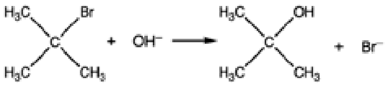
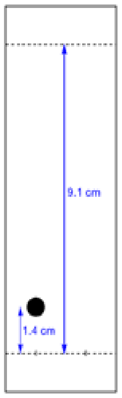
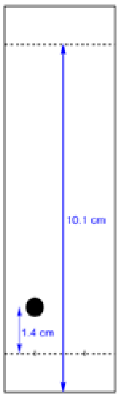
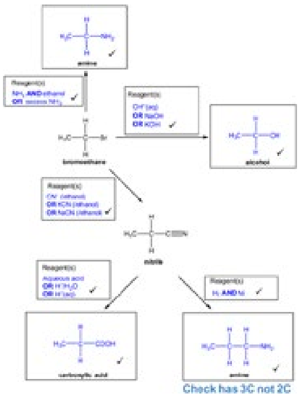
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	 Structure of **BOTH** organic compounds ✓ ***DO NOT ALLOW*** *if H(s) are missing* OH^- on left **AND** Br^- on right ✓ **ALLOW** NaOH/KOH with NaBr/KBr	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** state symbols **ALLOW** OH^- **AND** Br^- in a balanced mechanism **ALLOW** OH^- over the arrow for LHS of equation **DO NOT ALLOW** unbalanced charges, e.g. OH^- with Br **DO NOT ALLOW** H_2O AND HBr *question specifies aqueous alkali*. **DO NOT ALLOW** 2nd mark if a CON reagent is present, e.g. an acid **<u>Examiner's Comments</u>** This question discriminated very well. Most candidates were given a first mark by showing correct structures for the organic reactant and its product, 2-methylpropan-2-ol. The question asked for an equation for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable responses would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given marks, a common error for alkaline hydrolysis. Candidates are advised to carefully read the requirements in the question. For the most successful responses, candidates often underline these to draw their attention.
		ii	**Rates of hydrolysis of all 3 haloalkanes**	2	**IGNORE** reactivity of halogens **ALLOW** unambiguous comparison of two haloalkanes e.g. RI is fastest

			Fastest RI > RBr > RCl slowest ✓ **Bond enthalpies/strength of bonds for any one RX** Strongest: C−Cl > C−Br > C−I weakest ✓ **MUST** refer to C−X bond in some way		**AND** RCl is slowest **ALLOW** C−Cl is strongest bond **ALLOW** R−Cl, etc **BUT NOT** RCl > RBr > RI *no bonds* **DO NOT ALLOW** just ‘strongest bond enthalpy iodine has weakest bond ***Examiner’s Comments*** Candidates found this question difficult. Many fell into a trap of their own making by comparing the relative reactivities of the halogens chlorine, bromine and iodine and it was common to see responses claiming that a chloroalkane has the fastest rate and that an iodoalkane has the slowest rate. Only the most successful candidates related a correct order of reactivity to the different strengths of the carbon–halogen bond.
			Total	**4**	
2		i	$R_f \sim \frac{1.4}{\mathbf{9.1}}$ in cm **OR** $\frac{14}{\mathbf{91}}$ in mm = **0.15** ✓ *Working required* ***Check for ~ 9.1 as denominator*** 	1	**ALLOW** 0.12 - 0.18 (i.e. ±0.03) **DO NOT ALLOW** $\frac{1.4}{\mathbf{10.1}}$ = 0.14 ***10.1** measured from bottom of plate to solvent front*  ***Examiner’s Comments*** Candidates are well versed with calculating an R_f value, with nearly all

					candidates obtaining a value in the acceptable range of 0.12-0.18.
		ii	 Correct balanced equation **ALLOW** OH- above the arrow **DO NOT ALLOW** if a **CON** reagent is present, e.g. an acid For OH- and Br- **ALLOW** KOH and KBr **OR** NaOH and NaBr **BUT DO NOT ALLOW** K-OH *implies covalent bond*	1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW Missing H atoms** **DO NOT ALLOW** H_2O and HBr *Question asks for **alkaline** hydrolysis* **DO NOT ALLOW** C_3H_7, i.e. C_3H_7Br **OR** C_3H_7OH *Structure asked for in Question* **IGNORE** connectivity, e.g.  **BUT DO NOT ALLOW —HO** **<u>Examiner's Comments</u>** This question was answered well by candidates, with most showing correct structures for the organic reactant and its product, propan-1-ol, and skeletal formulae mostly used. The question asked for an equation for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable answers would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given a mark, a common error for alkaline hydrolysis.
		iii	**Difference** propan-1-ol/product/bottom spot is smaller **OR** 1-chloropropane/reactant/top spot bigger ✓ **Reasons**	3	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF and ORA throughout** -- **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide

			propan-1-ol/product/bottom spot is smaller C-Cl bond is stronger than C-Br **AND** 1-chloropropane reacts slower/is less reactive ✓ **Use of propan-1-ol** shows **formation** of propan-1-ol **OR** shows when reaction has **finished** **OR** monitors **course/progress** of reaction ✓		**DO NOT ALLOW** 1-chloropropane has larger bond enthalpy *C-Cl bond required* **IGNORE** 1-chloroproane has different R_f value **IGNORE** 'as a control' **OR** 'as a comparison' .... with no further explanation **Examiner's Comments** This novel question assessed whether candidates realised why chemists used TLC when carrying out organic reactions. A good response would identify the following key features after 20 minutes: • The C-C*l* bond energy is greater than C-Br and so the reaction would be slower. • The haloalkane spot would be larger and the propan-1-ol spot smaller. • The propan-1-ol is spotted on the chromatogram to monitor the progress of the reaction. The question differentiated very well between candidates, but many did not seem to know where to start with many candidates not scoring any marks. This suggested that candidates recognised chromatography as a technique but did not appreciate its relevance in organic chemistry. Some candidates referred to pigments, recalling their early chromatography experiments in finding the colours in ink.
			Total	5	
3				9	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** structure if H(s) are missing from **ONE**

					structural/displayed formula… **BUT ALLOW** any further omissions as **ECF** **ALLOW** any vertical bond to the OH **OR** NH_2  **DO NOT ALLOW** OH−, **OR** NH_{2-} but **ALLOW ECF** for subsequent use in this part **ALLOW** names of reagents e.g. ethanolic ammonia, if no formulae given **DO NOT ALLOW** other additional reagents **IGNORE** Conditions **For bromoethane to amine:** **IF** a secondary / tertiary amine is given **ALLOW** one mark for a correct structure **AND** one mark for an appropriate reagent to produce the amine shown. **For bromoethane to alcohol:** **ALLOW** H_2O **IGNORE** ethanol (as a solvent) **For bromoethane to nitrile:** **DO NOT ALLOW** HCN **OR** CN^- / H^+ **DO NOT ALLOW** H_2O / (aq) **For nitrile to carboxylic acid:** **ALLOW** any mineral acid **IGNORE** dilute/concentrated **For nitrile to amine:** **ALLOW** suitable non-specification alternative e.g. $LiAlH_4$, H_2 with Pd or Pt **<u>Examiner's Comments</u>** This question was well-answered with around a half of candidates scoring 8 or 9 marks. The full range of marks was seen across the whole cohort. The most common reasons for losing marks were for the addition of extra, contradictory reagents or for missing

hydrogens from structures.

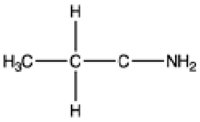
Bromoethane to amine: The amine structure was mostly correct with a few adding an extra hydrogen to the amine i.e. $CH_3CH_2NH_3$. Most gave the correct reagent as NH_3 but some omitted either ethanol or excess, so did not score here.

Bromoethane to alcohol: The alcohol structure was usually correct. However, many lost the reagent mark here for the addition of acid/ H^+/H_2SO_4 alongside the hydroxide.

Bromoethane to nitrile: A suitable cyanide was often used, but again many included an acid catalyst or aqueous conditions (aq) so lost the mark here. Ideally candidates would react in ethanol to prevent hydrolysis of the haloalkane.

Nitrile to carboxylic acid: Most gave the correct carboxylic acid structure, while occasionally ethanoic acid was given instead of propanoic acid. Most identified the need for acid as a reagent but some omitted water or (aq).

Nitrile to amine: H_2 was often seen as the reagent but sometimes without a catalyst. Many gave an incorrect structure here either with a missing C (i.e. ethylamine) or missing hydrogens on the first carbon
i.e.

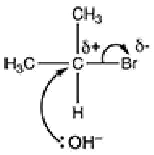
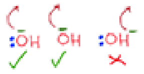


$H_3C-\underset{H}{\overset{H}{C}}-C-NH_2$

OCR support

A useful resource for teaching about organic synthetic routes including functional groups, reagents and two-

					step processes can be found in the Topic Exploration pack on Teach Cambridge.
			Total	**9**	
4			**D**	1	**Examiner's Comments** Most correctly identified the colour of the precipitate as yellow, D. The most common incorrect response was brown, A, possibly linking to the colour of iodine.
			Total	**1**	
5			**A**	1	**Examiner's Comments** Most candidates gave the incorrect response D as their answer. Ultraviolet radiation does cause bonds in CFC molecules to break, and candidates may have been influenced by Question 8. However it is not a valid scientific reason for global warming. It suggests candidates may be confused about global warming verses the depletion of the ozone layer. This question was looking for candidates to link global warming to infrared active molecules i.e. C-H bond in methane. Just under a fifth of candidates gave the correct answer A. ? **Misconception** Many candidates believed there was a link between ultraviolet radiation and global warming. This is a topical issue so can be explored by looking at a range of resources including current news reports or exploring the United Nations resources.
			Total	**1**	

6			**C**	1	**Examiner's Comments** Most candidates correctly identified C as the correct initiation step forming a chlorine radical. A few gave B which forms an ·F radical instead. It is always good to discuss the reason why the C-C*l* bond will break but C-F won't in the presence of ultraviolet light.
			Total	**1**	
7			**D**	1 (AO 2.7)	**Examiner's Comments** Candidates find it difficult to identify an intermediate within a synthesis and less than half selected the correct option, D.
			Total	**1**	
8	a		**Mechanism** Curly arrow from OH– to C atom of C−Br bond in 2-bromopropane✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C−Br bond to Br atom ✓  **Name** nucleophilic substitution ✓ **NOTE**: Curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows	3 (AO 1.2) (AO 2.1) (AO 1.1)	**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 $Br^{\delta-}$,

<table>
<tr>
<td></td>
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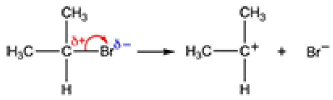
<td></td>
<td>AND curly arrow from C−Br bond to Br atom ✓


Second mark
Curly arrow from OH$^-$ AND to correct 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) ✓

<u>Examiner’s Comments</u>

Just under half the candidates gained all 3 marks for this mechanism. Marks were often lost for incorrect positioning or a missing arrow for the breaking of the C-Br bond. Dipoles were often added to the hydroxide ions. Some also showed the lone pair for OH- going to the C-Br bond and not to the C$^{\delta+}$.

A range of spellings of nucleophilic were seen, including: nucleophilic, nucleophilic, nucleophilic, and nucleophilic. It is important to promote good literacy in science, including meanings and spellings of technical language.</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>i</td>
<td>
<table>
<tr><th><i>Haloalkane</i></th><th><i>Formula</i></th><th><i>Colour</i></th><th></th></tr>
<tr><td><i>2-bromopropane</i></td><td>AgBr</td><td>cream</td><td>✓</td></tr>
<tr><td><i>2-iodopropane</i></td><td>AgI</td><td>yellow</td><td>✓</td></tr>
</table>
Formula AND colour required for each mark</td>
<td>2
(AO 1.1 x 2)</td>
<td>ALLOW 1 mark if correct formula for both OR correct colour for both

<u>Examiner’s Comments</u>

The majority of candidates scored both marks. Some scored 1 mark only mainly for correct colours of the precipitates but with incorrect formulae. Common errors included AgBr$_2$ and AgI$_2$, giving the formula of the haloalkane or formulae involving a halogen and a nitrate ion.</td>
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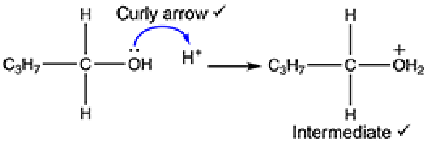
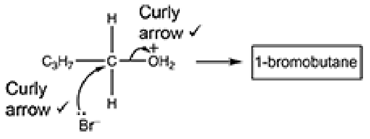
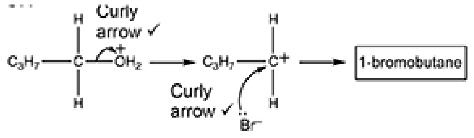
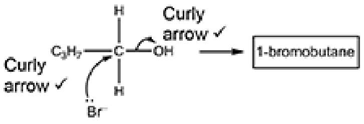
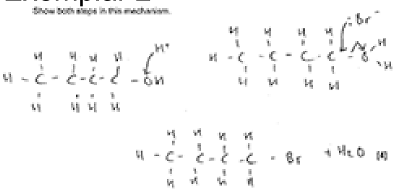
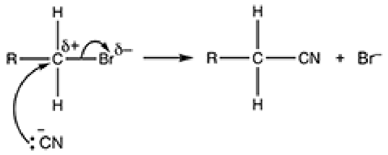
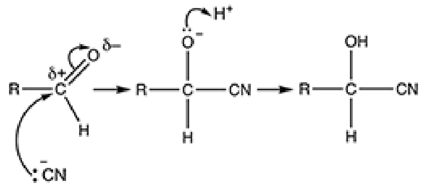
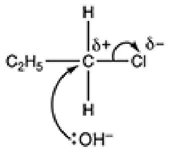
<tr>
<td></td>
<td></td>
<td>ii</td>
<td>AgI OR yellow (precipitate forms first)</td>
<td>1
(AO2.3)</td>
<td>ALLOW (precipitate from) 2-iodopropane</td>
</tr>
</table>

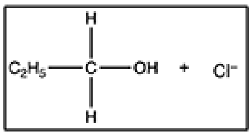
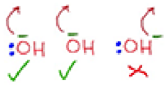
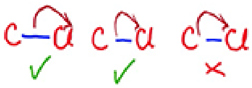
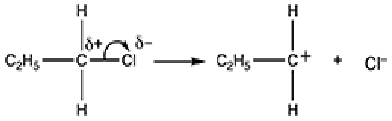
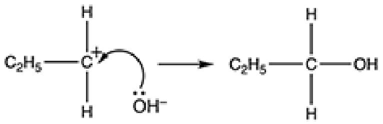
			AND C–I bond is weaker (than C–Br bond) ✓		**ALLOW** ECF from incorrect formula or colour ppt from 3(d)(ii) **ALLOW** C–I bond has a lower bond enthalpy **OR** C–I bond is longer **ORA** **IGNORE** references to bond length, polarity and electronegativity **Examiner's Comments** Most responses did not gain credit here. Some recognised that AgI would form first but then gave an incorrect reason (such as 'held by weaker London forces') or their answers lacked detail (e.g., 'weaker bonds' without specifying which bonds). Many said AgBr because Br is more reactive or more electronegative.
			Total	**6**	
9			**Step 1** The oxygen atom of the alcohol group accepts a proton to form a positively-charged intermediate. ***2 marks***  **Step 2** Bromide ions react with the intermediate by nucleophilic substitution to form 1-bromobutane. ***2 marks*** *2 possible routes:* **EITHER**	4 (AO3.2 ×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For $CH_3CH_2CH_2$, **ALLOW** $CH_3(CH_2)_2$, C_3H_7 **IGNORE** dipoles --- **ALLOW** curly arrow to H of H-O-SO_3H **OR** H-Br **IGNORE** absence of curly arrow from H-O or from H-Br + charge **MUST** be on O of intermediate **Curly arrow** must • start from, **OR** be traced back to **any point across width** of lone pair on :Br^- **OR** :OH **OR** start from - charge on Br^- *(Lone pair **NOT** needed if curly arrow shown from - charge on Br)* **IGNORE** final products: 1-bromobutane and H_2O **IF** $C_3H_7CH_2$-O^+H_2 is **not** shown, **ALLOW** intermediate mark for carbocation: $C_3H_7CH_2^+$

			 OR  		**ALLOW** 2 marks max for mechanism without positively charge intermediate, i.e.  **If in doubt, contact Team Leader** **Examiner's Comments** This question is one of two on this paper assessing understanding of unfamiliar organic reaction mechanisms. The stem to the question includes important information and clues that should have then guided candidates towards this unfamiliar mechanism (which is related to the familiar nucleophilic substitution of haloalkanes). The two prompts for Step 1 and Step 2 are critical but many candidates did not use these, instead inventing their own mechanisms. However, there were many successful responses seen that gained the full 4 marks. Exemplar 2  Exemplar 2 illustrates a limited appreciation of what curly arrows mean and the importance of charges and dipoles. Step 1 is an attempt to show the alcohol OH group accepting a proton, but a curly arrow shows the movement of an electron pair. It cannot travel from a + charge to a lone pair. The intermediate shown does contain the correct atoms but the + charge has been omitted from the O atom. Marks were given for the curly arrow from the Br$^-$ lone pair and from the C-O bond. However, the candidate has drawn the bonds with very short lines

					making it all too easy for a curly arrow to be shown imprecisely. This response was given 2/4 marks. **Assessment for learning** In organic chemistry mechanisms, a curly arrow shows the movement of an electron pair and demonstrates the direction of electron flow in organic reactions. A curly arrow must start from: • A lone pair or negative charge and go to an atom to show where a bond **forms** • A bond to show where a bond **breaks**. In Q3b, curly arrows start • from a lone pair on the alcohol OH and a Br$^-$ ion • from a C-O bond A curly arrow will **not** originate from a + charge.
			Total	**4**	
10			**Level 3 (5–6 marks)** Describes, in detail, reactions of **two** aliphatic compounds that form a C–C bond **AND** mechanisms for the **two** aliphatic reactions. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Describes a reaction of **one** aliphatic compound that forms a C–C bond with few omissions/errors. **AND** mechanism for **one** aliphatic reaction. **OR** Describes reactions of **two** compounds that forms a C–C bond	6 (AO1.2×4) (AO2.5×2)	**Indicative scientific points may include:** **<u>Reactions of aliphatic compounds and mechanisms</u>** • Haloalkane, RX and CN^- → RCN + X^- Reagents: NaCN and ethanol Reaction: Nucleophilic substitution Mechanism: 

			AND attempts a mechanism for **one** of the reactions *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Selects suitable reagents for reactions of **two** compounds that form a C–C bond. **OR** Attempts to describe a reaction and mechanism of **one** compound that forms a C–C bond, with omissions/errors. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		• Aldehyde or ketone and HCN e.g. RCHO + HCN → RCH(OH)CN Reagents: NaCN and H^+ Reaction: Nucleophilic addition Mechanism:  OR H_2O instead of H^+ for 2nd stage **If alternative reactions are shown contact your TL** **e.g. radical substitution, polymerisation** **<u>Examiner's Comments</u>** This question differentiated well. Candidates who were given Level 3 (5-6 marks) understood the term aliphatic and were able to provide two different mechanisms that produced a C-C bond. The most common responses seen involved the nucleophilic substitution of a halogenoalkane and a cyanide ion and the nucleophilic addition of a carbonyl with a cyanide ion. Some candidates offered radical substitution mechanisms, detailing initiation, propagation and termination steps, with the termination step producing a C-C bond. Candidates who scored Level 2 (3-4 marks) frequently detailed a reaction involving aromatic compounds or polymerisation of alkenes for which they were unable to give a mechanism.
			Total	6	

11			A	1 (AO1.1)	**Examiner's Comments** Many candidates did not identify CH_3NH_2 as a nucleophile and selected option B.
			Total	**1**	
12			B	1 (AO1.1)	**Examiner's Comments** The majority of candidates identified B as the correct answer.
			Total	**1**	
13			B	1 (AO1.1)	**Examiner's Comments** Candidates found this multiple choice question challenging. While some identified B as the correct answer, many candidates selected C.
			Total	**1**	
14			**B**	1(AO1.1)	**Examiner's Comments** Most candidates selected the correct option, B. The main distractors were A (confusing which C–X bondis stronger) and C (confusing which effect of bond strength and polarity is dominant for this reaction).
			Total	**1**	
15			Curly arrow from HO$^-$ to C 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 ✓  or **IGNORE** presence of Na$^+$ but OH$^-$ needed	3 (AO1.2) (AO1.2) (AO2.5 ×1)	**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 C of C-Cl **AND** · start from, **OR** be traced back to **any point** Cl **across width** of lone pair on O of OH$^-$

			i.e. Na$^+$OH$^-$can be allowed if criteria met **DO NOT ALLOW** H_2O instead of OH$^-$ Correct organic product **AND** Cl$^-$ ✓ or  **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 ECF** NaCl$^-$**ONLY** from NaOH$^-$ **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> Although a simpler mechanism than electrophilic addition in Question 21 (a) (ii), candidate responses here were less successful. Many candidates weren't able to identify the

					OH$^-$ ion attacking the carbon atom and the curly arrow often did not originate from an O lone pair or the negative charge. Candidates often omitted the dipole on the C–Cl bond or did not include a curly arrow. Candidates were expected to show both the resulting alcohol and Cl$^-$ as products. Many tried to incorporate Na into their organic structure. Organic mechanisms are a key concept in organic chemistry and it is essential for candidates to learn all the mechanisms in preparation for examinations. **Assessment for learning** Reactions mechanisms are the organic chemist's way of communicating electron transfers in organic chemistry. It is essential that curly arrows, dipoles and charges are used appropriately and accurately. AS Chemistry includes three important reaction mechanisms: electrophilic addition, nucleophilic substitution and radical substitution. This paper includes two of these in Questions 21 (a) (i) and 26 (a). It is essential that candidates learn these three mechanism types.
			Total	**3**	