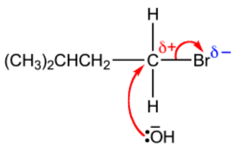
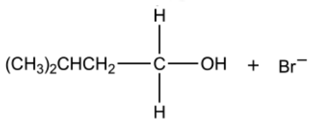
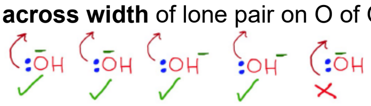
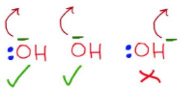
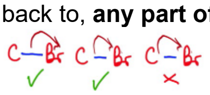
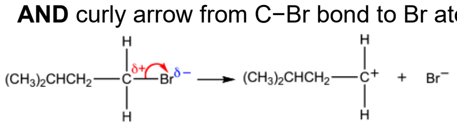
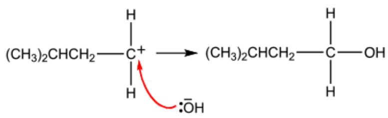
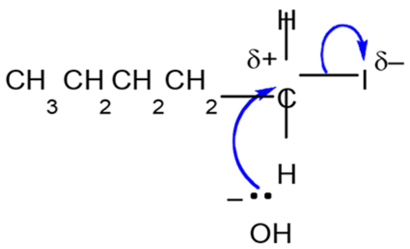
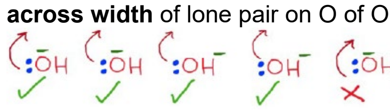
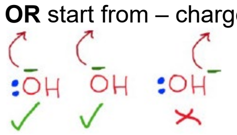
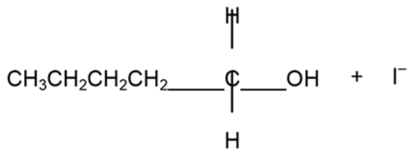
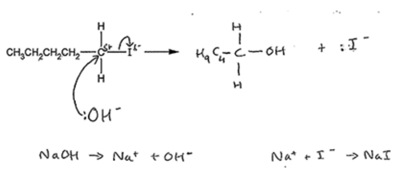
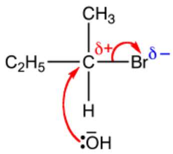
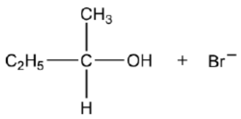
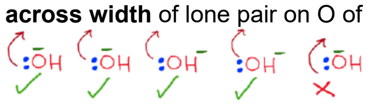
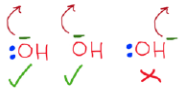
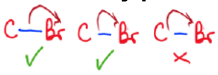
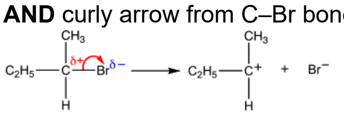
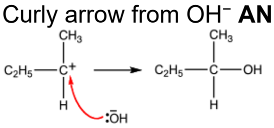
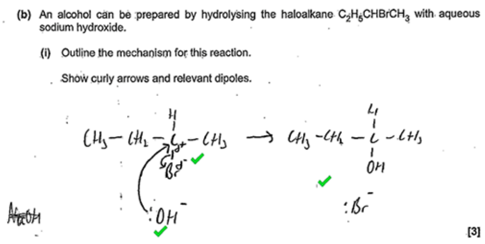
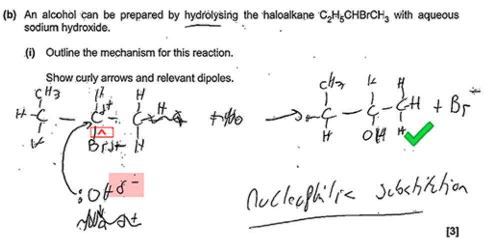
Mark scheme - Haloalkanes

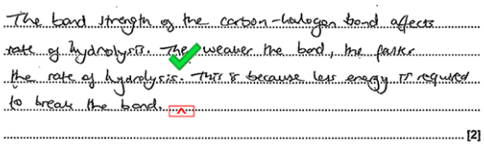
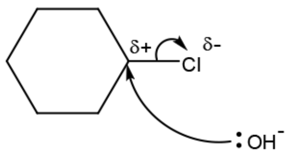
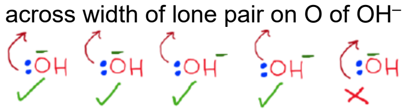
Question	Answer/Indicative content	Marks	Guidance
1 a i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF atom economy = 46.1(%) award 2 marks** -- Atom economy $= \frac{M_r \text{ of } (CH_3)_2CHCH_2CH_2OH}{M_r\ (CH_3)_2CHCH_2CH_2OH + M_r\ NaBr} \times 100$ **OR** $= \frac{88}{190.9} \times 100$ ✓ = 46.1(%)✓	2 (AO1.2×1) (AO2.2 ×1)	**ALLOW** $\frac{M_r\ (CH_3)_2CHCH_2CH_2OH}{M_r\ (CH_3)_2CHCH_2CH_2Br + M_r\ NaOH} \times 100$ **ALLOW** 46% up to calculator value (46.09743321) **ALLOW ECF** from incorrect M_r values **Examiner's Comments** Most candidates were able to recall the formula to calculate atom economy, however a number made errors in working out M_r values. However, some left this blank or just gave an answer without any working.
ii	**ANNOTATE ANSWER WITH TICKS AND CROSSES** -- **Curly arrows 2 marks** curly arrow from OH– to C atom of C−Br bond ✓ dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C−Br bond to Br atom ✓  **IGNORE** incorrect R groups for curly arrow marks **IGNORE** presence of Na+ but OH– needed i.e. Na+OH–can be allowed if criteria met --- **Products 1 mark** correct organic product AND Br– ✓  **IGNORE** presence of Na^+ but Br^- needed i.e. Na^+Br^-can be allowed **BUT** NaBr does **NOT** show Br– **NOTE:** curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows	3 (AO2.5×1) (AO1.1×1) (AO2.5×1)	**1st curly arrow** must • go to the C of C–Br **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of OH–  • **OR** start from – charge **on O** of ⁻OH ion  (*Lone pair **NOT** needed if curly arrow shown from O–*) **2nd curly arrow** must start from, **OR** be traced back to, **any part of** C–Br bond and go to Br  --- **ALLOW** S_N1 mechanism for 2 curly arrow marks **First mark** Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C−Br bond to Br atom ✓  **Second mark** Curly arrow from OH– **AND** to correct carbocation  Use curly arrow criteria in guidance above

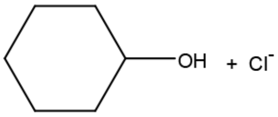
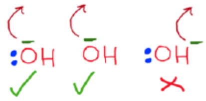
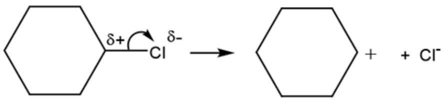
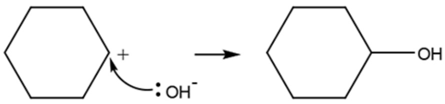
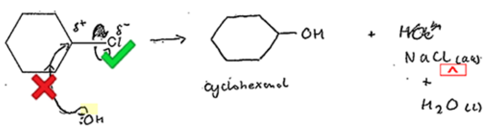
					Examiner's Comments Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, charges and dipoles were often incorrect, and partial changes used where full charges were required. Writing mechanisms is an important skill in organic chemistry so it is vital that time is spent practising writing them out and fully understanding the significance of the curly arrow.
		iii	Nucleophilic substitution ✓	1 (AO1.1×1)	**Examiner's Comments** Many candidates gave the correct mechanism here, with common incorrect responses being other types of mechanism, substitution only, or isomerism.
	b		Rate slower with chloroalkane **ORA** ✓ C–C*l* bond is stronger than C–Br bond **OR** C–C*l* bond has greater bond enthalpy **OR** more energy needed to break C–C*l* bond ✓	2 (AO3.1×1) (AO2.5×1)	**IGNORE** reference to bond polarity **Examiner's Comments** Very few candidates gained both marks here. It was not enough here to just state faster/slower without specifying which haloalkane they were referring to. It was also important to specify the C-X bond not just vague reference to the chlorine or bromine bond. Many described the difference in bond polarity so had the wrong order. Some were more general and discussed the reactivity of bromine and chlorine themselves.
			Total	**8**	
2		i	Curly arrow from HO^- to carbon atom of C−I bond ✓ Dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ **AND** curly arrow from C−I bond to I atom ✓  **IGNORE** presence of Na^+ but OH^- needed i.e. Na^+OH^- can be allowed if the criteria are met --- Correct organic product **AND** I^- ✓	3(AO2.5×3)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the C of C–I **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of OH^-  • **OR** start from – charge **on O** of ^-OH ion  *(Lone pair **NOT** needed if curly arrow shown from O^-)*

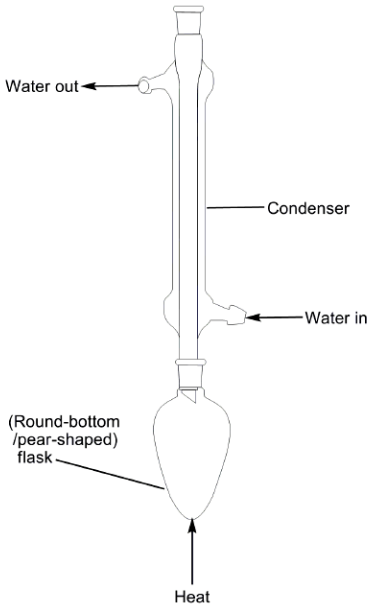
			 **IGNORE** presence of Na^+ but I^- needed i.e. Na^+I^- can be allowed BUT NaI does not show I^-		**2nd curly arrow** must start from, **OR** be traced back to, **any part of** C–I bond and go to I  **Examiner's Comments** Those that had learnt this important mechanism scored all 3 marks with very precisely drawn arrows and partial charges. Although many candidates wrote out the correct organic product, many wrote NaI instead of I^- which lost them the final mark. **Exemplar 4**  This candidate scored all 3 marks. The lone pair of electrons on the oxygen and partial charges on the C-I bond are clearly marked on the diagram and the arrows are precisely drawn. Connectivity is good on the organic product and I^- identified as the additional product.
		ii	**Time** for **precipitate** to appear ✓	1(AO3.3)	Time **AND** precipitate required *Question asks for measurement* **Examiner's Comments** The question asked for the measurement AND observation, many students did not answer both parts and therefore did not gain any marks. "How fast" and "how long" were not given as they did not detail the measurement.
		iii	C–I bond is weaker (than C–Br bond) **OR** C–I bond has a lower bond enthalpy (than C–Br bond) ✓ Carbon – halogen **bond breaks** ✓	2(AO3.2)	**For 2 marks,** **ALLOW** C–I is broken more easily (than C–Br) as the bond is weaker There must be a **comparison** between C–Br and C–I bonds **Examiner's Comments** Answers were too vague to be given in most cases. Candidates referred to bonds being broken or overcome, but did not specify C-I bonds breaking, or discussed iodine and bromine in terms of reactivities.

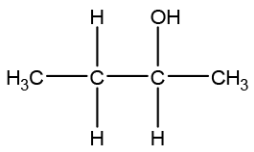
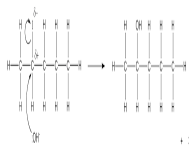
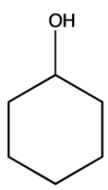
			Total	**6**	
3		i	**ANNOTATE ANSWER WITH TICKS AND CROSSES** --- **Curly arrows 2 marks** curly arrow from OH− to C atom of C–Br bond ✓ dipole shown on C−Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom  **IGNORE** incorrect R groups for curly arrow marks **IGNORE** presence of Na^+/Na but OH^- needed i.e. Na^+OH^-; $NaOH^-$ can be allowed with correct use of curly arrow --- **Products 1 mark** correct organic product **AND** Br^- ✓  **IGNORE** presence of Na^+ but Br^- needed i.e. Na^+Br^-/$NaBr^-$ can be allowed **BUT** NaBr does **NOT** show Br^- **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows	3	**1st curly arrow must** • go to the C of C–Br **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of OH^-  • **OR** start from – charge **on O** of ^-OH ion  *(Lone pair **NOT** needed if curly arrow shown from O^-)* **2nd curly arrow** must start from, **OR** be traced back to, **any part of** C–Br bond and go to Br  --- **ALLOW** S_N1 mechanism for 2 curly arrow marks **First mark** Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom  **Second mark** Curly arrow from OH^- **AND** to correct carbocation  Use curly arrow criteria in guidance above <u>**Examiner's Comments**</u> As with 25(a)(i), this question rewarded the well-prepared candidate. The large number of proposed mechanisms showed little resemblance to the accepted mechanism for nucleophilic substitution. Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, charges and dipoles were often incorrect, and partial changes used where full charges were required. Two exemplars are shown. The first exemplar shows clear curly arrows, the role of the lone pair and all charges correct. The second exemplar shows a typical muddled response. Although the curly arrow from the hydroxide ion has been accurately drawn, the hydroxide ion has a partial charge rather than a - charge. There is also no curly arrow showing breaking of the C–Br bond. The only

					mark available is for the correct organic product and a Br^- ion. Some mechanisms were so poor that it was impossible to credit many candidates with any marks. Writing mechanisms is an important skill in organic chemistry and it is recommended that candidates learn and practice their writing. **Exemplar 7**  **Exemplar 8** 
		ii	**Disappearance** of peak at 500-800 cm^{-1} **OR** C–Br peak ✓ Appearance of peak at 3200-3600 cm^{-1} **OR alcohol** O–H peak	**2**	**ALLOW** value within range 500–800 $cmcm^{-1}$ **ALLOW** value within range 3200–3600 $cmcm^{-1}$ **DO NOT ALLOW** responses that only describe the spectrum shown **Examiner's Comments** This part discriminated very well with able candidates identifying that the absorption for the C–Br bond would disappear, with a new peak appearing for the alcohol O–H bond. A significant number of candidates did not seem to understand what was required, with many interpreting the spectrum as that of the alcohol, rather than predicting how the spectrum would change during the reaction. A common error was to interpret the absorption for a C–H bond at ~3000 cm^{-1} as that of an O–H bond.
			Total	**5**	
4	a		Links rate of reaction to strength of bond/bond enthalpy ✓	**2**	**Each marking point must be a comparison**

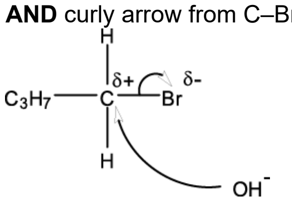
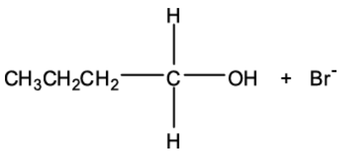
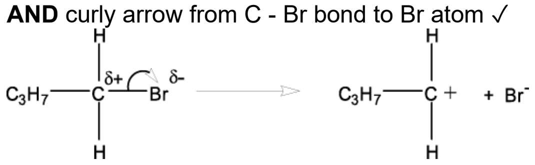
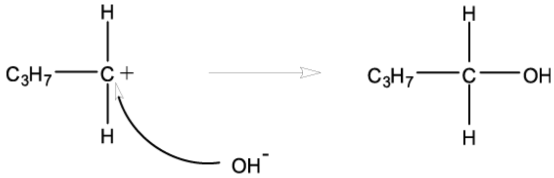
			e.g. the weaker the bond the faster the reaction stronger bond takes longer to break lower bond enthalpy reacts faster Correct comparison of rate of reaction for at least **two** C–Hal bonds e.g. C–F bond is hydrolysed slow**est** C–I bond is hydrolysed faster than C–Br C–Br has shorter reaction time than C–Cl **OR** Correct comparison of C–Hal bond strength/enthalpy of at least **two** of C–Hal bonds e.g. C–I bond is the weak**est** C–I has lower bond enthalpy than C–Br C–Br is broken more easily/readily than C–Cl C–Hal bond strength decreases down group (7) ✓		**IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide and iodide **IGNORE** references to bond length, polarity and electronegativity **<u>Examiner's Comments</u>** This question required candidates to link the rate of hydrolysis with the strength of the carbon-halogen bond present in different haloalkanes. Higher ability candidates were able to do this succinctly, making clear comparisons between different C-X bonds. Exemplar 5 shows a commonly seen one mark response. **Exemplar 5**  This response correctly describes the effect of bond strength on the rate of hydrolysis and receives one mark. To score the second mark a comparison of two different carbon-halogen bonds is required.
	b		Curly arrow from HO^- to carbon atom of C–Cl bond ✓ Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C–Cl bond to Cl atom ✓  **IGNORE** presence of Na^+ but OH^- needed i.e. Na^+OH^- can be allowed if criteria met --- Correct organic product **AND** Cl^- ✓	3	**ANNOTATE ANSWER TICKS AND CROSSES** **NOTE:** curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the C of C–Cl AND • start from, OR be traced back to any point across width of lone pair on O of OH^- 

			 **IGNORE** presence of Na^+ but Cl^- needed i.e. Na^+Cl^- can be allowed **BUT** NaCl does **NOT** show Cl^-		• OR start from – charge on O of ^-OH ion  *(Lone pair **NOT** needed if curly arrow shown from O^-)* **2nd curly arrow** must start from, **OR** be traced back to, **any part of** C–Cl bond and go to Cl  -- **ALLOW** S_N1 mechanism **First mark** Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  Curly arrow must come from lone pair on O of HO^- OR OH^- **OR** from minus on O of HO^- ion (no need to show lone pair if curly came from negative charge) ✓ **Third mark** Correct organic product **AND** Cl^- ✓ -- **<u>Examiner's Comments</u>** Candidates were very familiar with this nucleophilic substitution mechanism. Consequently the majority of candidates scored two or three marks. Common errors included inaccurate curly arrows from the hydroxide ion and failure to show the chloride ion as a product. Exemplar 6 highlights both of these. **Exemplar 6**  This response demonstrates the two most common errors seen in this part. The first marking point

					cannot be credited as the curly arrow from the hydroxide ion does not involve either the lone pair or minus sign on the O atom. The organic product is correct but the chloride ion produced by the heterolytic fission of the C-C*l* bond is not shown so marking point three cannot be credited. This response only scores one mark for the correct partial charges and curly arrow on the C-C*l* bond. Candidates are encouraged to practice drawing mechanisms so as to avoid costly errors during examinations.
	c	i	**Diagram** Diagram showing round bottom/pear shaped flask **AND** upright condenser ✓  **Labels** (Round-bottom/pear-shaped) flask **AND** condenser **AND** water in at bottom and out at top **AND** heat (source) ✓	2	**DO NOT ALLOW** conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask **DO NOT ALLOW** distillation **DO NOT ALLOW** stopper/bung on top of condenser **IGNORE** a thermometer in condenser **IGNORE** a small gap between flask and condenser **ALLOW** diagram of heating apparatus as an alternative to heat label <u>**Examiner's Comments**</u> Most candidates were able to draw a suitable diagram to show the apparatus required for reflux but some included a stopper on top of the condenser. Many of the diagrams were labelled appropriately but common errors included incorrect direction of water flow or omission of the 'flask' label. A small but significant proportion of candidates drew a diagram showing distillation.
		ii	**Precipitate G** **1 mark** silver bromide/AgBr **AND** *M* = 1.88/0.01 = 188 (g mol^{-1}) 188 – 107.9 = 80.1 (so halide is Br^-)✓	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** working is **required** for first mark **ALLOW** use of 108 as *A*r of Ag

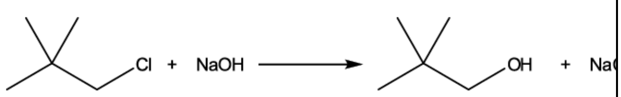
			Alcohol F and Haloalkane E **2 marks** **E** and **F** clearly identified **F/alcohol:** butan-2-ol  **E/haloalkane:** E is haloalkane of C_4H_9X with • same halogen as **G** **AND** • same carbon chain as **F** ✓		**Note:** **E** and **F** can be identified by correct name or structure **BUT IGNORE** incorrect names **<u>Examiner's Comments</u>** This question, requiring candidates to analyse the information to identify compounds **E**, **F** and **G**, discriminated well. Many candidates deduced that G was a silver halide but not all provided working to back up their choice of AgBr. Some candidates appeared to guess and AgC*l* was commonly seen. Some candidates used the molar mass of **F** provided to deduce the molecular formula of $C_4H_{10}O$ but lower ability responses did not process this further. Higher ability candidates identified **F** as butan-2-ol, showing the chiral carbon clearly. Other alcohols were also seen including butan-1-ol and methylpropan-2-ol. The highest ability candidates linked all the information and provided a structure for **E** that was consistent with their suggestions for **F** and **G**.
			Total	**10**	
5		i	Reflux	1	
		ii	Nucleophilic substitution (1) *Mechanism* Curly arrow from lone pair on OH^- to δ+ carbon atom (1) Curly arrow and dipole on C–I bond (1) Correct products (1)	4	The curly arrow must start from the oxygen atom of the OH^- and must start from either the lone pair or the negative charge  **do not allow** attack by NaOH
			Total	**5**	
6		i	 ✓ Acid (catalyst) **AND** heat ✓	**2**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** (heat under) reflux **ALLOW** H_3PO_4 OR H_2SO_4 OR H+ **DO NOT ALLOW** other named acids **IGNORE** concentration / pressure

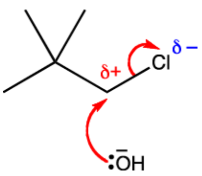
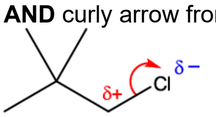
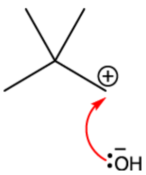
					IGNORE water / steam **Examiner's Comments** Candidates who were able to give the structure of the intermediate were not always able to state the conditions for the elimination of water from an alcohol. The presence of an acid catalyst and heat are stated in the specification. Some candidates confused this reaction with addition reactions of alkenes suggesting that a Ni catalyst or the presence of steam is required.
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 44.4(%) award all 3 marks for calculation *Amount cyclohexene (m / M)* = 1.23/82 **OR** 0.0150 mol ✓ *Amount of brnmocyclohexane (m / M)* = 5.50/162.9 **OR** 0.0338 mol ✓ % yield = (0.0150/0.0338) × 100 = 44.4(%) ✓ Final answer **must** be to 3 significant figures	**3**	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW 3 SF**: 0.0338 up to calculator value of 0.033763044 correctly rounded **Common ECFs** (2 marks) • Incorrect M_r → incorrect moles of cyclohexene • Incorrect M_r → incorrect moles of 2- bromocyclohexane e.g. **ALLOW two marks** for use of incorrect mass of bromocyclohexane with other calculations correct e.g. (5.50/163) = 0.033742331 → 44.5% **ALLOW** calculation in mass *Theoretical mass yield:* *m*(C_6H_{10}) = 0.0338 × 82 = 2.77 g % yield = (1.23/2.77) × 100 = 44.4% **Examiner's Comment:** Although some candidates simply calculated 1.23/5.50, most followed an effective strategy for the calculation of percentage yield. Many gained full marks but a large number of candidates relied on the application of error carried forward when they made one or more careless errors during the calculation of molar mass and / or moles. Intermediate answers were sometimes rounded to 2 significant figures and marks were lost by candidates who presented their final answer to 2 or 4 significant figures.
			Total	**5**	
7	a	i		3	**ANNOTATE ANSWER WITH TICKS AND CROSSES**

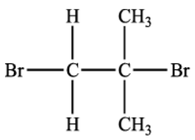
			curly arrow from HO^- to carbon atom of C - Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓  correct organic product **AND** Br^- ✓ 		Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus on O of HO^- ion (no need to show lone pair if curly arrow came from negative charge) **IGNORE** alkyl group in the first marking point **ALLOW** S_N1 mechanism **First mark** Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C - Br bond to Br atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus on O of HO^- ion (no need to show lone pair if curly arrow came from negative charge) ✓ **Third mark** correct organic product **AND** Br^- ✓
		ii	Nucleophilic substitution ✓	1	
		iii	1-iodobutane **AND** C–I bonds are weaker (than C-Br) **OR** C–I bond has a lower bond enthalpy **OR** C–I bond needs less energy to break **OR** C–I bond is easier to break ✓	1	**Note:** the haloalkane could be identified by a correct structure e.g. $CH_3CH_2CH_2CH_2I$ **IGNORE** molecular formula **IGNORE** iodobutane (*no locant number*) Statement **must** be comparative **ALLOW ORA** **IGNORE** C–I bond is longer **IGNORE** polarity and references to electronegativity
	b	i	$CF_3Cl \rightarrow CF_3\bullet + Cl\bullet$ ✓	1	**Note:** dots are **required**
		ii	Step 1: $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ ✓ Step 2: $ClO\bullet + O \rightarrow Cl\bullet + O_2$ ✓ Overall equation: $O_3 + O \rightarrow 2O_2$ ✓	3	**ALLOW** one mark for both correct symbol equations in propagation steps with (any or all) dots missing or extra dots. e.g. $Cl\bullet + O_3\bullet \rightarrow ClO + O_2$ $ClO\bullet + O\bullet \rightarrow Cl + O_2\bullet$

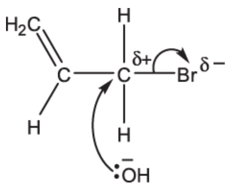
		iii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 9.98×10^4 award 3 marks $n(Cl\bullet) = \frac{1}{35.5} = 0.02817$ (mol)✓ $n(O_3) = \frac{135000}{48} = 2812.5$ (mol) ✓ $n(Cl\bullet) : n(O_3) = \frac{2812.5}{0.02817} = 9.98 \times 10^4$ ✓ *Must be in standard form* ***AND*** *to 3SF*	3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW** 0.0282 up to calculator value of 0.02816901408 correctly rounded to 3 or more sig. fig. **ALLOW 3SF**: 2810 up to calculator value of 2812.5 correctly rounded **Note**: use of 0.0282 mol $Cl\bullet$ gives 9.97×10^4
			Total	**12**	
8	a		***Empirical / molecular formula 3 marks*** Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C_3H_7Br ✓ **QWC** (Molecular formula) = C_3H_7Br **AND** relative mass linked to 150 evidence ✓ ***Structural isomers 2 marks*** $CH_3CH_2CH_2Br$ ✓ $CH_3CHBrCH_3$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$ Evidence could include a calculation of the relative mass of C_3H_7Br as 122.9 linking to M_r being less than 150 **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structure **Note:** structures from an incorrect molecular formula will be credited on their merits. Please consult TL for advice on how to mark the subsequent parts of this question **Examiner's Comments** Calculation of empirical formula has always been a strength of candidates at this level. Consequently the vast majority were able to deduce the structures of the two isomers correctly. A significant number of candidates failed to secure full marks as they did not link the M_r of the empirical formula with the information about the M_r of the isomers being less than 150. Some candidates tried to use the value of 150 to determine the formula of **C** and **D**, ultimately ending up with an incorrect answer. However, error carried forward marks were allowed through

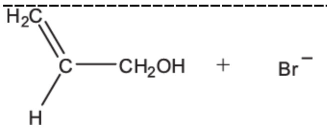
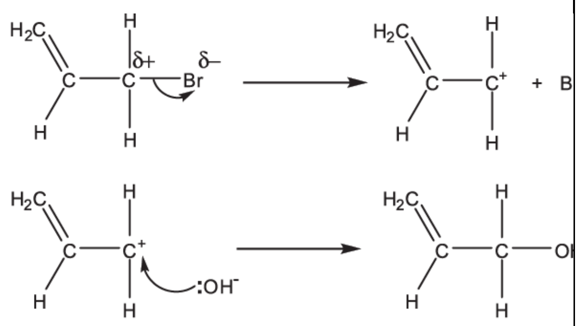
					subsequent parts of this question where appropriate.
	b	i	***Infrared for G 2 marks*** 1700 cm^{-1} **AND** C=O/carbonyl group ✓ (broad) 2300–3600 cm^{-1} **AND** O–H in carboxylic acid ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **ALLOW** ranges from *Data Sheet*: C=O within range 1640−1750 cm^{-1}; (broad) O−H within range 2500−3300 cm^{-1}
		i	***Structures 3 marks*** $CH_3CH_2CH_2OH$ ✓ $CH_3CHOHCH_3$ ✓ CH_3CH_2COOH ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $CH_3CH_2CO_2H$ for carboxylic acid **IGNORE** names **IGNORE** labels **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structures
		i	***Equation for formation of G 1 mark*** $C_3H_8O + 2[O] \rightarrow C_3H_6O_2 + H_2O$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above in equation **Examiner's Comments** Candidates were well prepared for a structural determination question and examiners were encouraged by the number of high quality of responses to this question. Most candidates were able interpret the key peaks in the IR spectrum and identified the O-H bond of a carboxylic acid and C=O bond accurately. Most candidates identified all three structures correctly. Only the strongest responses included a correct equation for the formation of **G** by oxidation of **E**. Many responses failed to include this and others often had H_2 as the inorganic product. Candidates are advised to revise oxidation reactions of alcohols thoroughly as it is often the case that incorrect equations are frequently seen in responses to exam questions.
		ii		2	**ANNOTATE ANSWER WITH TICKS AND CROSSES**

			2 marks for correct ester. $CH_3CH_2COOCH(CH_3)_2$ ✓✓ Award 1 mark for: $CH_3CH_2COOCH_2CH_2CH_3$ **OR** Ambiguous ester: $CH_3CH_2COOC_3H_7$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $C_2H_5CO_2CH(CH_3)_2$ **IF** there is one bond and its H missing from the correct ester award 1 mark **Examiner's Comments** Most candidates were able to show the structure of the ester formed from propanoic acid (**G** and propan-2-ol **(F)** correctly. Some candidates used the incorrect alcohol, propan-1-ol **(E)** and such responses received only one of the two marks available.
			Total	**13**	
9		i	Thunderstorms / lightning **AND** aircraft ✓	3	**IGNORE** car engines **Examiner's Comments** This question required candidates to state two sources of nitrogen oxides in the stratosphere. Whilst most candidates identified one, this was often accompanied by vague or irrelevant statements such as 'car engines' or 'the burning of fossil fuels'. Consequently only the strongest candidates scored in this part.
		ii	$NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	2	**ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$ **IGNORE** dots **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$ **Examiner's Comments** The majority of candidates were able to provide the two equations that describe the catalytic role of NO in ozone depletion. A small but, significant proportion, of candidates provided equations involving N atoms.
			Total	**3**	
1 0		i		1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** equation with OH^- as reactant and Cl^- product

					e.g $(CH_3)_3CCH_2Cl + OH^- \longrightarrow (CH_3)_3CCH_2OH + Cl^-$ **IGNORE** equations with KOH / H_2O as reactant *(question states sodium hydroxide)* **IGNORE** molecular formulae *(question requires structures)* **Examiner's Comments** Most candidates were able to identify the correct chloroalkane required to produce 2,2-dimethylpropan-1-ol and provided a correctly balanced equation. A small but significant proportion of candidates failed to show the inorganic product in their equation. Candidates are encouraged to check equations carefully to ensure the correct formulae appear on both sides.
		ii	 curly arrow from HO^- to carbon atom of C—Cl bond ✓ Dipole shown on C—Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C–Cl bond to Cl atom ✓	2	Curly arrow must come from lone pair on O of HO^- OR OH^- **OR** from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) **NOTE:** **ALLOW** mechanism involving **ANY** halogenoalkane as structures have been assessed in (**i**) .... **ALLOW** S_N1 mechanism: **First mark** Dipole shown on C—Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C—Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  **Note:** '+' is fine for charge (circle used for clarity) Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) ✓ .... **Examiner's Comments**

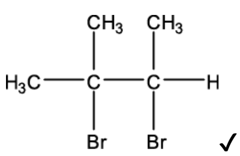
					The mechanism of the hydrolysis of a primary halogenoalkane was well known and consequently most candidates scored both marks. A small, but significant, proportion of candidates started their curly arrow from the H atom of the hydroxide ion. Candidates should be advised to take care when drawing mechanisms to ensure curly arrows are used accurately.
			Total	**3**	
11		i	C_2H_5O ✓	1	**ALLOW** elements in any order **DO NOT ALLOW** any other answer **Examiner's Comments** This part was answered well by most candidates. Some candidates however wrote the molecular rather than the empirical formula, or attempted to show the empirical formula as C_2H_4OH instead of C_2H_5O.
		ii	Compound E:  ✓ **Stage 1**: Compound **E**: Bromine/Br_2 ✓ **Stage 2**: NaOH/KOH **OR** OH^- ✓ *Only award if intermediate contains at least **one** halogen atom*	3	**For structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **ALLOW** dichloro/diiodo compound **IGNORE** connectivity of bonds to CH_3 **ALLOW** chlorine/Cl_2 **OR** iodine/I_2 **IGNORE** conditions, e.g. u.v. **DO NOT ALLOW** H_2O **IGNORE** conditions **NOTE:** Max of **2 marks** available for **monobrominated** intermediate **1 mark** Reagent: HBr **AND** Intermediate: $CH_3C(CH_3)_2Br$ **OR** $BrCH_2CH(CH_3)_2$ **1 mark** Intermediate: $CH_3C(CH_3)_2Br$ **OR** $BrCH_2CH(CH_3)_2$ **AND** Reagent: NaOH **Examiner's Comments**

					This demanding part was answered poorly by weaker candidates and was good for differentiating higher ability candidates. The mark scheme allowed some credit for using a hydrogen halide to obtain a monosubstituted haloalkane for compound E. Surprisingly, reaction mechanism names were often given instead of reagents. Many candidates seemed to guess, sometimes showing the same reagents for both stages in the hope of getting a mark. Many showed an intermediate containing no halogen atom.
			Total	**4**	
12			Propagation step 1 $NO\cdot + O_3 \rightarrow NO_2\cdot + O_2$ ✓	1	**ALLOW** one mark for both correct symbol equations with (any or all) dots missing or extra dots
			Propagation step 2 $NO_2\cdot + O \rightarrow NO\cdot + O_2$ ✓	1	e.g. $NO + O_3 \rightarrow NO_2\cdot + O_2$ $NO_2 + O \rightarrow NO + O_2\cdot$ **Examiner's Comments** Many incorrect equations or correct symbol equations containing incorrect radicals were observed. A large proportion of candidates scored no marks on this question although the most able often provided both equations to gain two marks.
			Total	**2**	
13	a	i	Movement of an electron pair ✓	1	**ALLOW** movement of a lone pair **OR** movement of a bond **Examiner's Comments** Although the definition of a curly arrow was well known, many imprecise responses were seen. The most common was that a curly arrow represents the movement of electrons. Candidates should be aware that it is important to refer to an electron pair, when describing the meaning of a curly arrow.
		ii	Electron pair donor ✓	1	**ALLOW** can donate a lone pair **Examiner's Comments** Most candidates could state the correct definition. However, as with part (i) a significant number of candidates failed to specify 'electron pair' and stated that a nucleophile is an electron donor.
	b	i		3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No

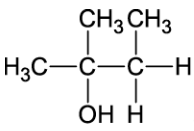
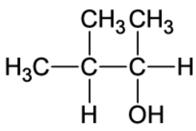
			curly arrow from HO^- to carbon atom of C−Br bond ✓ Dipole shown on C−Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓ --  correct organic product **AND** Br^- ✓		need to show lone pair if curly arrow came from negative charge on O) -- **ALLOW** S_N1 mechanism: Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓ Correct carbocation **AND** curly arrow from HO^- to carbocation Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No need to show lone pair if curly arrow came from negative charge on O) ✓ correct organic product **AND** Br^- ✓  -- **Examiner's Comments** This question discriminated well and most candidates were able to score at least one mark, often by showing the curly arrow and dipole on the C-Br bond. The best responses included neatly drawn structures and accurately placed curly arrows. The use of NaOH, rather than OH^-, by a lot of candidates led to difficulties for both the first and third marking points. The latter of which was missed as candidates stated the inorganic product as NaBr and neglected to show the Br^- ion formed from the heterolytic fission of the C—Br bond. Candidates are advised to only show the relevant ions when drawing mechanisms.
		ii	Nucleophilic substitution ✓	1	**Examiner's Comments** The majority of candidates could name this mechanism as nucleophilic substitution.
	c	i	H_2 **AND** Ni (catalyst) ✓	1	**ALLOW** name or formula for each **IGNORE** any stated temperature and pressure **Examiner's Comments** To score the mark in this question candidates had

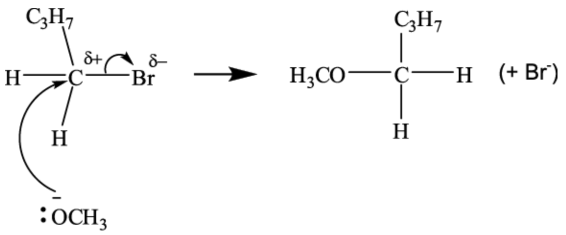
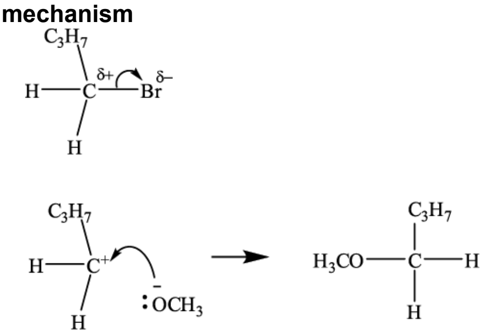
					to state that both hydrogen and nickel were required for step 1. It was often the case that only one of these was stated. Although hydrogen was often seen as a reagent it was common to see an incorrect catalyst, such as H_2SO_4.
		ii	(Initiation) $Cl_2 \rightarrow 2Cl$ **AND** UV ✓ (Propagation) $C_3H_7Br + Cl \rightarrow C_3H_6Br + HCl$ ✓ $C_3H_6Br + Cl_2 \rightarrow C_3H_6BrCl + Cl$ ✓ (Termination) Two from the three termination equations below ✓ $2Cl \rightarrow Cl_2$ $C_3H_6Br + Cl \rightarrow C_3H_6BrCl$ $2C_3H_6Br \rightarrow C_6H_{12}Br_2$ names of steps initiation, propagation and termination linked to one correct equation for each step in this mechanism✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **DO NOT ALLOW** any ECF in this question **IGNORE** references to temperature **THROUGHOUT, ALLOW** correct molecular formulae **OR** structural **OR** displayed **OR** skeletal **OR** mixture of the above **IGNORE** dots **IGNORE** state symbols **IGNORE** one incorrect termination equation **Examiner's Comments** This question required candidates to apply their knowledge of the radical substitution mechanism to form a bromochloroalkane. Examiners were encouraged by the number of excellent attempts and it is clear that candidates had prepared well for this type of question. Consequently most candidates scored four or five marks. A common reason for a candidate only scoring four marks was the omission of UV radiation as an essential condition.
		iii	further substitution **OR** produces different termination products **OR** More than one termination step✓ substitution at different positions along chain ✓	2	**IGNORE** mixture of organic products (*in question*) **ALLOW** dichloro / multichloro / dibromo / multibromo compounds formed **OR** an example of a further substitution product **OR** 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 **ALLOW** forms different structural isomers **ALLOW** a hydrogen (atom) on a different carbon (atom) can be replaced **Examiner's Comments** Candidates often found it difficult to provide clearly written explanations for this question. The majorly of responses focused on further substitution or the idea of different termination steps. Only the best candidates recognised that chlorination of 1-

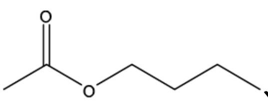
					bromopropane would produce a mixture of structural isomers.
			Total	**14**	
14		i	**ANY TWO FROM THE FOLLOWING ✓** Low reactivity **OR** will not burn / non-flammable Volatile **OR** low boiling point non-poisonous **OR** non-toxic	1	**ALLOW** inert **OR** stable **DO NOT ALLOW** inflammable **ALLOW** it is a gas **IGNORE** easily compressed **IGNORE** not harmful **IGNORE** references to solubility **Examiner's Comments** Stronger candidates were able to identify two suitable properties of **G**. Although the majority were able state a single property it was often accompanied by a repetitive or incorrect statement. Vague statements, which included ‘it is a CFC’ and ‘it is easily compressed’ were also frequently seen.
		ii	*Benefit of ozone layer to life (1 mark)* Ozone absorbs **UV** (radiation) ***UV*** at Earth's surface is reduced ✓ **OR** --- *Maintenance of* O_3 *concentration* (1 mark) $O_3 \rightleftharpoons O_2 + O$ ✓ --- *Production of radicals from* ***G*** *(1 mark)* $CF_2Cl_2 \rightarrow Cl + CF_2Cl$ ✓ --- *Breakdown of* O_3 *(2 marks)*	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** For all equations, **IGNORE** dots on radicals --- Essential idea for first mark is that **UV** is removed in some way. **ALLOW** Prevents **UV** damaging life or stated type of damage, e.g. cataracts, skin cancer, mutation, crop damage **DO NOT ALLOW** ozone absorbs IR --- **ALLOW** $O_3 \rightarrow O_2 + O$ **AND** $O_2 + O \rightarrow O_3$ **DO NOT ALLOW** $2O_3 \rightleftharpoons 3O_2$ **OR** $O_3 + O \rightarrow 2O_2$ for this mark ---

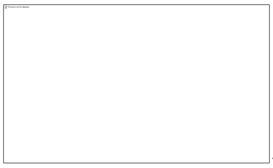
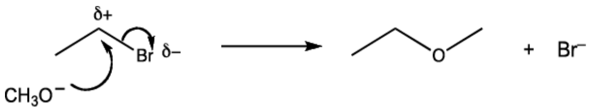
			$Cl + O_3 \rightarrow ClO + O_2$ ✓ **OR** $ClO + O \rightarrow Cl + O_2$ $ClO + O_3 \rightarrow Cl + 2O_2$✓		**DO NOT ALLOW** equations with other CFCs **DO NOT ALLOW** $CF_2Cl_2 \rightarrow 2Cl + CF_2$ -- These are the only acceptable equations **IGNORE** overall equation (*does not show role of catalyst*) e.g. $O_3 + O \rightarrow 2O_2$ **Examiner's Comments** This question was answered very well. Almost all candidates were able to recall the benefit of the ozone layer. The equations showing the catalytic breakdown of ozone with C*l* radicals were reproduced accurately by the majority of the cohort. Although most candidates were able explain how the concentration of ozone was maintained in words, the statements were not always accompanied by the relevant equations. The majority of candidates did not provide an equation to show the formation of C*l* radicals from **G** and consequently only the strongest candidates received full marks.
		iii	**D** ✓	1	**ALLOW** CHF_2Cl **ALLOW B OR** C_2F_4 **OR** CF_2CF_2 **Examiner's Comments** The majority of candidates suggested a suitable compound from the selection provided.
			Total	**7**	
15			The C−Br bond is weaker (than the C−C*l* bond)	1	**ORA**
			Total	**1**	
16	a		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **DO NOT ALLOW** molecular formula **ALLOW** dichloro or diiodo compound instead of the dibromo compound as the **only** alternatives. **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol

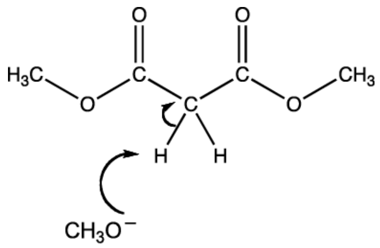
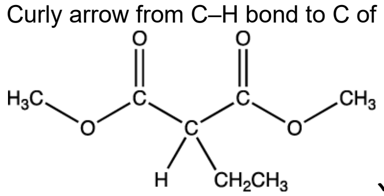
					shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).
	b		Reagent **A**: correct halogen✓ e.g. Br_2 / bromine	1	**ALLOW** Cl_2 if dichloro compound drawn **ALLOW** I_2 if diiodo compound drawn **IGNORE** state symbols Answer must match box from **(a)** to score **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).
	c	i	Steam **AND** acid catalyst ✓	1	**ALLOW** H^+ / named acid / H_2SO_4 / H_3PO_4 **ALLOW** $H_2O(g)$ **ALLOW** water only if a temperature of 100 °C or above is quoted. **IGNORE** any temperature given with steam **IGNORE** pressure **Examiner's Comments** One would expect the majority of candidates to do well in a question which required them to state the

					reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100 °C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure Same formula is **not** sufficient Different arrangement of atoms is **not** sufficient **Examiner's Comments** The majority of candidates were able to explain the term structural isomers.
		iii	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** any vertical bond to OH **DO NOT ALLOW** OH− **Examiner's Comments** Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula $C_5H_{12}O$, but that could not be formed from 2- methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1- ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methlybut-2-ene. Candidates should be reminded to check that any structures they suggest are consistent with the context of the question.
		i v	Does not contain OH group(s) **OR** does not contain hydroxyl group(s) **OR** is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	**ALLOW ORA** throughout **DO NOT ALLOW** OH^- (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is **not** sufficient **Examiner's Comments** The majority of candidates were able to recognise

					that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.
			Total	**8**	
17	a		It is an electron pair donor **OR** can donate a lone pair ✓	1	**Examiner's Comments** Most candidates were able to state that the methoxide ion acted as an electron pair donor. In some cases imprecise responses such as 'donates electrons' were seen. Candidates should be encouraged to give specific answers when asked to explain scientific terms.
	b		 Dipole shown on the C-Br bond, $C^{\delta+}$ and $Br^{\delta-}$ and curly arrow from the C-Br bond to the Br atom ✓ Curly arrow from :$\bar{O}CH_3$ to carbon atom in the C-Br bond ✓ Correct organic product ✓ **S_N1 mechanism** 	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** connectivity to C_3H_7 throughout **IGNORE** alkyl group in first marking point. Curly arrow must start from C–Br bond and not from C atom. Dipole must be partial charge and not full charge CH_3O^- curly arrow must come from one lone pair on O of CH_3O^- ion **OR** from negative sign on O of the CH_3O^- ion **ALLOW** arrow from lone pair on O in OCH_3^- Lone pair not required **DO NOT ALLOW** $CH_3O^{\delta-}$ **DO NOT ALLOW** incorrect connectivity of CH_3O group in the final product $-CH_3O$ **IGNORE** $Br^{\delta-}$ as a product **ALLOW S_N1 mechanism** Dipole shown on the C—Br bond, $C^{\delta+}$ and $Br^{\delta-}$ and curly arrow from C—Br bond to the Br atom ✓ curly arrow from CH_3O^- to carbonium ion ✓ correct organic product ✓ **Examiner's Comments** This question required candidates to apply their knowledge of the nucleophilic substitution mechanism in an unfamiliar context. The first mark was awarded for showing the dipole on the C-Br bond and the curly arrow to demonstrate the heterolytic fission of the bond. This

					proved to be the most accessible mark and most candidates scored it. The second mark was awarded for the curly arrow from the methoxide ion to the C atom of the C-Br bond. The more able candidates were able to show their understanding and provided accurately drawn arrows. A common misconception was to start the curly arrow from a lone pair on the C atom of the methoxide ion. The third mark was awarded for the correct organic product and was often scored by the stronger candidates. As a consequence of showing nucleophilic attack from the C atom of the CH_3O^- ion, a significant number of responses showed the incorrect connectivity, as the nucleophile was joined via the C atom rather than the O atom. Unfortunately a number of candidates attempted to show the mechanism using OH^- ions as the nucleophile rather than CH_3O^-. Although they were able to score the first mark no other marks were awarded. A very small proportion of candidates chose to show the S_N1 mechanism rather than the expected S_N2 and full credit was allowed if the response was correct.
	c		1-Iodobutane increases the rate ✓ **AND** C—I bonds are weaker (than C—Br) **OR** C—I bond has a lower bond enthalpy **OR** C—I bond needs a smaller amount of energy to break **OR** C—I bond is easier to break ✓	1	All statements must be **comparative** **ALLOW ORA** **IGNORE** C—I bond is longer **IGNORE** polarity and references to electronegativity **Examiner's Comments** Many candidates were able to predict that the rate of the reaction would increase. In addition to this the Mark Scheme required candidates to explain this by referring to the effect of the different C-halogen bond. Most candidates were able to identify that the C-I bond would be weaker. Some candidates often referred to 1-iodobutane having weaker bonds but failed to specify which bond. Other candidates referred to the reactivity of iodine and bromine.
	d		 ✓ butyl ethanoate ✓	2	**ALLOW** only skeletal formula **DO NOT ALLOW** ECF from incorrect structure.

					ALLOW butylethanoate **ALLOW** butanyl for butyl **DO NOT ALLOW** but**ly** **Examiner's Comments** This question required candidates to interpret the information and deduce that an ester would be produced. Many candidates found this challenging but the strongest candidates were able to provide a correct skeletal formula and name for the product. Common incorrect responses showed carboxylic acid structures and names.
			Total	**7**	
18	a		 ✓	1	
	b	i	$2Na + 2CH_3OH \rightarrow 2Na^+ + 2CH_3O^- + H_2$ ✓	1	**ALLOW** $2Na + 2CH_3OH \rightarrow 2CH_3ONa + H_2$
		ii	 Curly arrow from CH_3O^- to carbon atom of C-Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$ **AND** curly arrow from C–Br bond to the Br atom ✓ Products of reaction (must not be ambiguous) ✓	3	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous. The curly arrow must start from **O atom** of CH_3O^- **AND** must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. **ALLOW** S_N1 Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, and curly arrow from C–Br bond to the Br atom. Correct carbocation drawn. **AND** curly arrow from CH_3O^- to carbocation. The curly arrow must start from the oxygen atom of the CH_3O^-, and must start either from a lone pair or from the negative charge.
		iii	CH_3O^- donates an electron pair **AND** heterolytic fission ✓	1	**ASSUME** 'it' refers to CH_3O^-
	c		**Chemical shift, δ/ppm** | **Relative peak area** | **Splitting pattern** 0.5−1.9 | 3 | Triplet ✓ 3.0−4.3 | 2 | Quartet ✓ 0.5−1.9 | 6 | Doublet ✓ 3.0−4.3 | 1 | Heptet ✓	4	**ALLOW** δ values ± 0.2 ppm, as a range or a value within the range **ALLOW** multiplet for heptet

	d	i	 Curly arrow from CH_3O^- to H of CH_2 ✓ Curly arrow from C–H bond to C of CH_2 ✓  ✓	3	The curly arrow must start from **O atom** of CH_3O^- **AND** must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. **ALLOW** any unambiguous structure, skeletal, displayed, structural or combination.
		ii	CH_3O^- accepted a proton ✓	1	**ASSUME** 'it' refers to CH_3O^-
			Total	**14**	
19		i	$Ag^+ + Cl^- \rightarrow AgCl$ **OR** $Ag^+ + Br^- \rightarrow AgBr$ **OR** $Ag^+ + I^- \rightarrow AgI$	1	
		ii	Bond enthalpy decreases C−Cl > C−Br > C−I	1	**allow** chlorine–carbon bonds are strongest.
		iii	Heat the test tubes in a water bath.	1	
			Total	**3**	