

	<p>Indicative content</p> <ul style="list-style-type: none"> • Ethanol – use of ethanol as a solvent (added to each halogenoalkane / liquid in separate containers) • Fair test – use of equal volumes/amounts / specified volumes/amounts in each tube or warm the tubes in a water bath / specified temperature / room temperature • Silver nitrate - silver nitrate (solution) / Ag⁺(aq) to each tube (of halogenoalkane) • Time - find the time taken for a precipitate to form • Rate - expected trend is 2-iodobutane > 2-bromobutane > 2-chlorobutane or 2-iodobutane is the fastest <u>and</u> 2-chlorobutane is the slowest • Bond enthalpy - bond enthalpy C-I < C-Br < C-Cl / decreases from C-Cl to C-I / C-Cl is the strongest <u>and</u> C-I is the weakest / C-X bond strength decreases down the group (of halogens) 	<p>Allow description of experiment from a labelled diagram</p> <p>Ignore nitric acid / HNO₃</p> <p>Allow find how quickly the precipitates form</p> <p>Allow time taken for 2-iodobutane < 2-bromobutane < 2-chlorobutane Allow I⁻ forms first, Cl⁻ forms last Allow the halogenoalkanes get more reactive from chloro to iodo / 'down the group' Allow reverse trends</p> <p>Allow 'the bond enthalpy decreases down the group' or a comparison of bond enthalpy in 2-iodobutane and 2-chlorobutane</p> <p>Ignore references to bond length / bond polarity / electronegativity / effective nuclear charge</p>	
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Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)(i)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • the (bulb of the) thermometer should be opposite the opening to the condenser (1) • the water in and out of the condenser should be reversed (1) • put a vent after the condenser or leave a gap between the condenser and the receiver or conical flask must be open (1) 	<p>Allow these changes if shown on the diagram</p> <p>Allow thermometer should be higher up / above the liquid / should measure the temperature of the vapour / out of the mixture/liquid</p> <p>Allow water should enter the bottom (of the condenser)</p> <p>Ignore just 'vent' / the apparatus should not be completely sealed</p> <p>Ignore references to using a fume cupboard</p>	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(a)	$C_{10}H_{18}O$ (1)	Ignore $C_{10}H_{17}OH$	(2)
	154 ($g\ mol^{-1}$) (1)	no TE on incorrect molecular formula except for $C_{10}H_{17}OH$	

Question Number	Acceptable Answer	Additional Guidance	Mark
4(b)(i)	furthest peak to right/ highest $m/z = 154$	Ignore just 'highest peak' may be shown on spectrum alone provided 154 stated Allow parent ion/molecular ion/last peak at 154 Must see the figure 154 in text or on graph	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(b)(ii)	$C_5H_9^+$ / $[C_5H_9]^+$	+ charge is essential, allow charge anywhere on the ion/ outside / inside brackets Allow displayed/structural/skeletal formula or any combination of these. Ignore name of ion even if incorrect (Correct name: 2-methylbut-2-ene ion)	(1)

Question Number	Answer Acceptable	Additional Guidance	Mark
4(c)	alkene and $C=C$ and (IR) peak between 1669 and 1645 (cm^{-1})	can be in either order	(2)
	OR alkene and $C-H$ and (IR) peak between 3095 and 3010 OR 3095 and 2995 (cm^{-1}) (1)	Allow CH (bond)	
	alcohol and $O-H$ and (IR) peak between 3750 and 3200 (cm^{-1}) (1)	Ignore any qualification of the wavenumber range eg isolated alcohol or phenol Allow Hydroxyl Do not award Hydroxide Allow OH (bond) Do not award $-OH$ / $-O-H$ If both bonds missing and everything else correct, award 1 mark Ignore all references to alkanes Allow single IR value or range within the data book range	

Question Number	Acceptable Answer	Additional Guidance	Mark
4(d)	<p>An answer that makes reference to the following points:</p> <p>Alkene</p> <ul style="list-style-type: none"> • bromine water/Br₂(aq)/bromine (1) • decolourised or orange/yellow/brown to colourless (1) <p>Alcohol</p> <ul style="list-style-type: none"> • PCl₅/phosphorus pentachloride /phosphorus(V)chloride (1) • Misty/steamy/white fumes (1) 	<p>Allow alkene and alcohol in either order. No TE for other groups incorrectly identified in 4c or alkanes Result dependent on correct test for both functional groups</p> <p>allow acidified potassium manganate/KMnO₄. Decolourised (from purple)</p> <p>allow (warm with) acidified Cr₂O₇²⁻ turns from orange to green / blue If name and formula, both must be correct</p> <p>sodium (metal) effervescence OR any other workable test and correct result</p>	(4)

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	<ul style="list-style-type: none"> • diagram showing bond polarity using partial charges δ+ on iodine and δ- on chlorine 	$\text{I}^{\delta+} - \text{Cl}^{\delta-}$	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	<ul style="list-style-type: none"> • arrow from double bond to I^{δ+} and arrow from I-Cl bond to Cl^{δ-} (1) • intermediate secondary carbocation with positive charge on carbon in the 2 position (1) • arrow from lone pair on Cl⁻ to electron deficient carbon of carbocation (1) 	<p>Award M1 if dipoles are reversed in (b)(i) and arrow to Cl^{δ+} Arrows should come from, or very close to, bonds and go to, or very close to, atoms. Allow arrow to I with no δ+ if given correctly in (i)</p> <p>Mark is for secondary carbocation so TE from (b)(i) for carbocation from addition of Cl first in M1 Do not award δ+ instead of +</p> <p>Do not award δ- instead of - If dipole is reversed in (i) award mark for arrow from lone pair on I⁻ to electron deficient carbon of carbocation</p> <p>Ignore missing final product Allow M1 & M3 for minor product</p>	(3)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	<ul style="list-style-type: none"> ethanol is added to dissolve both the halogenoalkane and water / to allow the halogenoalkane and water to mix / to form a homogeneous mixture / to act as a co-solvent 	Allow silver nitrate as an alternative to water Allow so the halogenoalkane becomes soluble in water Do not award descriptions of dissolving one of the two reactants but not the other Do not award ethanol is a solvent Do not award to allow the halogens to mix	(1)

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	<ul style="list-style-type: none"> so they are the same temperature OR <ul style="list-style-type: none"> so only the type of halogen affects the rate of reaction 	Allow to ensure the temperature remains constant Allow heat for temperature Ignore constant conditions Ignore to make it a fair test	(1)

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	<ul style="list-style-type: none"> To ensure the reactants are mixed (thoroughly) 	Allow so the mixture is homogeneous Ignore so the particles collide Ignore to form the precipitate Do not award references to kinetic energy of the molecules	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	<ul style="list-style-type: none"> chloride white precipitate and bromide cream precipitate and iodide yellow precipitate 	Penalise the incorrect use of chlorine, bromine and iodine once only in 7(b)(i) and 7(b)(ii) Accept Off-white or (very) pale yellow Do not award pale yellow	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	<ul style="list-style-type: none"> use of dilute and concentrated ammonia solution / aqueous ammonia (1) <ul style="list-style-type: none"> silver chloride / precipitate from 1-chlorobutane is soluble in dilute (and concentrated ammonia) and silver bromide / precipitate for 1-bromobutane is soluble only in concentrated ammonia and silver iodide / precipitate from 1-iodobutane is insoluble in both dilute and concentrated ammonia (1)	Allow partially soluble	(2)

	<p>Indicative content:</p> <ul style="list-style-type: none"> IP1 Use equal amounts / numbers of moles / volumes of either halogenoalkane or silver nitrate solution IP2 and IP3 Use isomeric primary, secondary and tertiary bromoalkanes e.g 1-bromobutane or 1-bromo-2-methylpropane and 2-bromobutane and 2-bromo-2-methylpropane IP4 Time how long it takes for a precipitate to form / observe the order in which the precipitates form IP5 Shorter the time the faster the rate IP6 Correct order of precipitation given / tertiary forms before secondary before primary 	<p>Allow ethanol Do not award equal masses Ignore lack of ethanol</p> <p>Any two scores IP2 All 3 scores IP3 provided they are isomers Accept names or formulae but if both given they must both be correct</p> <p>$1 \div \text{time} = \text{rate of reaction}$</p>	
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Question Number	Answer	Additional Guidance	Mark
6(d)(i)	An answer that makes reference to the following points: <ul style="list-style-type: none"> potassium hydroxide / KOH (1) alcohol / ethanol and reflux (1) 	<p>Mark independently</p> <p>Allow sodium hydroxide / NaOH</p> <p>Allow just 'heat' in place of reflux Do not award aqueous ethanol</p>	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	<ul style="list-style-type: none"> repeat unit 	<p><u>Example of repeat unit</u></p> $\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \quad \\ \left[\text{C}-\text{C} \right] \\ \quad \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$ <p>Allow non-displayed methyl groups (-CH₃) Ignore connectivity of the methyl group Allow n outside brackets</p> <p>Ignore missing brackets / round brackets</p>	(1)

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	<ul style="list-style-type: none"> curly arrow from double bond to H of HBr and correct structure of 2-methylpropene (1) curly arrow from H-Br bond to Br atom and correct dipole on HBr molecule (1) intermediate with + on correct Carbon and Br⁻ (1) lone pair on Br⁻ and curly arrow from lone pair to C⁺ (1) 	<p><u>Example of mechanism</u></p> <p>incorrect structure of 2-methylpropene loses M1 only + on incorrect carbon loses M3 only</p>	(4)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> the bond energies in the table are mean / not specific to ammonia 	<p>(1) Ignore heat losses</p>	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(iv)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> 98 peak is due to $\text{C}_2\text{H}_4^{35}\text{Cl}_2^+$ and 102 peak is due to $\text{C}_2\text{H}_4^{37}\text{Cl}_2^+$ 100 peak is due to $\text{C}_2\text{H}_4^{35}\text{Cl}^{37}\text{Cl}^+$ 	<p>Allow $\text{C}_2\text{H}_4^{35}\text{Cl}^{35}\text{Cl}^+$</p> <p>Allow $\text{C}_2\text{H}_4^{37}\text{Cl}^{37}\text{Cl}^+$</p> <p>Allow structural formulae of the molecular ions of either 1,1- or 1,2-dichloroethane or both</p> <p>Allow structures with the positive charge anywhere including outside of brackets of any type.</p> <p>Penalise omission of + once only</p>	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(v)	<p>An answer that makes reference to the following point</p> <ul style="list-style-type: none"> ^{35}Cl and ^{37}Cl atoms are in a 3:1 ratio 	<p>Answer must refer to the isotopes of chlorine. Ignore comments about isotopes of carbon or hydrogen or just isotopes</p> <p>Allow a larger proportion of chlorine atoms are chlorine-35 than chlorine-37</p> <p>Allow the ratio of the peak heights to be 9:6:1</p> <p>Allow the abundance of chlorine-35 and chlorine-37 are different</p> <p>Allow there are two isotopes of chlorine</p>	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)(vi)	<p>An answer that makes reference to the following points:</p> <p>Either</p> <ul style="list-style-type: none"> the peaks are formed by fragments containing both chlorine atoms attached to one carbon atom or the fragments are $\text{CH}^{35}\text{Cl}^{37}\text{Cl}^+$, $\text{CH}^{35}\text{Cl}_2^+$ and $\text{CH}^{37}\text{Cl}_2^+$ this fragmentation / configuration is only possible from 1,1-dichloroethane / is not possible from 1,2-dichloroethane <p>Or</p> <ul style="list-style-type: none"> the peaks at 83, 85 and 87 represent the loss of a CH_3 group only 1,1-dichloroethane has a methyl group 	<p>Allow a diagram showing the fragmentation of 1,1-dichloromethane to form a fragment containing one carbon and two chlorine atoms</p> <p>Allow the use of molecule instead of fragment</p> <p>Do not award fragments where the number of hydrogens on the carbon changes</p> <p>Allow just CHCl_2^+</p> <p>Do not penalise the absence of the positive charge</p> <p>Do not award fragments where the number of hydrogens changes to allow for the different masses</p> <p>Allow only 1,1-dichloroethane has two chlorines on the same carbon / 1,2-dichloroethane does not have two chlorines on the same carbon</p> <p>Allow the peaks are 15 below the molecular ion values so they represent the loss of a CH_3 group</p>	(2)

<p>Indicative content:</p> <ul style="list-style-type: none"> IP1 add anti-bumping granules IP2 to prevent the formation of large bubbles / rapid heating / transfer of reaction mixture to collecting vessel (leading to impure product) IP3 the thermometer should be opposite the entrance of the condenser IP4 collecting over the wrong temperature range (therefore impure or the wrong product) IP5 add more ice-water mixture IP6 ensure you collect as much product as possible 	<p>Ignore stated errors which are not present</p> <p>Allow to prevent uneven boiling / ensure smooth boiling</p> <p>Ignore prevents bumping</p> <p>Do not award so reaction does not explode / shatter glassware / damage apparatus</p> <p>Allow thermometer should be measuring the vapour temperature not the liquid temperature</p> <p>Allow collecting impure product but must be linked to wrong position of thermometer</p> <p>Do not award just the temperature is inaccurate without mention of vapour</p> <p>Allow collection flask should be further in the ice-water mixture</p> <p>Allow to ensure greater / quicker condensation</p>	
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Question Number	Acceptable Answer	Additional Guidance	Mark
3(d)(i)	<ul style="list-style-type: none"> fully displayed formula of isomer B (butan-2-ol) 	<p><u>Example of displayed formula</u></p> <pre> H H H H H — C — C — C — C — H H H O—H H </pre> <p>Allow O—H shown as OH and ignore connectivity unless shown horizontally as —HO</p> <p>Do not award methyl and ethyl groups to be shown as CH₃ and C₂H₅</p>	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(d)(ii)	<ul style="list-style-type: none"> structural formula of butane-1,2-diol 	<p><u>Example of structural formula</u></p> <p>CH₃CH₂CH(OH)CH₂OH</p> <p>Allow partially displayed formula eg</p> <pre> CH₃CH₂CH CH₂ OH OH </pre> <p>Allow C₂H₅</p> <p>Ignore connectivity of vertical OH groups</p>	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(a)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> ethanol / ethanol & water mixture is used to ensure all reactants mix efficiently / are in same phase same volumes (of each reactant) ensures a fair test warm water bath used to speed up reaction <p>Or</p> <p>water bath ensures all reactions carried out at same temperature (fair test)</p>	<p>(1) Allow ethanol enables halogenoalkane to be soluble</p> <p>(1) Allow use the same volume of silver nitrate</p> <p>Allow use the same volume of halogenoalkane</p> <p>Allow alternative wording to 'fair test' such as improves reliability</p> <p>(1) Allow because the hydrolysis / reaction of chloroalkanes / some halogenoalkanes is (very) slow</p>	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(a)(ii)	<p>An explanation that makes reference any two of the following three points:</p> <ul style="list-style-type: none"> (hydrolysis by water) releases halide ions halide ions react with silver (ions) to give an insoluble silver halide/ product / ppt 	<p>(1) Allow a correct equation with / without states</p> <p><u>Example of equation</u></p> <p>$R-X + H_2O \rightarrow R-OH + X^- + H^+$</p> <p>If shown, states must be correct but allow ethanol as solvent</p> <p>(1) Do not award use of halogen for halide</p> <p>(1) A correct equation with states to score (2)</p> <p><u>Example of equation</u></p> <p>$X^-(aq) + Ag^+(aq) \rightarrow AgX(s)$</p>	(2)

Question Number	Answer	Mark
4(a)(iii)	The only correct answer is A (X, Y, Z)	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(b)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> tertiary bromoalkanes react fastest <p>OR</p> <p>primary bromoalkanes react slowest</p>	<p>Allow names as identifiers in explaining reason e.g. Allow answers in terms of bond strength, ie C-Br bond is weakest in 2-bromo-2-methylpropane</p> <p>OR</p> <p>strongest in 1-bromobutane</p> <p>Allow primary bromoalkanes are more stable</p> <p>Ignore reference to secondary bromoalkane</p>	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(d)(i)	<p>An answer that makes reference to two of the following points:</p> <ul style="list-style-type: none"> many organic reactions are equilibria (with a significant equilibrium constant) side reactions may also take place a specific handling loss 	<p>(1) Allow reverse reactions lower yield Allow eqm not achieved, takes too long / slow reaction / high activation energy Reaction stopped before eqm achieved Allow reactions are incomplete</p> <p>(1) e.g. substitution v elimination Allow reference to by-products/minor products</p> <p>(1) e.g. loss of liquid during transfer between containers, volatility</p>	(2)

