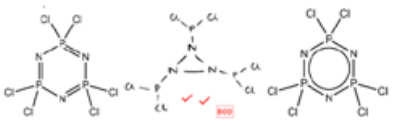
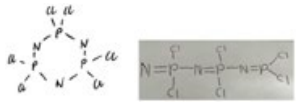
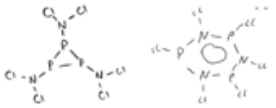
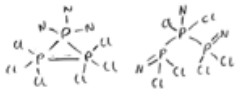
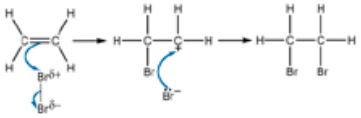
Mark scheme

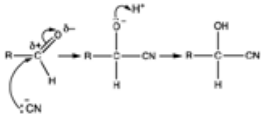
Question			Answer/Indicative content	Marks	Guidance
1		i	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong **Examiner's Comments** This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride. Candidates are expected to know that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report. As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course. **Assessment for learning** The specification states the following. ***Formulae and equations*** ***2.1.2(a)*** *the writing of formulae of ionic compounds from ionic charges, including:* i. *prediction of ionic charge from the position of an element in the periodic table*

					ii. *recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+* This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE IF % by mass = 26.72, award 2 marks IF % by mass = 26.7, award 1 mark ----------** M_r of $P_3N_3Cl_6$ = 348(.0) ✓ $\%\text{ by mass of P} = \frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓ **2 DP required**	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW** ECF from incorrect M_r **ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times 100 = 8.91$ **Examiner's Comments** In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72. Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).
		iii	(P-N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C-C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds **Examiner's Comments** About half the candidates suggested a range of creditworthy responses with

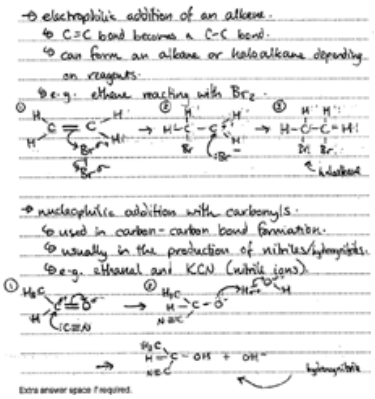
					'different bond lengths' and 'decolorises bromine' being the most common.
		iv	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark** • Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark (dependent on 1st mark)** • Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 	2	1st mark *Meets criteria for 1st mark*  **ZERO** marks  *N bonded to Cl*  *N atom(s) with 1 bond only* **Examiner's Comments** This was another question where valuable information: *'all N and Cl atoms are bonded to P atoms'* had been provided. Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds. Most structures contained 6 or 3-membered rings. This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark. The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules

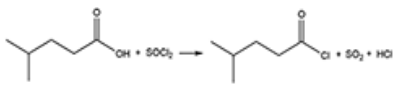
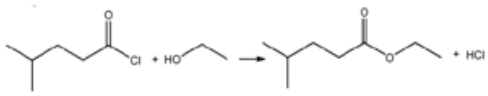
			Total	**6**	
2			1-ethyl-2,4-dimethylbenzene ✓	1	**ALLOW** other unambiguous names using smallest numbering. e.g. **ALLOW** 1,3-dimethyl-4-ethylbenzene 2,4-dimethylethylbenzene ethyl-2,4-dimethylbenzene 2,4-dimethyl-1-ethylbenzene **IGNORE** alphabetical order of methyl and ethyl **IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces **DO NOT ALLOW** 1,5-dimethyl-2-ethylbenzene **OR** 1,3-dimethyl-6-ethylbenzene *Needs smallest numbers* **DO NOT ALLOW** the following for dimethyl: dimethy, dimeth, dimethly, dimethanyl **DO NOT ALLOW** the following for ethyl: ethy, eth, ethly, ethanyl **<u>Examiner's Comments</u>** This question appeared to be equally challenging for candidates. Common errors included names without the lowest possible numbering. The methyl group was given on the top which could have influenced candidates to start counting from there – more practice is needed to help with naming simple aromatics. Other common errors included:1-ethyl-2,4-methylbenzene (missing di-) and 1-ethyl-2,3-dimethylbenzene (miss counting groups).
			Total	**1**	
3			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks)** Describes addition reactions including	6	**Indicative scientific points may include:** **<u>Reaction of alkene and mechanism</u>**

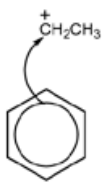
			the mechanisms of **one** alkene **AND one** carbonyl compound **AND** some additional details *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Describes an addition reaction including the mechanism of **one** alkene **OR one** carbonyl compound **AND** some additional details **OR** Describes addition reactions including an attempt to give the mechanisms of **one** alkene **AND one** carbonyl compound *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 addition reactions of **one** alkene **AND one** carbonyl compound. **OR** Attempts to describe an addition reaction including an attempt to give the mechanism of **one** alkene **OR one** carbonyl compound. *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.*		• Suitable reaction, e.g. alkene and Br_2 **OR** X_2 **OR** HX **OR** H_2O **OR** H_2 **OR** polymerisation *May be shown within mechanism* • Mechanism, e.g.  **ALLOW** mechanism for H_2 **AND** H_2O to be shown as electrophilic addition even though incorrect - consider impact on communication statement. **ALLOW** suitable non-specification alternative e.g. HCN **Additional details (NOT INCLUSIVE)** • Electrophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. alkene to dibromo • Details on reagents required e.g. - H_2 with Ni Catalyst - $H_2O(g)$ with H_3PO_4 catalyst • Explanation of major and minor product from electrophilic addition of HX with unsymmetrical alkene • Explanation of carbocation intermediate stability • Heterolytic fission **<u>Reaction of carbonyl compound and mechanism</u>** Suitable reactions, e.g. • Aldehyde or ketone and HCN **OR** H^- e.g. RCHO + HCN → RCH(OH)CN *May be shown within mechanism*

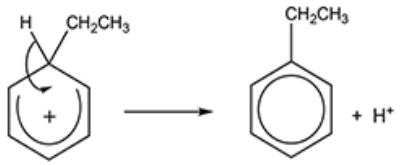
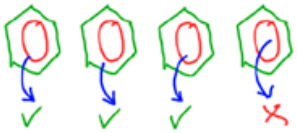
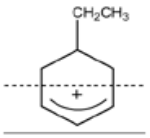
					• Mechanisms, e.g.  **OR** H_2O instead of H^+ for 2nd stage **ALLOW** suitable non-specification alternative e.g. H_2O, NH_3, 1° amine **IGNORE** reactions with carboxylic acids (or derivatives) i.e. addition-elimination mechanism (condensation reaction) **Additional details (NOT INCLUSIVE)** • Nucleophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. aldehyde to hydroxynitrile • In reduction, aldehydes form 1° alcohols and ketones form 2° alcohols • Details on reagents required e.g. - formation of hydroxynitriles with $NaCN/H^+(aq)$ - formation of alcohols with $NaBH_4$ • Heterolytic fission Aspects of the **communication statement** being met might typically include: • Curly arrows starting from lone pairs / negative charges / bonds. • All reactants and intermediates have relevant charges and dipoles. • Mechanisms given are chemically feasible for the reactions.

					• No additional incorrect reactants have been included. **Examiner's Comments** A very good proportion of candidates scored all 6 marks, giving well-drawn mechanisms with some additional details such as mechanism names, functional group interconversions or other additional reaction information. Some attempted to 'describe' the mechanism using only words rather than drawing it out with a conventional curly arrow mechanism. Candidates may need more clarity on what 'describe' means in an organic chemistry context. Equally, a few gave just the mechanisms with no additional details, limiting themselves to Level 2. Candidates were usually more confident with the addition to alkenes using an electrophilic addition mechanism. Some gave additional details about major and minor products, although not always relevant as for a symmetrical alkene. Some represented the addition of hydrogen or water to alkenes via an electrophilic addition mechanism. While not correct it showed an understanding of mechanisms and a correct addition reaction for alkenes, so credit was given. Some candidates included incorrect reagents for reactions, such as acid catalysts with addition of a hydrogen halide, or incorrect conditions, such as the requirement for ultraviolet light on addition of a halogen. The addition to carbonyl compounds was not always as well-described. Some candidates struggled to identify carbonyl compounds, selecting carboxylic acids or their derivatives, with attempts at addition-elimination mechanism i.e. condensation reactions. Some gave incorrect reagents for carbonyls, including H_2O and HBr. However, some used off-specification reactions such as the addition of H_2O to form a geminal diol which was given but as the mechanism differs from the nucleophilic addition mechanism taught in

					this specification, full credit was rarely achieved. Some also considered oxidation of aldehyde or ketone to be an addition reaction. Most who presented a correct mechanism for addition to a carbonyl used the reaction with cyanide rather than reduction with $NaBH_4$. Common errors included arrows coming from the N of CN^-, a lack of putting dipoles on carbonyl bonds, missing charges on O in intermediates or showing the wrong direction of arrows. **OCR support** The OCR Guide to Level of Response questions can be found on Teach Cambridge and can be used to help your students better understand this type of question. Exemplar 1  Level 3 – 6 marks Two correct addition mechanisms have been shown, one for an alkene and one for a carbonyl compound. Additional details include the names of the mechanisms, names of the functional groups in the products, and the fact that a C-C bond is formed in the second mechanism. All curly arrows, charges and dipoles are correctly positioned so this response was also given the communication mark.
			Total	**6**	

4		i	ethyl 4-methylpentanoate ✓	1	**ALLOW** one word: ethyl4-methylpentanoate **OR** more words, e.g. ethyl 4-methyl pentanoate **DO NOT ALLOW** 1-ethyl-4-methylpentanoate **IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces **DO NOT ALLOW** the following for methyl:methy, meth, methly, methanyl **DO NOT ALLOW** the following for ethyl:ethy, eth, ethly, ethanyl **Examiner's Comments** Candidates found this difficult, with less than half gaining the mark. The most common error was incorrectly numbering the methyl group due to counting from the wrong end, giving ethyl-2-methylpentanoate.
		ii	**Step 1**  **Step 2**  $SOCl_2$ used in **Step 1** ✓ Acyl chloride: $(CH_3)_2CHCH_2CH_2COCl$ correct ✓*Seen anywhere* **Step 1** correct equation ✓ **Step 2** correct equation ✓	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous e.g. $(CH_3)_2CHCH_2CH_2COOH + SOCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + SO_2 + HCl$ $(CH_3)_2CHCH_2CH_2COCl + C_2H_5OH \rightarrow (CH_3)_2CHCH_2CH_2COOC_2H_5 + HCl$ **DO NOT ALLOW** incorrect connectivity on OH **BUT ALLOW ECF** on subsequent structures **ALLOW** suitable non-specification alternatives for step 1 e.g. PCl_3, PCl_5, $COCl_2$ e.g. $3(CH_3)_2CHCH_2CH_2COOH + PCl_3 \rightarrow 3(CH_3)_2CHCH_2CH_2COCl + H_3PO_3$ $(CH_3)_2CHCH_2CH_2COOH + PCl_5 \rightarrow (CH_3)_2CHCH_2CH_2COCl + POCl_3 + HCl$ $(CH_3)_2CHCH_2CH_2COOH + COCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + HCl + CO_2$ **Examiner's Comments** This question differentiated between candidates well with the full range of marks seen. Some couldn't identify the correct reagent to use to form an acyl chloride i.e. $SOCl_2$, so lost 2 marks for the first step. Use of HC*l* as an alternative was

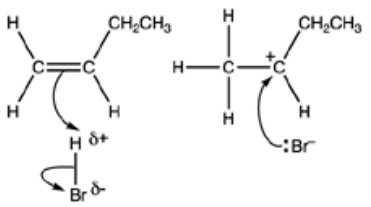
					common. A significant number used $SOCl_2$ but struggled to balance the equation. Many made errors with structures used, for example missing the CH_3 side chain, adding CH_3 to 3-position instead 4, inserting an additional CH_2 group or using a much easier structure, e.g. ethanoic acid. None of these structures were given marks as they would not form Ester F. Some used R- instead to simplify, for which credit was given, but only if it was clear what structure R represented. Another common error was to include an additional O in the acyl chloride group i.e. COOC*l* not COC*l*. The most common error made in Step 2 was to omit the formation of HC*l* or to use H_2O instead. A few lost the final mark for a connectivity error on ethanol i.e. $OHCH_2CH_3$.
			Total	**5**	
5		i	**ALLOW correct Kekulé representation of benzene throughout question 21** An electron pair acceptor ✓	1	**ALLOW** gains an electron pair / lone pair **Examiner's Comments** Most candidates were able to give the correct definition here. A common error was omission of 'pair' of electrons. Manyalso described that electrophiles are 'species attracted to areas of high electron density'or words to that effect, either alongside the accepted definition gaining credit or as the sole definition not gaining a mark.
		ii	**Generation of electrophile** $AlCl_3 + CH_3CH_2Cl \rightarrow CH_3CH_2^+ + AlCl_4^-$ ✓ **Electrophilic substitution**  Curly arrow from π-bond to $^+CH_2CH^3$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_2H_5Cl **AND** $C_2H_5^+$ **ALLOW** positive charge anywhere on CH_2CH_3 e.g. $CH_2CH_3^+$ **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must

			----------  Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring **AND** H^+ as product ✓ **Regeneration of catalyst** $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓		• start from, **OR** close to **circle of benzene ring AND** • go to anywhere on $^+CH_2CH_3$  **DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure **AND** 'horseshoe' the right way, *i.e.* gap towards C with CH_2CH_3 **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **Examiner's Comments** Most candidates were well prepared for this question, with over half of candidates gaining all 5 marks. A significant number of candidates showed halogenation, generating Cl^+ as an electrophile, instead ofalkylation. Others attempted to substitute the ethylbenzene ring rather than benzene. Further commonerrors included incorrect connectivity in the ethyl group on the intermediate, curly arrows coming fromhydrogen atoms rather than C-H bond to reform the π-ring and omission of an H^+ ion at the end ofmechanism.
			Total	**6**	
6			**B**	1	**Examiner's Comments** A large majority of candidates were able to correctly identify shape at x as being

					trigonal planar and y as being tetrahedral. The most common incorrect responses seen were for getting one of these incorrect i.e. D incorrect for x or C incorrect for y.
			Total	**1**	
7			**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**	
8			**C**	1	**Examiner's Comments** More than three quarters of candidates were able to identify C as being the secondary amide, with many annotating each structure with the correct functional group. Some gave B, i.e. a secondary amine not amide, and a few gave A, i.e. tertiary amide not secondary.
			Total	**1**	
9	a		B, C, D **AND** E only ✓	1	**ALLOW** letters in any order **Examiner's Comments** Over half the candidates found this question challenging an did not score the mark here. The most common error was to omit Structure C, but some also omitted Structure E. This suggested that many candidates may only apply the term 'unsaturated' to alkenes. It also highlights a potential lack of understanding of the delocalised ring in benzene and the relationship to the Kekulé structure.
	b		A **AND** B only ✓	1	**ALLOW** letters in any order **Examiner's Comments** Most candidates were able to correctly

					identify the alicyclic compounds. Some candidates also included Structure C showing some confusion between terms alicyclic and aromatic. This was also noted in last year's paper on Question 13. **Misconception** A molecule is either aromatic, if it contains a benzene ring, or aliphatic. Aliphatic molecules which contain a ring can also be described as alicyclic. OCR have previously offered clarification for classification of organic compounds.
			Total	**2**	
10			**C**	1	**Examiner's Comments** This question proved to be an excellent discriminator with most above average candidates choosing monomer (option C).
			Total	**1**	
11	a		**CORRECT DOTS REQUIRED FOR ALL MARKS** **Initiation** ultraviolet / UV **AND** $Br_2 \rightarrow 2Br\cdot$ **OR** $Br_2 \rightarrow Br\cdot + Br\cdot$ **OR** $Br{-}Br \rightarrow 2Br\cdot$, etc ✓ **Propagation** **1** $C_2H_6 + Br\cdot \rightarrow C_2H_5\cdot + HBr$ ✓ **2** $C_2H_5\cdot + Br_2 \rightarrow C_2H_5Br + Br\cdot$ ✓ **Termination** In either order:	5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** charged formulae **IGNORE** position of dots within a formula **DO NOT ALLOW** if reagents also present, e.g..steam **ALLOW** $\cdot CCH_5$ for $C_2H_5\cdot$ **ALLOW** $C_2H_5C_2H_5$ for C_4H_{10} ✓ **Examiner's Comments** This question was answered extremely well with most candidates obtaining the full 5 marks. It was encouraging to see the widespread correct use of dots to indicate radicals, with relatively few omissions. Of the three steps, initiation and termination

			$C_2H_5\cdot + C_2H_5\cdot \rightarrow C_4H_{10}$ **OR** $2C_2H_5\cdot \rightarrow C_4H_{10}$ ✓ $C_2H_5\cdot + Br\cdot \rightarrow C_2H_5Br$ ✓		were answered better than the equations for propagation.
	b		<table><tr><th>Carbon atom</th><th>Bond angle</th><th>Name of shape</th></tr><tr><td>1</td><td>109.5</td><td>tetrahedral</td></tr><tr><td>2</td><td>120</td><td>trigonal planar</td></tr></table> **2 OR 3** correct ✓ **4** correct ✓ ***Number of electron pairs*** In **C1**/109.5°, **4** bonded pairs/bonding regions/bonds ✓ In **C2**/120°, **3** bonded regions/bonds ✓ **Electron pair repulsion** Electron pairs/bonded pairs repel (as far apart as possible) ✓ ***Electron pairs/bonded pairs essential*** ***DO NOT ALLOW 'bonded atoms' for this mark***	5	**ALLOW** 109−110 for **C1** **ALLOW** 118−122 for **C2** **ALLOW** planar triangle **ALLOW** table responses if in wrong columns **IGNORE** areas of electron density **For bonded pairs** **ALLOW** bp, **bonded** groups, **bonded** atoms ***Bonded/bonding** essential* **For C2, ALLOW** • 3 bonded areas/environments • 3 bonded pairs/groups/atoms • 2 bonded pairs and 1 double bond • 2 bonded pairs and 1 bonded region **DO NOT ALLOW** 'atoms repel' **IGNORE** • electrons repel • bonds repel • electron region **OR** electron density • lone pairs repel more *irrelevant here* • shapes, even if wrong **Examiner's Comments** The bond angles and shapes rewarded the well-prepared candidates, with many being given both available marks for this part of the question. This part discriminated very well.

					For the explanation, most candidates identified 4 and 3 for C1 and C2, but candidates often linked 4 and 3 to atoms, rather than to electron pairs or bonded pairs for C1 and to bonding regions for C2. A mark was available for stating that 'electron pairs repel', but this important fact was often omitted despite being the main principle that determines molecular shapes. The question discriminated well, giving a good spread of marks across the five available. **Misconception** Many students think that molecular shapes are determined solely by lone pairs or by repulsion between bonded atoms. The principle behind molecular shapes is called electron pair repulsion theory because it is based on repulsion between electron pairs, which may be bonded pairs or lone pairs, but **not** atoms.
			Total	**10**	
12			**C**	1	**Examiner's Comments** About half the candidates correctly chose C. Options A and B were incorrectly chosen by many candidates, presumably by counting from the left or not first identifying the longest carbon chain. This question proved to be an excellent discriminator.
			Total	**1**	
13		i		4	**Throughout**, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **For curly arrows,** **ALLOW straight or snake-like arrows and small gaps (see examples)**

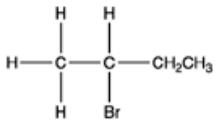
1st curly arrow (from ANY alkene)
Curly arrow from double bond to H of H–Br ✓
DO NOT ALLOW partial charge on C=C

2nd curly arrow
Correct dipole on H–Br
AND curly arrow for breaking of H–Br bond ✓

3rd curly arrow
Correct carbocation with + charge on C
AND curly arrow from Br^- to C+ of carbocation ✓

DO NOT ALLOW δ+ on C of carbocation

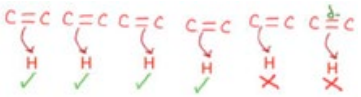
Correct product (***independent mark***) ✓



DO NOT ALLOW half headed or double headed arrows but allow
ECF if seen more than once

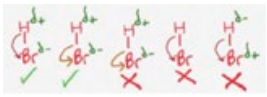
1st curly arrow must

- go to a H atom of H-Br
- **AND**
- start from, **OR** be traced back to **any point across width** of C=C



2nd curly arrow must

- start from, **OR** be traced back to, **any part of** $^{\delta+}H–Br^{\delta-}$ bond
- **AND** go to $Br^{\delta-}$



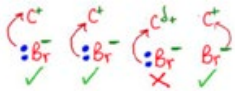
ALLOW ECF for 2nd and 3rd curly arrow marking points if used Br_2 instead of HBr

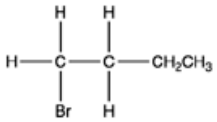
3rd curly arrow must

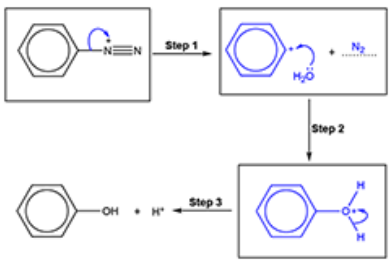
- go to the C^+ of carbocation

AND

- start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$
- **OR** start from - charge on Br^- ion



					*(Lone pair **NOT** needed if curly arrow shown from - charge on Br^-)* **IGNORE** connectivity of alkyl groups in carbocation and product **IF** drawn both intermediates and products with no labelling **ALLOW** 3rd curly arrow mark **BUT NOT** product mark, unless clearly labelled as'2-bromobutane' or 'major' product **ALLOW ECF** for product from incorrect carbocation. e.g. 1-bromobutane:  **Examiner's Comments** Approximately half of candidates scored all 4 marks. Very few scored no marks as they were able to give the correct structure of the named product (2-bromobutane). The most common reasons for losing marks included: • Adding dipoles to C=C • Missing dipoles on H-Br or reversed dipole on H-Br (i.e. δ+ Br) • Missing charge on bromide ion or adding δ- • Arrows the wrong way round or not coming from a bond or lone pair (or negative charge for bromide ion) Some attempted a radical mechanism. **OCR Support** For ideas on teaching this topic please look at our Topic Exploration Pack: Electrophilic Addition and Markownikoff's rule: https:/teachcambridge.org/item/b4220e86-bc04-492c-b354-8103687ce594

		ii	(major product forms from) most/more stable intermediate/carbocation ✓ major product forms from a) secondary carbocation **OR** carbocation bonded to more C atoms / more alkyl groups **OR** carbocation bonded to fewer H atoms ✓	2	**ALLOW** carbonium ion for carbocation **IGNORE** descriptions of the major/minor product in terms of Markownikoff's rule e.g. H atom joins to C with most H **IGNORE** references to stability of the product **ALLOW ORA** **Examiner's Comments** Over half of candidates didn't gain any credit for their response here. Answers often focused on Markownikoff's rule, i.e. adding H to C with most H atoms already attached, or described the stability of the product. Students need more support in understanding that the more stable carbocation will be formed in preference and result in forming more product. Many referred to the 'secondary haloalkane' being more stable, rather than the 'secondary carbocation'. Some stated that 2-bromobutane is a 'secondary carbocation', showing some misunderstanding about the terminology used here. **OCR Support** We have a useful PowerPoint Presentation for teaching about Markownikoff's rule and carbocation stability: https:/ocr.org.uk/Images/250388-markownikoff-s-rule-presentation.ppt
			Total	**6**	
14			**Mechanism**:  	4 (AO 3.2 ×4)	**ANNOTATE ANSWER TICKS AND CROSSES** --- **NOTE**: Curly arrows can be straight, snake-like, etc. but **NOT** half arrows **1st curly arrow** must start from, **OR** be traced back to, **any part of** C–N^+ bond and go to N **OR** + of N^+

M1: Curly arrow from C−N bond to N^+ ✓

M2:  **AND** N_2 ✓

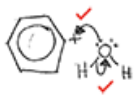
M3: Curly arrow from lone pair of O of H_2O to C^+ ✓

M4  **AND** Curly arrow from O–H bond to O+ ✓

For all marks, treat additional curly arrows as CON

ALLOW M3 shown in bottom box

IGNORE partial charges
ALLOW M3 AND M4 combined
e.g.

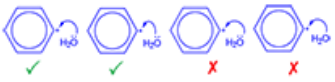


For  **DO NOT ALLOW M2** for carbocation

BUT
ALLOW for M3 and/or M4 by ECF, e.g.

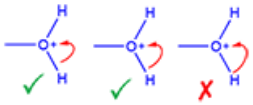
2nd curly arrow must

- start from, **OR** be traced back to **any point across width** of lone pair on O of H_2O
- go to the C or + of C^+ of $C_6H_5^+$



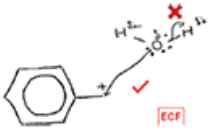
3rd curly arrow must

- start from '–' **of O–H** of $–OH_2^+$
- go to O or + of O^+



For  **DO NOT ALLOW M2** for carbocation

BUT
ALLOW for M3 and/or M4 by ECF, e.g.

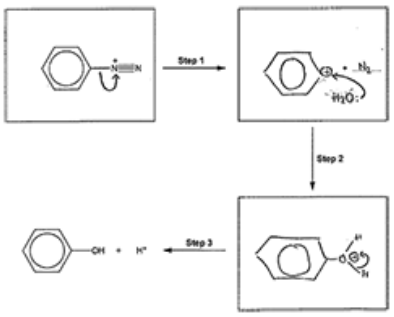


Examiner's Comments

This question required candidates to apply their understanding of organic mechanisms to an unfamiliar reaction. The stem to the question includes important information and clues that should have guided candidates towards this unfamiliar mechanism, with the prompts for the three steps being critical. Many responses fell back to the familiar mechanism for electrophilic substitution, an approach that could not be credited.

This question discriminated very well but many candidates scored few marks.

Exemplar 1



This response has been included to show a candidate with an excellent understanding of the meaning of curly arrows and the importance of charges and dipoles. The prompts in the question are followed and the candidate has been given all four marks.

Notice how the curly arrows start either from a bond or from a lone pair. The candidate has also realised that the addition of H_2O produces a positively charged oxonium ion. Many candidates omitted the '+' charge or showed the curly arrow for loss of a proton going to a H atom rather than the O atom of water.

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.

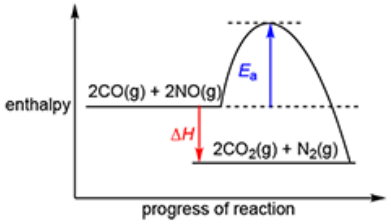
A curly arrow must start from:

- 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**.

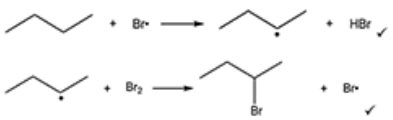
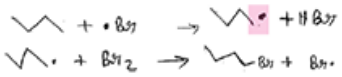
In Question 2 (c), curly arrows:

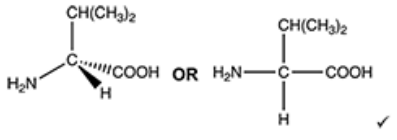
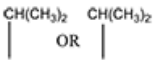
					• start from a C–N bond to form the intermediate carbocation by elimination of N_2 • go from a lone pair on the water O atom to the + charge of the carbocation • go from an O–H bond to the + charge on the oxonium ion, losing a proton H^+ in the process.
			Total	**4**	
15			**Correct structural isomers of C_3H_8O** *1 mark* $CH_3CH_2CH_2OH$ **AND** $CH_3CHOHCH_3$ ✓ **Reaction conditions** *1 mark* Distillation for aldehyde **AND** reflux for carboxylic acid **OR** ketone ✓ **Functional group of organic product** *2 marks* $CH_3CH_2CH_2OH$ → aldehyde → carboxylic acid ✓ **OR** $CH_3CHOHCH_3$ → ketone ✓ **One correct equation** *1 mark* $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ **OR**		**ANNOTATE WITH TICKS AND CROSSES** **Throughout,** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IF functional group is NOT given,** **ALLOW** propanal / RCHO **ALLOW** propanoic acid / RCOOH **ALLOW**propanone / ..... RCOR **IGNORE** small slips in formulae (assessed in equation) **Examiner's Comments** There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions

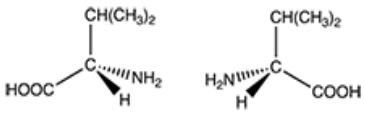
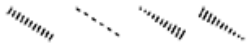
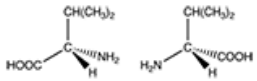
			$CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ **OR** $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		required to produce the organic products. The equation proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead. A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.
			Total	**5**	
16		i	$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ Correct species ✓ Balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols For heptane formula, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW 1 mark** for balanced combustion equation for a different alkane (**ECF**) e.g. $C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$ **Examiner's Comments** Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.
		ii		2 (AO2.1) (AO1.2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols

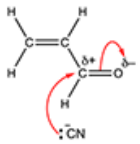
			 **Reactants, products and Δ*H*** **2CO + 2NO** on LHS **AND** **$2CO_2$ + N_2** on RHS **AND** Δ*H* labelled with products **below** reactants **AND** **Arrow downwards** ✓ ***E_a (independent of ΔH)*** curve with arrow from reactants to top of curve **AND** *E_a* labelled ✓ **IF** endothermic diagram shown, **ALLOW ECF** for E_a using MS criteria		Δ***H*** **DO NOT ALLOW –**Δ*H* **DO NOT ALLOW** double headed arrow on Δ*H* **ALLOW** Δ*H* arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line. **ALLOW** –746 for Δ*H* ***E_a*** **ALLOW** AE **OR** A_E **ALLOW 2** arrowheads at **each** end of E_a line **OR** no arrowhead **BUT DO NOT ALLOW** arrowhead down E_a line must reach maximum (or near to maximum) on curve **Examiner's Comments** Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a doubleheaded arrow for Δ*H* or a –Δ*H* label. Some candidates showed endothermic profiles and these could create issues with positioning of the Δ*H* and E_a arrows. Generally, positioning of Δ*H* and E_a arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.
		iii	Catalyst lowers activation energy **OR** Catalyst increases rate without itself changing ✓	2 (AO1.2 ×2)	**ALLOW** 2nd labelled curve on profile diagram in **23(a)(ii)** with lower activation energy/E_c with catalyst **ALLOW** E_c needs less energy to start reaction

			Reaction proceeds via a different route/pathway **OR** More molecules/particles exceed activation energy ✓		**ALLOW** E_c curve is lower than E_a curve **IGNORE** 'shorter route' for alternative route **IGNORE** more successful collisions **Examiner's Comments** Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.
			Total	**6**	
17	a		*Each marking point is independent* **Chain length: interaction between molecules** Chain length (in pentane) is longer **AND** more (surface) contact **OR** greater surface area/SA✓ **London forces: strength and energy** **Stronger / more** London forces **OR more energy to break** London forces ✓	2 (AO1.1 ×2)	**Comparisons** needed throughout **ORA** throughout **Assume the following for longer chain** • larger/bigger molecule • more C (and H) • more atoms • more electrons **BUT** 'branching' is a **CON** **IGNORE** comments about packing **ALLOW** induced dipole(–dipole) interactions for London forces **IGNORE** van der Waals'/vdw forces **Examiner's Comments** Most candidates were given 1 or 2 marks, with some omitting the idea of surface area or surface contact. Most candidates identified London forces or induced dipole interactions as the relevant intermolecular force. A few candidates gave a general comment in terms of 'intermolecular' forces without specifying the type of intermolecular forces. There has been a general improvement in candidate responses to this type of question with fewer candidates than in previous exams suggesting the breaking of hydrogen bonds or covalent bonds.

	b		**Skeletal formulae required** 	2 (AO3.1 ×2)	**ALLOW** 1 mark (**ECF**) for 2 'correct' equations with dot omitted or incorrectly positioned **ALLOW** 1 mark for forming 1-bromobutane with dots correct for 1-bromobutane e.g.  **No credit for responses using molecular formulae for organic structures** **Examiner's Comments** This question discriminated very well at the top end of the ability range, but many ignored the instruction to use skeletal formula and obtained no marks as a result. Of those that did use skeletal formula, many placed the dot on the wrong carbon atom or produced 1- brombutane, rather than 2-bromobutane, stated in the question. A mark was still available by ECF for misplaced or absent dots or formation of 1-brombutane with dots. This question was aimed to be demanding and so it proved to be.
			Total	**4**	
18			**D**	1 (AO 1.2)	**Examiner's Comments** Most candidates showed a good understanding of organic nomenclature to obtain the correct option of D. Candidates who drew out the structures for options A and B were able to easily eliminate them. Those trying to interpret the A and B options without drawing out the structures were often less successful.
			Total	**1**	
19			**C**	1 (AO 2.5)	**ALLOW 4** **Examiner's Comments**

					As with Question 15, the strategy of drawing out structures was more likely to lead to success with the correct option of C. Despite this, less than half of candidates obtained the correct response with many missing one of the isomers and opting for option B.
			Total	**1**	
20		i	2-amino-3-methylbutanoic acid **OR** 3-methyl-2-aminobutanoic acid ✓	1 (AO1.2)	**IGNORE** lack of hyphens, extra hyphens, or addition of commas **DO NOT ALLOW** the following for methyl: methy, meth, methly **DO NOT ALLOW** the following for amino: amine, amin **<u>Examiner's Comments</u>** Over half of candidates were unable to give the systematic name of valine, despite many being able to draw out a structure in the following question. A minority of candidates did not attempt the question. The best strategy was to use displayed formula, find the longest chain which included the COOH and label this as C number 1 to make sure of correct numbering. Common errors included 2-amino-3,3- dimethylpropanoic acid or 3-amino-2-methylbutanoic acid. Many candidates did not know how to name the amine functional group with errors including, amine, N-, nitro-, nitrile, etc. Some simply attempted to name the R group alone, e.g. '2-methylethyl- or 'dimethyl'.
		ii	Correct groups attached to chiral C of valine seen **once** e.g.  ✓ Two **3D structures** of valine that are mirror images with correct connectivity in both ✓	2 (AO1.1) (AO1.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity for the first marking point but must be correct for the second mark. **ALLOW** bond to any part of the CH of the $CH(CH_3)_2$ group e.g. **ALLOW** 

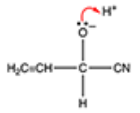
					Each structure must have four central bonds with **at least two wedges.** For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **ALLOW** R or C_3H_7 to be shown for $CH(CH_3)_2$ for second mark only. **ALLOW ECF** for second mark for small slips such as missing H e.g. $C(CH_3)_2$ **Examiner's Comments** Most candidates (more than half) were able to score both marks here, on what was a well-practised question from previous examination series. Most were able to identify the correct chiral carbon, with four different groups attached, and draw a 3-D representation of the two optical isomers with correct connectivity. Some candidates inadvertently drew the same structure (e.g. switched groups and gave a mirror image) so if not drawn in a standard way it needed extra checking. Some lost the second mark due to incorrect connectivity or use of C_3H_7. Some attempted to write formulae out as literal mirror images, e.g. $_2(_3HC)C$ and need to be told that this isn't necessary as can sometime lead to connectivity errors.
			Total	**3**	
21		i	**NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows --- **Nucleophilic attack** *2 marks*	4 (AO1.2 ×2) (AO2.5 ×2)	**ANNOTATIONS MUST BE USED** --- **1st curly arrow must** • go to the C atom of C=O **AND** • start from, **OR** be traced back to any point across width of lone pair on C of $^-$**:**CN **OR :**CN^-



Curly arrow from ⁻CN to C of C=O ✓

Correct dipole shown on C=O
AND
curly arrow showing breaking of C=O ✓

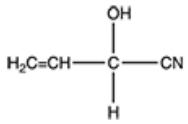
Intermediate *1 mark*



Correct intermediate
AND curly arrow from O⁻ to H⁺ ✓

DO NOT ALLOW δ– on O of intermediate
IGNORE connectivity of H_2C=CH–

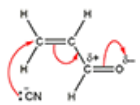
Product *1 mark*



Correct product ✓

Possible alternative 1,4 (conjugate) addition can be credited as follows (not in specification):

Nucleophilic attack *2 marks*



Curly arrow from ⁻CN to C of CH_2 of C=C ✓

Curly arrow from C=C to C-C
AND
curly arrow showing breaking of C=O ✓

Intermediate *1 mark*

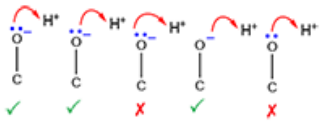
- **OR** start from – charge on C of ⁻CN (then lone pair on CN^- does not need to be shown)

2nd curly arrow must

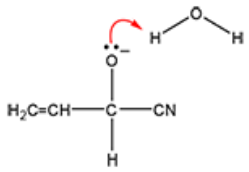
- start from, **OR** be traced back to any part of $^{\delta+}C{=}O\ ^{\delta-}$ bond
  AND
- go to $O^{\delta-}$ (across width of $O^{\delta-}$)

3rd curly arrow must

- go to H^+
  AND
- start from, **OR** be traced back to any point across width of lone pair on $:O^-$
- **OR** start from – charge of O^- of intermediate (then lone pair on O^- does not need to be shown)



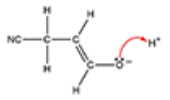
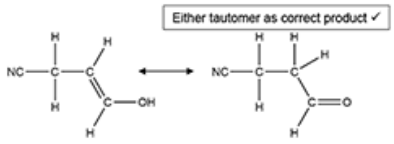
NOTE: For arrow to H^+
ALLOW arrow to H of H_2O
i.e.

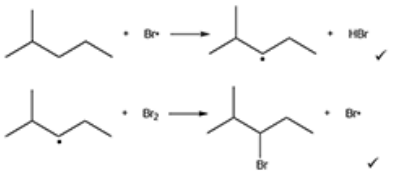
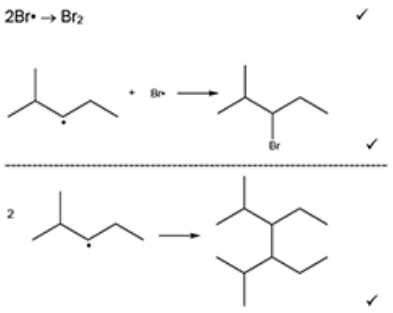
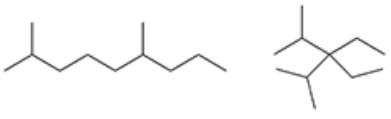


IGNORE attempt to draw curly arrow showing breaking of H–O in H_2O

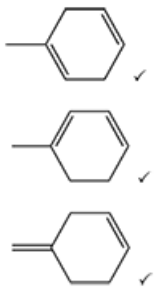
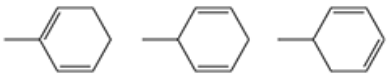
IGNORE lack of dipole on H_2O

IGNORE absence of OH^- as 2nd product

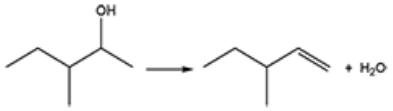
			 --- **Product** *1 mark* 		*Otherwise this more difficult mechanism could cost 2 marks* **Product mark can only be given here if clear from mechanism that there is nucleophilic attack of CH_2 in C=C.** Same product could be seen with an attempt at electrophilic addition across C=C. **Examiner's Comments** There were many excellent examples of precisely drawn mechanisms for the reaction of acrolein with sodium cyanide in acidic conditions and so most candidates gained at least 3 marks. The importance of accuracy when drawing curly arrows needs to be emphasised when teaching mechanisms - arrows must start at lone pairs or negative charges or come from bonds. Many candidates lost marks due to incorrect arrows. Common errors included the use of NaCN or HCN rather than the cyanide ion, the first curly arrow coming from the N of CN-, omission of partial charge across the C=O double bond and addition of partially charges to hydrogen or oxygen. Lower scoring responses often included an intermediate and/or product containing sodium. Some attempted electrophilic addition using HCN across the double bond. A few gained some credit for the mechanism for a competing reaction with nucleophilic addition on CH_2 of C=C. This is not covered in the A Level specification and no candidates scored full marks for this alternative.
		ii	Nucleophilic addition ✓	1 (AO1.1)	**IGNORE** just 'addition' **Examiner's Comments** Most candidates were able to recall the correct response here, especially for those more confident with drawing out the

					mechanism. The most common incorrect response was nucleophilic substitution. Some suggested reduction or nucleophilic addition elimination. Misspellings of 'nucleophilic' were often seen.
			Total	**5**	
22		i	**Initiation** $Br_2 \rightarrow 2Br\bullet$ **AND** ultraviolet / UV ✓ **Propagation**  **Termination** 	6 (AO1.1) (AO2.5) (AO2.5) (AO2.5) (AO3.1)	**DOT REQUIRED** throughout **IGNORE** temperature and pressure **ALLOW ECF** for use of Cl• (from Cl2) in subsequent propagation and termination steps **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position **DO NOT ALLOW ECF** from incorrect radical intermediate for termination steps **<u>Examiner's Comments</u>** Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.  Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect positioning of the radical dot, most typically on the terminal carbon,

					addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.
		ii	C_6Br_{14} ✓ Correct balanced equation $C_6H_{14} + 14\ Br_2 \rightarrow C_6Br_{14} + 14\ HBr$ ✓	2 (AO2.6 ×2)	**ALLOW** 1 mark for correct balanced equation using any combination of skeletal **OR** structural **OR** displayed formula **Examiner's Comments** Most responses gained at least 1 mark for this question giving the correct molecular formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.
		iii	$n(\mathbf{B}) = \frac{72.0}{40000}$ OR $\frac{0.072}{40}$ **OR** $1.8(0) \times 10^{-3}$ (mol) ✓ $M(\mathbf{B}) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓ Molecular formula = $C_6H_9Br_5$ ✓	3 (AO2.2 ×2) (AO3.2)	**ALLOW 2SF** up to calculator value **ALLOW ECF** from incorrect *n***(B)** **ALLOW ECF** from incorrect *M*(**B**) from *n*(**B**) --- **COMMON ERROR** $n(\mathbf{B}) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) × $M(\mathbf{B}) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$ .....✓ Molecular formula = $C_6H_{12}Br_2$ **OR** $C_6H_{11}Br_3$ ✓ **ALLOW ECF** for viable molecular formula with C_6 but must be derived from a calculated value for *M*(**B**)

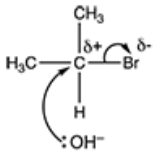
					Examiner's Comments Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use PV=nRT or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.
			Total	**11**	
23		i		3 (AO2.5 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** Lots struggled here with just under half of candidates gaining no credit. Only the strongest responses recognised that a carbon-carbon double bond could be formed external to the ring from the methyl branch. A common error was repeating one of the first two isomers as a mirror or rotated image and so lost a mark - candidates need to be able to recognise same structures (especially using skeletal formula) Lower scoring candidates didn't recognise this reaction would result in the elimination of water. So, it was common to see responses with three structures still containing the OH group or ketones (possible oxidation products), despite the molecular formula C_7H_{10} being provided twice in the question. Some candidates attempted to give structural isomers of C_7H_{10} that would not form from this reaction (see below) including those with smaller rings and even unsaturated straight chain compounds. Some even gave benzene structures. 

					This question was particularly problematic to mark if previous structures drawn were then rubbed out. **Drawing structures in exams** Please remind candidates to draw structures clearly in black ink. If incorrect cross them out and redraw them. Drawing in pencil then rubbing out often leads to extra lines showing when exam papers are scanned making it appear that structures are incorrect.
		ii	NaI / KI **AND** H_2SO_4 ✓	1 (AO1.2)	**ALLOW** HI **ALLOW** NaI / KI **AND** H_3PO_4 **OR** HNO_3 **IGNORE** Conc or dilute **Examiner's Comments** Many candidates were unable to provide reagents and conditions for this reaction. Iodo- seemed unfamiliar to some with responses including NaBr or HBr suggesting substitutions with Br are more familiar. The most common errors were to use iodide with no acid or to use iodine, sometimes in conjunction with other reagents such as AlI_3 or FeI_3.
			Total	**4**	
24			**B**	1 (AO1.2)	**Examiner's Comments** Few students gained marks on this question. The distinction between aliphatic and aromatic compounds was not well understood with many candidates giving D as their response. It is evident that there is confusion that a molecule can be both alicyclic and aliphatic. Alternatively, candidates may have believed that a cyclic compound with a double bond is aromatic. **Misconception** A molecule is either aromatic, if it contains a benzene ring, or aliphatic. Aliphatic molecules which contain a ring can also

					be described as alicyclic. This OCR article offers clarification for classification of organic compounds.
			Total	**1**	
25			**B**	1 (AO2.1)	
			Total	**1**	
26			**A**	1 (AO1.2)	**Examiner's Comments** This question was well answered. Some candidates used the strategy of numbering the C atoms in the structure to aid the deduction of the correct systematic name. D was the most common incorrect response by numbering from left to right.
			Total	**1**	
27		i	3-methylpentan-2-ol ✓	1 (AO 2.1)	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylpentane-2-ol **DO NOT ALLOW** 2-methylpentan-3-ol 3-methylpent-2-ol 3-methpentan-2-ol 3-methypentan-2-ol 3-methlypentan-2-ol **Examiner's Comments** A significant number of candidates lost the mark for missing -an- in their answer i.e. 3-methylpent-2-ol. Others lost the mark for incorrect spelling of methyl.
		ii	 Correct structure of organic product ✓ Balanced equation ✓	2 (AO 2.7 × 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** additional reactants such as H^+ or [O] in the equation. **ALLOW** incorrect isomer 3-methylpent-2-ene for balancing mark. **Examiner's Comments**

					Most candidates did not score either mark here, despite the structures for B and C being given in the table below for (iii). Many thought this was oxidation, showing [O] in equations and giving a carbonyl product. Many had alkenes but still with the -OH present. Some attempted to use structural or displayed formulae but errors were made in giving the correct number of H atoms. For those that did have the correct structure, they often did not give an equation, added the acid as a reactant , or missed off the water as a product.
		iii	Priority groups on same side ✓ High(est) priority groups are CH_3CH_2 and CH_3 **OR** Low(est) priority groups are CH_3 and H ✓	2 (AO 3.1 × 2)	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic number or more important groups etc. **ALLOW** priority groups are both on the top **IGNORE** references to relative mass of groups, Ar, Mr, **ALLOW** identification by name e.g. ethyl and methyl, or by circling on the structure. **IF** 'priority' is not mentioned **ALLOW** 1 mark for CH_3CH_2 and CH_3 are on same side **OR** H and CH_3 are on same side **Examiner's Comments** Many responses made no reference to 'priority' and/or discussed alkene C, suggesting that they didn't read the question fully. Candidates often struggled to find the right language to express themselves, such as reference to 'functional groups' or 'molecules' rather than priority groups. Lots discussed using *Mr* to assign priority with only a few stating correctly that it is atomic number that is used for CIP rules. Many, despite stating that priority groups are on the same side, didn't identify these groups so didn't get the second mark.
			Total	**5**	
28			**Mechanism** Curly arrow from OH– to C atom of C−Br bond in 2-bromopropane✓	3 (AO 1.2) (AO 2.1) (AO 1.1)	**1st curly arrow** must • go to the C of C–Br **AND**

Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$,
AND
curly arrow from C−Br bond to Br atom ✓

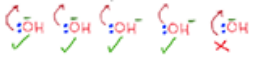


Name

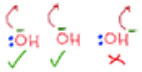
nucleophilic substitution ✓

NOTE: Curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows

- start from, **OR** be traced back to **any point across width** of lone pair on O of OH^-



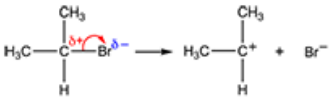
- **OR** start from – charge **on O** of $^-$ OH ion



*(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 ✓

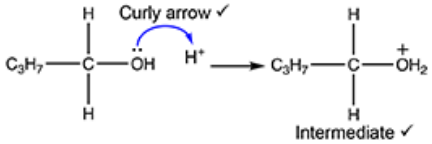
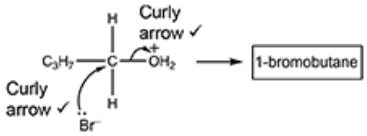
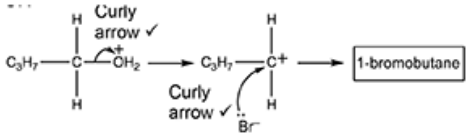
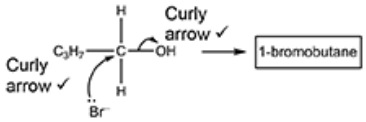


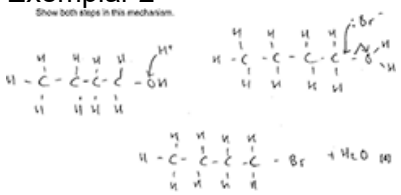
Second mark
Curly arrow from OH^- **AND** to correct carbocation ✓

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) ✓

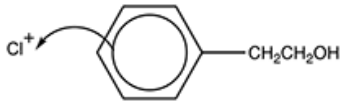
Examiner's Comments

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 $C^{\delta+}$.

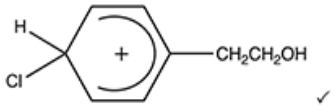
					A range of spellings of nucleophilic were seen, including: nucleophilic, nucleophilic, nucleophilic, and nucleophilic. It is important to promote good literacy in science, including meanings and spellings of technical language.
			Total	**3**	
29			**Step 1** The oxygen atom of the alcohol group accepts 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**  OR  	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: $C_3H_7CH_2^+$ **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**	
30		i	Indicator **AND** observation of acidity **AND** No reaction with carbonate ✓	1 (AO1.2×1)	**ALLOW** (Add) bromine **AND** white precipitate ✓ **ALLOW** (Add) $FeCl_3$ **AND** violet/purple colour ✓
		ii	Compound **J** has **6** peaks/environments/types of carbon ✓ Compound **K** has **5** peaks/environments/types of carbon ✓ Compound **L** has **8** peaks/environments/types of carbon ✓	3 (AO3.2×3)	**IGNORE** any numbers shown on structures **IGNORE** chemical shifts
		iii	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Action of catalyst 1 mark** Formation of electrophile: $Cl_2 + AlCl_3 \rightarrow Cl^+ + AlCl_4^-$ **AND** Regeneration of catalyst: $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓ **----------** **Electrophilic attack 1 mark** Curly arrow from π-bond to Cl^+ ✓	4 (AO1.2×2) (AO2.5×2)	**ALLOW** use of $FeCl_3$ or other halogen carriers ($AlBr_3$) **----------** **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **----------** **1st curly arrow** must

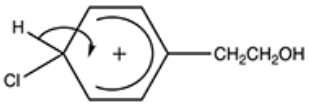


Correct intermediate only 1 mark



Reforming benzene ring 1 mark

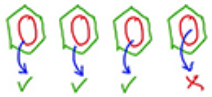
Curly arrow from C–H bond to reform π-ring ✓



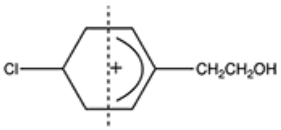
• start from, **OR** close to **circle of benzene ring**

AND

• go to Cl^+



DO NOT ALLOW the following intermediate:

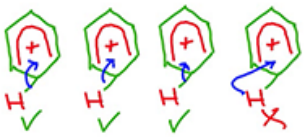


π-ring must cover more than half of benzene ring
AND
correct orientation, *i.e.* gap towards C with Cl

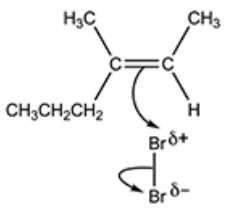
ALLOW + sign anywhere inside the 'hexagon' of intermediate

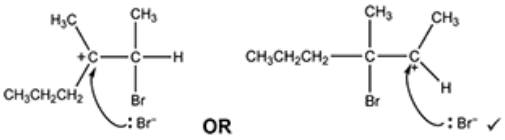
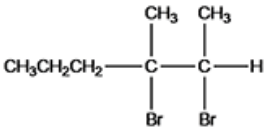
DO NOT ALLOW intermediates substituted at positions 3 or 5
IGNORE intermediates substituted at position 2
OR di-substituted at positions 2,4

Curly arrow must start from, **OR** be traced back to, **any part of** C–H bond and go inside the 'hexagon'

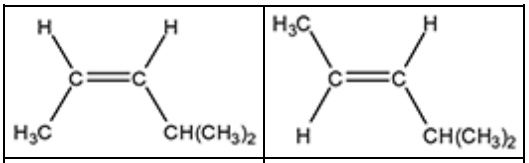
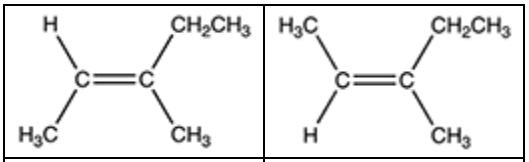
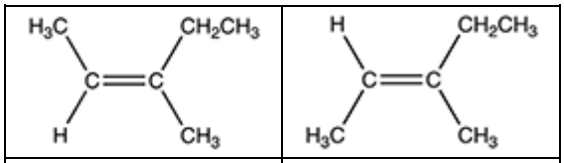
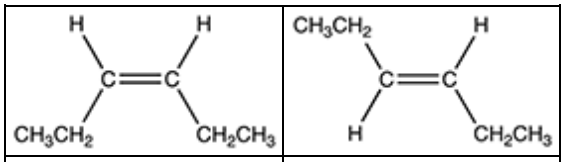
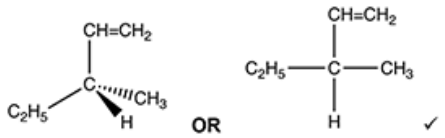


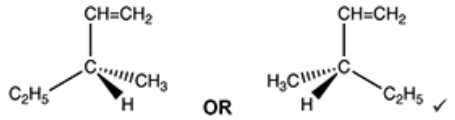
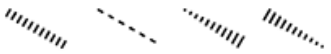
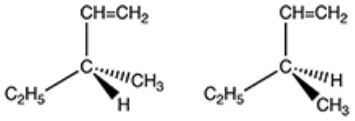
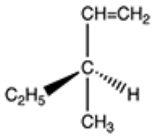
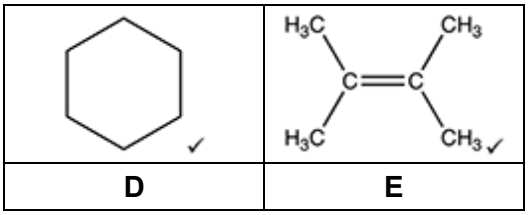
Examiner's Comments

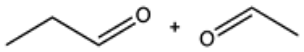
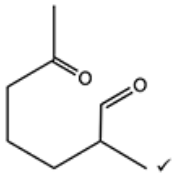
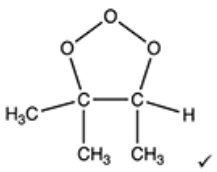
					Few candidates knew the test for a phenol group. Frequent incorrect responses involved the production of a gas with a carbonate or stating that bromine water is decolourised but failing to state that a white precipitate is also formed. A significant number of candidates also stated that the reaction with sodium hydroxide confirms the presence of the phenol group. This question proved challenging to candidates with few scoring all 3 marks. Where no marks were given, this was frequently because candidates did not state the number of carbon environments in compounds J, K and L. Candidates who were given 1 or two marks frequently stated the incorrect number of peaks that would be observed. This question required candidates to apply their knowledge of the mechanism of electrophilic substitution. Examiners were encouraged by the number of excellent responses to this question, with the majority of candidates securing 3 out of 4 marks. Common errors included the omission of HCl as product from the regeneration of the catalyst or candidates attempting to substitute at the 2 position.
			Total	**8**	
31	a	i	3-methylhex-2-ene ✓	1 (AO1.2)	**IGNORE** lack of hyphens, or addition of commas **DO NOT ALLOW** 3-methyhex-2-ene OR 3-methhex-2-ene OR 3-methlyhex-2-ene OR 3-methylhexan-2-ene **IGNORE** references to *E/Z* or *cis/trans*
		ii	**ANNOTATE ANSWER WITH TICKS AND CROSSES**  	3 (AO1.2×1) (AO2.5×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity of $CH_3CH_2CH_2$ and CH_3 groups in carbocation and product **ALLOW** C_3H_7 for $CH_3CH_2CH_2$ **DO NOT ALLOW** half headed or double headed arrows but allow **ECF** if seen more than once

			Curly arrow from C=C bond to $Br^{\delta+}$ of Br–Br **AND** Correct dipole on Br–Br **AND** curly arrow for breaking of Br–Br bond ✓ **Correct carbocation to match mechanism** **AND** curly arrow from Br^- to C^+ of carbocation  ***i.e. ALLOW*** *carbonium + on either C atom* --- **<u>Correct product to match mechanism</u>** ✓ 		**DO NOT ALLOW** use of HBr but ECF for subsequent use **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** --- **DO NOT ALLOW** partial charge on C=C **1st curly arrow** must • go to a Br atom of Br–Br **AND** start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow** must • start from, **OR** be traced back to, **any part of** $^{\delta+}$Br–Br$^{\delta-}$ bond • **AND** go to Br $^{\delta-}$  **3rd curly arrow** must • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$ • **OR** start from – charge on Br^- ion

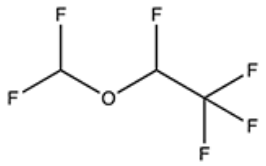
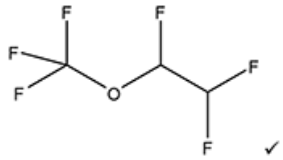
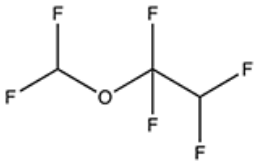
					 *(Lone pair **NOT** needed if curly arrow shown from – charge on Br^-)* **ALLOW** bromonium ion (Contact TL) **Examiner's Comments** The majority of candidates were able to correct name hydrocarbon **A** as 3-methylhex-2-ene. A number of responses used incorrect numbering or suggested 3-methylhexan-2-ene as the name. Candidates are familiar with the mechanism for the bromination of hydrocarbons. So, the majority of candidates scored 3 marks. Common errors included the use of HBr rather than Br_2 or putting a dipole on the carbon-carbon double bond.
	b	i	Same **molecular** formula **AND** Different **structural** formulae ✓ **OR** Both have the **molecular** formula C_6H_{12} **AND** Different **structural** formulae ✓	1 (AO1.1)	Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient *(no reference to structure/structural)* For 'structural formulae', **ALLOW** structure/displayed/skeletal formulae/functional groups **DO NOT ALLOW** any reference to spatial/space
		ii	Same structural formula **AND** Different arrangement (of atoms) in **space** **OR** different **spatial** arrangement (of atoms) ✓	1 (AO1.1)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula

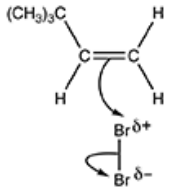
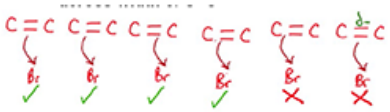
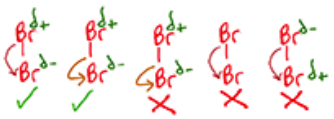
					Reference to *E/Z* isomerism or optical isomerism is **not** sufficient
		iii	Correct identification of *cis* **AND** *trans* isomers of 4-methylpent-2-ene ✓✓  *cis* isomer | *trans* isomer **OR** Identification of 3-methylpent-2-ene as *cis* **AND** *trans* isomers ✓✓  *cis* isomer | *trans* isomer	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous C_3H_7 is **not** sufficient (could be unbranched) **ALLOW** one mark if *cis* **AND** *trans* isomers of 4-methylpent-2-ene are in the wrong boxes **ALLOW** the isomers of 3-methylpent-2-ene in either box  *cis* isomer | *trans* isomer *Ambiguity with cis/trans identification system* **ALLOW** one mark for correct identification of *cis* **AND** *trans* isomers of unbranched C_6H_{12} e.g.  *cis* isomer | *trans* isomer
		iv	Correct groups attached to chiral carbon of compound C seen **once** e.g.  OR ✓	2 (AO2.5×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For C_2H_5–, ALLOW CH_3CH_2– For –$CH{=}CH_2$, ALLOW –C_2H_3 OR –$CHCH_2$ For bond into paper accept:

			Two **3D structures** of compound C that are mirror images with correct connectivity in both  ✓		 **ALLOW** two 3D structures with 2 groups swapped e.g.  **DO NOT ALLOW** a bond angle of 180° e.g. 
		v	 ✓ ✓ **D** **E** Two of the following for **D** ✓ • All H are equivalent/in the same chemical environment/ the same type • All C are equivalent/ in the same chemical environment/ the same type • No C=C present Two of the following for **E** ✓ • All H are equivalent/ in the same chemical environment/ the same type • 2 C environments • C=C present	4 (AO2.5×2) (AO2.2×2)	**ALLOW** 1 mark for structures if shown in wrong boxes. **CHECK** table 16.1 for annotations that may be worthy of credit **Examiner's Comments** The majority of candidates were able to correctly define a structural isomer. This definition was well known by candidates with the majority of responses given the mark. Some candidates omitted the reference to structural formula. This question required candidates to link their knowledge of *cis* and *trans* isomers

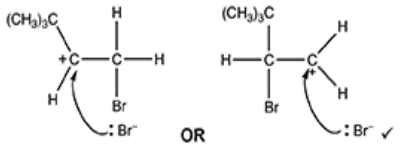
					with branched hydrocarbons. Higher ability candidates were able to do this. The majority of candidates scored 1 mark for correctly drawing *cis* and *trans* isomers of an unbranched hydrocarbon. This question discriminated well. Candidates were required to identify the groups around a chiral carbon This question discriminated well. Candidates were required to identify the groups around a chiral carbon and then draw the two corresponding optical isomers. Incorrect responses frequently had incorrect connectivity around the chiral carbon, bond angles of 180° or 2D structures. Most candidates were able to correctly draw the structure of D and E. Many candidates did not explain their answers in terms of the number of different hydrogen and carbon environments or the presence/absence of a carbon-carbon double bond.
	c	i	 **BOTH** structures required for ✓ 	2 (AO3.1×1) (AO3.2×1)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
		ii		1 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **<u>Examiner's Comments</u>** Most candidates were able to score 1

					mark for correctly drawing the structures of the two aldehyde products of the first reaction. The second reaction proved more challenging, with most candidates incorrectly drawing two products. Few candidates were given this mark. A common error was to produce multiple products (rather than a ring structure) or to put positive/negative charges on the oxygen atoms within the ring structure.
			Total	**17**	
32			**FIRST CHECK ANSWER LINES** **If M=168(.0) Award 4 marks for calculation providing unit conversions are correct** **---** ***Use of ideal gas equation*** $pV = nRT$ ***OR*** $n = \frac{pV}{RT}$ ✓ ***SI Unit conversions AND substitution into*** $n = \frac{pV}{RT}$: • *R = 8.314* ***OR*** *8.31* • *V* = 186 × 10^{-6} • *T in K: 303 K* *e.g.* $\frac{1.07 \times 10^5 \times 186 \times 10^{-6}}{8.314 \times 303}$ ✓ ***Calculation of n*** *n* = 7.90 × 10^{-3} (mol) ✓ ***Calculation of M*** $M = \frac{1.327}{7.90 \times 10^{-3}} = 168(.0)$ ✓ ***Molecular formula*** $C_3H_2F_6O$ ✓	6 (AO1.2×1) (AO2.4×3) (AO2.5×2)	**ALLOW ECF throughout** **ALLOW** calculator value of 167.968115 (using 8.314) for M **ALLOW** calculator value of 167.8873033 (using 8.31) for M Calculator value of *n*: from 8.314 = 7.900308915 × 10^{-3} from 8.31 = 7.904111711 × 10^{-3} **ALLOW** ECF that matches M but the formula MUST contain F_6O **----------** **Use of 24 dm^3**: e.g. $n = \frac{186.0}{24000} = 7.75 \times 10^{-3}$ **No mark** *(calculation much simpler)* $M = \frac{1.327}{7.75 \times 10^{-3}} = 171(.2)$ ✓ **ECF** $C_3H_5F_6O$ ✓

			Structure  **OR**  ✓		**ECF** **ALLOW** ECF for a feasibile chemical structure that matches M **AND** contains F_6O **AND** has a chiral carbon **DO NOT ALLOW**  *no chiral carbon* **Examiner's Comments** This question proved difficult and discriminated well. Higher ability candidates correctly used SI units and showed each step of their calculation and then using this to correctly identify a structure of compound X. Candidates frequently used the wrong interconversions and gave structures that lacked a chiral centre. A small number of candidates used molar gas volume rather than PV=nRT for their calculation.
			Total	**6**	
33			A	1 (AO1.1)	**Examiner's Comments** Most candidates correctly selected A. The most common incorrect response was option D as candidates had misinterpreted the amide group as a ketone and an amine.
			Total	**1**	
34			**A**	1(AO2.5)	**Examiner's Comments** Candidates found this question hard with many selecting C or D instead of the

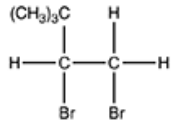
					correct option, B. Candidates appeared to have assigned the C–H absorption at 3000 cm^{-1} to an O–H group (from an alcohol or carboxylic acid). Candidates should appreciate that this C–H absorption will be present in any organic compound possessing a C–H group (that is, nearly all organic compounds).
			Total	**1**	
35		i	3,3-dimethylbut-1-ene ✓ **CARE**: Look for **di**methyl	1 (AO1.2 ×1)	**IGNORE** lack of hyphens, or addition of commas or spaces **ALLOW** full stops or spaces between numbers e.g. 3.3 dimethyl but-1-ene **DO NOT ALLOW** meth **OR** methy **Examiner's Comments** Candidates had difficulty in naming this compound correctly as 3,3-dimethylbut-1-ene. Many counted an incorrect number of carbons in the chain, numbered substituents from the wrong end (e.g. 1,1,1-) or used insufficient numbering (e.g. 3-dimethyl). Hex-1-ene was a common incorrect answer, presumably as there are six carbon atoms and one C=C double bond in the alkene
		ii	**ANNOTATE ANSWER WITH TICKS AND CROSSES**  or **1st curly arrow (from ANY alkene)** Curly arrow from double bond to Br of Br–Br ✓ **DO NOT ALLOW** partial charge on C=C **2nd curly arrow** Correct dipole on Br–Br **AND** curly arrow for breaking of Br–Br bond ✓ **3rd curly arrow** **Correct carbocation** with + charge on C with 3 bonds **AND** curly arrow from Br^- to C^+ of	5 (AO1.2) (AO1.2) (AO2.5) (AO2.5) (AO1.1)	**For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **1st curly arrow** must • go to a Br atom of Br–Br **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow** must • start from, **OR** be traced back to, **any part** of $^{\delta+}Br–Br^{\delta-}$ bond • **AND** go to $Br^{\delta-}$  **IGNORE** connectivity of CH_3 groups in carbocation and product and **ALLOW** C_4H_9 **3rd curly arrow** must

carbocation
DO NOT ALLOW δ+ on C of carbocation



or

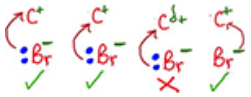
i.e. ***ALLOW*** *carbonium + on either C atom*
Correct product to match mechanism/intermediate ✓



or

DO NOT ALLOW half headed or double headed arrows but allow **ECF** if seen more than once
Name of mechanism: Electrophilic addition ✓

• go to the C^+ of carbocation
AND
• start from, **OR** be traced back to **any point across width** of lone pair on :Br^- •
OR start from – charge on Br^- ion



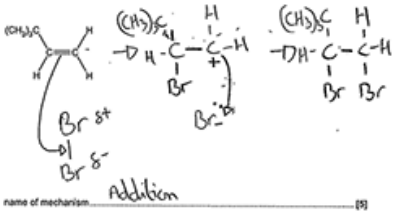
(Lone pair NOT needed if curly arrow shown from – charge on Br)
ALLOW bromonium ion
ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
NOTE: For a mechanism with HBr, ALLOW all marks EXCEPT for final product mark

Examiner's Comments

Many candidates answered the mechanism proficiently. However, many mistakes were seen with the direction of arrows, and confusing δ+/ δ– and +/– charges. In the intermediate carbocation, the C=C was often left intact and δ– used on the bromide ion attacking the intermediate. Some less successful responses did not position curly arrows accurately.

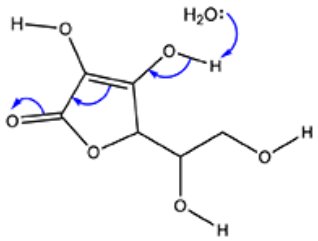
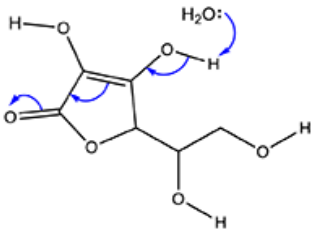
One common error was showing one or more C atoms missing from the $(CH_3)C$ groups. Candidates should take great care when drawing organic structures to make sure that all groups have been drawn accurately.

Exemplar 1



This exemplar has been included to emphasise the importance of accurately placed curly arrows and use of charges. It was only possible to award this response 1 out of 5 marks. With a few improvements, this response could easily

					have been 5/5. The start of the first curly arrow has been placed accurately starting from the C=C double bond but the arrow should have finished at the $Br^{\delta+}$: 0 marks The Br–Br dipole is correct but there is no curly arrow showing it breaking: 0 marks The intermediate carbocation is correct but the curly arrow should have been shown from a lone pair on the Br^- ion to the + charge of the carbocation: 0 marks The product is correct: 1 mark The reaction type is addition but the name of the mechanism is electrophilic addition: 0 marks **Assessment for learning** Reactions mechanisms are the organic chemist's way of communicating electron transfers in organic chemistry. Candidates must use curly arrows, dipoles and charges 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	**6**	
36			**C**	1(AO1.2)	**ALLOW** 12 **Examiner's Comments** Most candidates selected the correct response. Where an error had been made, it was usually option B, the result of ignoring the two tertiary H atoms.
			Total	**1**	
37		i		2 (2 ×AO3.2)	**IGNORE incorrect curly arrows** **IGNORE** 'double' curly arrows such as:

			 3 **OR** 4 curly arrows correct → 2 marks ✓ ✓ 1 curly arrow correct → 1 mark ✓		 **H_2O Curly arrow** must • start from, **OR** be traced back to **any point across width** of lone pair on H_2O**:** **Examiner's Comments** This novel mechanism assessed a candidate's understanding of curly arrows, and four curly arrows were needed. One mark was available for one correct curly arrow, usually from the H_2O: or from the C=O. 2 marks were given for three or four correct curly arrows. The two curly arrows within the ring structure proved to be the most difficult. The question discriminated extremely well: many candidates were able to secure one mark with the most able being given both marks. A candidate showing all four curly arrows correctly demonstrated an excellent understanding of curly arrows.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.16 award 3 marks** --- [Vitamin C] = 0.150 × 4 = 0.600 (mol dm^{-3}) ✓ *0.6 seen anywhere* $[H^+] = \sqrt{(K_a \times [\text{Vitamin C}])}$ $= \sqrt{(7.94 \times 10^{-5} \times 0.600)}$ $= 6.90 \times 10^{-3}$ (mol dm^{-3}) ✓ pH = -log $[H^+]$ = -log 6.90×10^{-3} = 2.16 ✓ **2 DP required**	3 (2 ×AO2.4) (1 ×AO1.2)	**For $[H^+]$** **ALLOW ECF** from incorrect [vitamin C] for pH **ALLOW ECF ONLY** if $[H^+]$ has been derived from K_a **AND** [vitamin C] --- **COMMON ERRORS** pH = 4.32 2/3 calculation marks *No square root of* $(7.94 \times 10^{-5} \times 0.600)$ pH = 2.46 2/3 calculation marks *No ×2 4* $(7.94 \times 10^{-5} \times 0.150)$ pH = 2.76 2/3 calculation marks *÷ 4* $(7.94 \times 10^{-5} \times 0.0375)$ pH = 4.92 1/3 calculation mark *No square root AND 0.150* pH = 5.53 1/3 calculation mark *No square root AND 0.0375* **Examiner's Comments** Most candidates had learnt a standard method for calculating the pH of a weak

					acid. with the correct answer of 2.16 being seen on very many scripts. Success required conversion of 0.150 moles of vitamin C in 250 cm^3 to its concentration as 0.600 mol^{-3}, calculation of $[H^+]$ using $[H^+] = \sqrt{(K_a \times [HA])}$ and determination of pH using $-\log[H^+]$. Common errors usually resulted from one mistake and could still be rewarded with 2 of the available 3 marks. Examples are shown below. • pH = 4.32 *No square root of* ($7.94 \times 10^{-5} \times 0.600$) • pH = 2.46 *No conversion of 0.150 mol to 0.600 mol* $dm^{-3} \rightarrow$ ($7.94 \times 10^{-5} \times 0.150$) • pH = 2.76 ÷ 4 instead of × 4 for concentration → ($7.94 \times 10^{-5} \times 0.0375$) **AfL** pH calculations are common in A Level Chemistry There are four different types, and it is essential that the standard methods for determination of $[H^+]$ in the calculations are **learnt**: • pH of strong acids • pH of weak acids, using K_a and [HA] • pH of strong bases, using Kw and $[OH^-]$ • pH of buffers, using K_a and $[HA]/[A^-]$ It is extremely likely that at least one of these types of pH calculation will feature in at least one of the A Level units.
			Total	**5**	