needs to be taken with rounding of final values.</p>
			Total	7	
15	i		$\text{C}_8\text{H}_{18} + \text{C}_2\text{H}_5\text{OH} + 15\frac{1}{2} \text{O}_2 \rightarrow 10 \text{CO}_2 + 12 \text{H}_2\text{O} \checkmark$	1 (AO2.6)	<p>ALLOW multiples e.g. $2 \text{C}_8\text{H}_{18} + 2 \text{C}_2\text{H}_5\text{OH} + 31 \text{O}_2 \rightarrow 20 \text{CO}_2 + 24 \text{H}_2\text{O}$</p> <p>ALLOW $\text{C}_{10}\text{H}_{24}\text{O}$ for $\text{C}_8\text{H}_{18} + \text{C}_2\text{H}_5\text{OH}$ <i>Combining ethanol and octane!</i></p> <p>Examiner's Comments</p> <p>Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and $\text{C}_2\text{H}_5\text{OH}$ were usually seen although some candidates combined these as a 'mixture formula' of $\text{C}_{10}\text{H}_{24}\text{O}$ (which was accepted).</p> <p>The balancing of the equation using $15\frac{1}{2}\text{O}_2$ was the hardest part of the equation and many different balancing numbers for O_2 were seen (10CO_2 and $12\text{H}_2\text{O}$ where usually correct).</p>

				<p>Less successful responses often attempted a combustion equation using octane OR ethanol, but not both.</p> <p>This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.</p>
	ii	<p>FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks</p> <p>-----</p> <p>-----</p> <p>$M(\text{C}_8\text{H}_{18}) = 114$ AND $M(\text{C}_2\text{H}_5\text{OH}) = 46$ OR 1 mol C_8H_{18} + 1 mol $\text{C}_2\text{H}_5\text{OH}$ has mass of 160 g ✓ 50 mol C_8H_{18} OR 50 mol $\text{C}_2\text{H}_5\text{OH}$ OR 50 mol (C_8H_{18} + $\text{C}_2\text{H}_5\text{OH}$) OR 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol $\text{C}_2\text{H}_5\text{OH}$ ✓ Energy = $(50 \times 5470) + (50 \times 1367)$ OR $50 \times (5470 + 1367)$ OR 50×6837 OR $273500 + 68350$ =341850(kJ)✓</p>	<p>3 (3 ×AO2.2)</p> <p>IGNORE sign throughout ALLOW approach based on mass for 2nd mark $m(\text{C}_8\text{H}_{18}) = (114/160) \times 8000 = 5700$ g AND $m(\text{C}_2\text{H}_5\text{OH}) = (46/160) \times 8000 = 2300$ g Energy = $5700/114 \times 5470 + 2300/46 \times 1367 = 341850$ (kJ) ALLOW 2 SF or more correctly rounded</p> <p>-----</p> <p>Common errors 310800 → 2 marks Use of equal masses (4 kg) of C_8H_{18} & $\text{C}_2\text{H}_5\text{OH}$ (rather than equal moles)</p> <p>Example</p>  <p>Examiner's Comments</p> <p>This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.</p>	
		Total	4	

