GCE

Chemistry A

H432/03: Unified chemistry

Advanced GCE

Mark Scheme for Autumn 2021

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

1. Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	Ignore

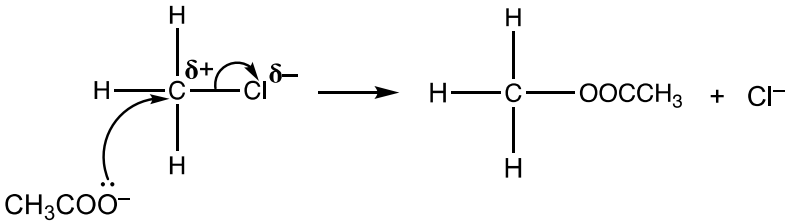
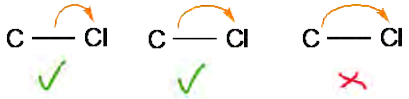
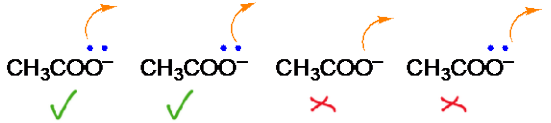
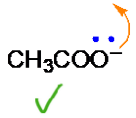
2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

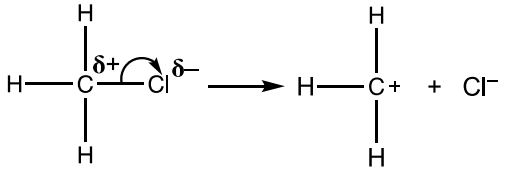
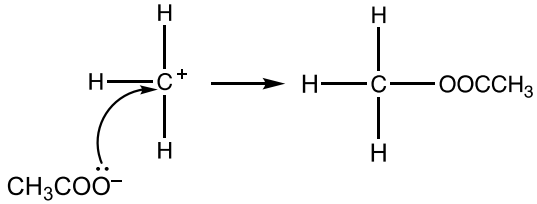
Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

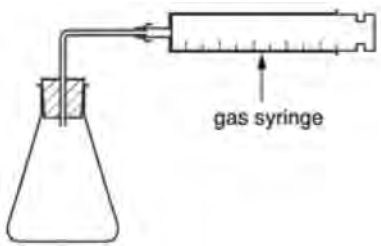
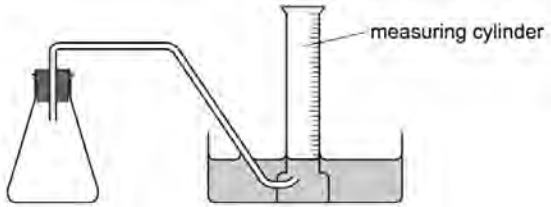
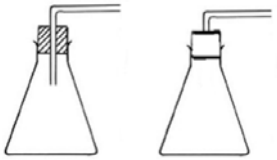
Question			Answer	Marks	AO element	Guidance
1	(a)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 20 award 2 marks** --- $n(CO_2) = \frac{110}{44}$ **OR** 2.5 (mol) **AND** $n(O_2) = \frac{120}{32}$ **OR** 3.75 (mol) ✓ $p(CO_2) = \frac{2.5}{6.25} \times 50.0$ **OR** $0.4 \times 50.0 = 20(.0)$ (atm) ✓	**2**	AO1.2 × 2	**ALLOW ECF** from incorrect Σ ($n(CO_2) + n(O_2)$) **ONLY**
	(b)		**FIRST CHECK THE ANSWER ON ANSWER LINES** **If $[PCl_3] = [Cl_2] = 0.02(00)$ award 2 marks** --- $K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}$ **OR** with number(s), e.g. $K_c = \frac{[PCl_3]\,[Cl_2]}{0.05(00)}$ ✓ $[PCl_3] = [Cl_2] = \sqrt{(K_c \times [PCl_5])}$ $= \sqrt{(8.00 \times 10^{-3} \times 0.0500)}$ $= \sqrt{(4.00 \times 10^{-4})}$ $=$ **2.00×10^{-2}** (mol dm^{-3}) ✓	**2**	AO1.1 AO2.2	Square brackets required --- **Common errors** 2.00×10^{-4} from $K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}$ 1 mark *÷2 instead of √* 2.5 from $K_c = \frac{[PCl_5]}{[PCl_3]\,[Cl_2]}$ 1 mark *Inverse K_c expression*

Question			Answer	Marks	AO element	Guidance
			Electronegativity and boiling point Boiling point/Energy increases with increased electronegativity (difference) ✓ **Type of intermolecular force** HF **AND** NH_3 have hydrogen bonding **AND** CH_4 has London forces/induced (dipole–)dipole interactions ✓ **Comparison between strength of intermolecular forces** HF has stronger hydrogen bonding than NH_3 **OR** hydrogen bonding is stronger than London forces ✓	**3** AO1.1 AO1.2 AO2.1	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW ORA** throughout --- **ORA** **IGNORE** permanent dipole interactions **IGNORE** IDID **IGNORE** HF and NH_3 are polar/CH_4 is non-polar **IGNORE** strength of ionic and covalent bonds
	(d)		**A**: Ca_3N_2 (formula required) ✓ **B**: NH_3 **OR** ammonia ✓ **C**: $Ca(OH)_2$ **OR** calcium hydroxide ✓ **Equation**: $Ca_3N_2 + 6H_2O \rightarrow 2NH_3 + 3Ca(OH)_2$ ✓	**4** AO1.1 AO2.7 ×2 AO2.6	**IGNORE** working If **B** and **C** labels are the wrong way round **OR** missing, award 1/2 for **B** and **C** labels, i.e. for **B** $Ca(OH)_2$ **C** NH_3 1/2 marks **ALLOW** CaO_2H_2 **ALLOW** multiples for equation **IF C** = CaO, **ALLOW ECF** for: $Ca_3N_2 + 3H_2O \rightarrow 2NH_3 + 3CaO$

Question	Answer	Marks	AO element	Guidance
(e)	$2CH_3CH(OH)COOH + Na_2CO_3 \rightarrow 2CH_3CH(OH)COONa + CO_2 + H_2O$ CO_2 and H_2O **OR** $CH_3CH(OH)COONa$ as product(s) ✓ Balanced equation correct ✓ $3CH_3CH(OH)COOH + Al \rightarrow (CH_3CH(OH)COO)_3Al + 1½\ H_2$ H_2 **OR** $(CH_3CH(OH)COO)_3Al$ as product ✓ Balanced equation correct ✓	**4**	AO2.6 ×4	**ALLOW** multiples **IGNORE** state symbols **ALLOW** ions shown separately For CO_2 AND H_2O, **ALLOW** H_2CO_3 **ALLOW** ….$COONa^+$ (i.e. one of charges missing) **ALLOW** ….$COO)_3Al^{3+}$ (i.e. one of charges missing)

Question	Answer	Marks	AO element	Guidance
(f)	**Mechanism**:  **NOTE**: Can be any C–X bond, e.g. C–Cl, C–Br, C–I but must be consistent. **Curly arrow on C–X** Dipole shown on C–X bond of CH_3X, $C^{\delta+}$ and $X^{\delta-}$ **AND** curly arrow from C−X bond to X atom ✓ **Curly arrow from CH_3COO^-** Curly arrow from CH_3COO^- to C atom of C–X bond ✓ --- **Products** Correct organic product **AND** X^- ✓	3	AO2.5 AO1.2 AO2.5	**ANNOTATE ANSWER TICKS AND CROSSES** --- **NOTE:** Curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must start from, **OR** be traced back to, **any part of** C–Cl bond and go to Cl  **2nd curly arrow** must • go to the C of C–Cl **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of CH_3COO^-  • **OR** start from '–' **on O** of CH_3COO^- ion  *(Lone pair **NOT** needed if curly arrow from O^-)* --- If CH_3COOH used instead of CH_3COO^-, **ALLOW** X^- **OR** HX as 2nd product

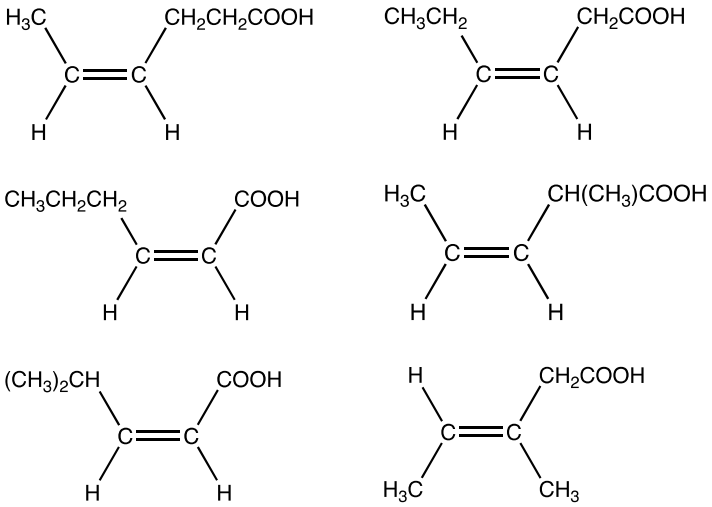
Question	Answer	Marks	AO element	Guidance
				ALLOW S_N1 mechanism **First mark** Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from CH_3COO^- to carbocation  Curly arrow must be from lone pair on O of CH_3COO^- **OR** from minus on O of CH_3COO^- ion (no need to show lone pair if curly came from – charge) ✓ **Third mark** Correct organic product **AND** Cl^- ✓

Question			Answer	Marks	AO element	Guidance
2	(a)		**Closed system that would work** (***Labels not required***) Reaction apparatus with tube/side arm **AND** gas collection apparatus **AND** closed system ✓ **Labels** ***Reaction apparatus, e.g.:*** Conical flask, Buchner flask/conical flask with side arm, test-tube, boiling tube. **AND** ***Gas collection apparatus:*** (gas) syringe **OR** gas collection over water with labelled measuring cylinder / burette ✓   	**2**	AO3.3 × 2	**ALLOW** small gaps provided there is an attempt to show closed system **DO NOT ALLOW** delivery tube below reaction mixture **For reaction apparatus,** • **DO NOT ALLOW** flask, volumetric flask, beaker, measuring cylinder • Delivery tube, bung does **NOT** need a label **ALLOW** labels for diagram without closed system (e.g. bung missing), i.e. 2nd mark but not 1st mark **ALLOW** any of these diagrams.  **ALLOW** a single line for the tube **IGNORE** Sealed end of delivery tube **IGNORE** size of syringe/measuring cylinder/burette

Question	Answer	Marks	AO element	Guidance
(b)	$n(H_2) = \frac{152}{24000}$ **OR** 6.33…. × 10^{-3} (mol) ✓ $n(Eu) = \frac{0.988}{152}$ **OR** 6.5(0) × 10^{-3} (mol) ✓ Ratio H_2 : Eu 1 : 1 **AND** Equation 2 is correct ✓ *Only **ALLOW** if n(H_2) **AND** n(Eu) are approximately equal* **ALLOW** use of ideal gas equation at a reasonable temperature and pressure. e.g. Using 100 kPa and 298 K, $n(H_2)$ = 6.14 × 10^{-3} mol	**3**	AO2.8 ×2 AO3.2 ×1	**152** 6.5(0) × 10^{-3} (mol) **ALLOW** 0.97(4) : 1 **ALLOW ECF** from incorrect *n*(Eu) **OR/AND** *n* (H_2) --- **ALLOW** approach that calculates mass Eu from 6.33…. × 10^{-3} mol H_2 for each equation, e.g. Equation 1: 2 × 6.33 × 10^{-3} × 152 = 1.9.. g Equation 2: 1 × 6.33 × 10^{-3} × 152 = 0.96.. g Equation 3: 2/3 × 6.33 × 10^{-3} × 152 = 0.64.. g ✓ 0.988 matched to 0.96 g and Equation 2 ✓ *Use judgment* --- **ALLOW** approach that calculates volume H_2 from 6.50 × 10^{-3} mol Eu for each equation, e.g. Equation 1: 0.5 × 24000 × 6.50 × 10^{-3} = 78 cm^3 Equation 2: 1 × 24000 × 6.50 × 10^{-3} = 156 cm^3 Equation 3: 1.5 × 24000 × 6.50 × 10^{-3} = 234 cm^3 ✓ 152 matched to 156 cm^3 and Equation 2 ✓ *Use judgment*

Question	Answer	Marks	AO element	Guidance
(c)	The gas volume would be larger (than at RTP) ✓ Ratio H_2 : Eu would be larger ✓	2	AO3.4 ×2	**IGNORE** effect of rate, e.g. rate increases **IGNORE** gas equation should be used to find $n(H_2)$ **ALLOW** Equation 3 linked to H_2 : Eu > 1
(d)	**Qual** Precipitates have different molar masses **OR** Precipitates have different formulae ✓ **Quant** Equation 2 forms precipitate with M = 186 **OR** with formula $Eu(OH)_2$ **OR** Equation 2 forms 1.86 g precipitate **OR** Molar mass M of precipitate = $\frac{\text{mass of precipitate}}{\text{moles precipitate}}$ **OR** $\frac{\text{mass of precipitate}}{\text{moles Eu}}$ **OR** $\frac{\text{mass of precipitate}}{0.01}$ ✓	2	AO3.4 ×2	**ALLOW** precipitates are EuOH, $Eu(OH)_2$ $Eu(OH)_3$ **OR** precipitates have different number of OH^- ions **ALLOW** Moles OH^- = $\frac{\text{mass of precipitate – mass of Eu}}{\text{molar mass of } OH^-}$ **OR** Moles OH^- = $\frac{\text{mass of precipitate –1.52}}{17}$

Question			Answer	Marks	AO element	Guidance
3	(a)		$n(Ba(OH)_2) = 0.150 \times \frac{250}{1000}$ **OR** 0.0375 (mol) ✓ Mass $Ba(OH)_2 = 0.0375 \times 171.3 = 6.42375$ (g) ✓ Dissolve solid in (distilled) water (less than 250 cm^3) in beaker ✓ Transfer (solution) to **volumetric** flask **AND** Transfer washings (from beaker) to flask ✓ Make up to mark/up to 250 cm^3 with (distilled) water **AND** Invert flask (several times to ensure mixing) ✓	**5**	AO2.4 ×2 AO1.2 ×3	**ALLOW ECF** from incorrect $n(Ba(OH)_2)$ **ALLOW** 6.42 up to 6.42375 correctly rounded 6.42 g subsumes 1st mark **ALLOW** conical flask for beaker **ALLOW** graduated flask **DO NOT ALLOW** round-bottom or conical flask
	(b)		$n(Ba(OH)_2) = 0.150 \times \frac{23.50}{1000}$ $= \mathbf{3.525 \times 10^{-3}}$ (mol) ✓ n(**D**) in 25.0 cm^3 $= 2 \times 3.525 \times 10^{-3}$ $= \mathbf{7.05 \times 10^{-3}}$ (mol) ✓ n(**D**) in 100 cm^3 $= 7.05 \times 10^{-3} \times \frac{100}{25.0}$ $= \mathbf{0.0282}$ (mol) ✓ **Molar mass** (**D**) $= \frac{3.215}{0.0282} = \mathbf{114}$ (g mol^{-1}) ✓ **Formula**: $= C_5H_9COOH$ **OR** C_nH_{2n-1}: $M(C_5H_9) = 114 - 45 = 69$ ✓ *If not stated, could be credited from structure*	**7**	AO2.8 ×4 AO3.2 ×1	**Use ECF throughout** Intermediate values for working to **at least 3 SF.** **TAKE CARE** as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited. --- **ALLOW** Mass **D** in 25.0 $cm^3 = \frac{3.215}{4} = 0.80375$ g **Molar mass** (**D**) $= \frac{0.80375}{7.05 \times 10^{-3}} = 114$

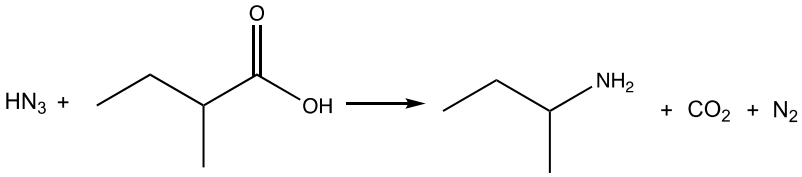
Question	Answer	Marks	AO element	Guidance
	***cis* stereoisomers.** The drawn stereoisomers must have • Different groups attached to each C atom of C=C • Each C of C=C has the same group on the same side Any 2 *cis* isomers ✓✓ *Many possibilities, e.g.*  **ALLOW** correct structural, with '*cis*' part displayed **OR** skeletal **OR** displayed formula **OR** mixture of above as long as non-ambiguous **ALLOW** side chains as molecular formula, e.g. C_3H_7 for $(CH_3)_2CH$ **OR** $CH_3CH_2CH_2$ e.g. $C_3H_5O_2$ for CH_2CH_2COOH **IGNORE** poor connectivity to all groups		AO3.2 ×2	**COMMON ERRORS:** *Up to Molar mass = 114 (1st 4 marks)* $M = 456 \rightarrow$ 3/4 marks (mol in 100 cm^3 omitted) $M = \frac{3.215}{7.05 \times 10^{-3}} = 456$ $M = 228 \rightarrow$ 3/4 marks (*No × 2 for n(**D**)*) $3.525 \times 10^{-3} \times \frac{100}{25.0} = 0.0141$ $M = \frac{3.215}{0.0141} = 228$ $M = 100.8 \rightarrow$ 3/4 marks *23.50 instead of 25.00 and scaling by* $\times \frac{100}{23.50}$ $25.0 \times \frac{0.150}{1000} = 3.75 \times 10^{-3}$ ✖ $\rightarrow 2 \times 3.75 \times 10^{-3} = 7.5 \times 10^{-3}$ ✓ $\rightarrow 7.5 \times 10^{-3} \times \frac{100}{23.50} = 0.0319$ ✓ $\rightarrow \frac{3.215}{0.0319} \rightarrow 100.8$ ✓ **THEN ALLOW ECF** for carboxylic acid closest to calculated *M*(alkyl group) but must be C_nH_{2n-1} e.g. For ***M(alkyl)* = 100**, **ALLOW** C_4H_7 (55) For ***M(alkyl)* = 411**, **ALLOW** $C_{29}H_{57}$ (405) **OR** $C_{30}H_{59}$ (419) **THEN** judge *cis* isomers with closest match **ALLOW** 1 mark for 2 *trans* isomers shown instead of 2 *cis* isomers ***ECF** for Same error made twice.*

Question			Answer	Marks	AO element	Guidance
4	(a)		(Large) excess of pent-1-ene **OR** There is a (large) excess ✓	**1**	AO3.1	**ALLOW** pent-1-ene concentration is (much) greater **OR** pent-1-ene has a high concentration
	(b)		*Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Obtains a comprehensive conclusion to determine **initial rate AND order AND rate constant** *k* *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)** Obtains a sound, but not comprehensive conclusion, to determine **initial rate AND order** **OR order AND rate constant *k*** **OR initial rate AND rate constant *k*** *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)** Obtains a simple conclusion to determine **initial rate OR order** *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.	**6**	AO3.1 ×4 AO3.2 ×2	*Indicative scientific points may include:* **Initial rate** • Evidence of tangent on graph drawn to line at t = 0 s **AND** gradient determined in range $4.5 – 6.5 \times 10^{-6}$ • *initial rate* expressed as gradient value with units of mol dm^{-3} s^{-1}, e.g. *initial rate* = 5.5×10^{-6} mol dm^{-3} s^{-1} **Reasoned order of I_2** **Half lives** • Half life measured on graph **OR** within text **OR** stated in range 2500 ±10 s • Constant half life **OR** two stated half lives within ±10 s **AND** conclusion that I_2 is 1st order **OR** **Comparison of rates from gradients** • Rate measured as gradient at a concentration, *c* • Rate measured at *c*/2 • *c* halves and rate halves • so order 1 e.g. initial rate at c = 0.02 = 5.5×10^{-6} mol dm^{-3} s^{-1} rate at c = 0.01 = 2.58×10^{-6} mol dm^{-3} s^{-1}

Question			Answer	Marks	AO element	Guidance
						Determination of *k* with units • Rate constant *k* clearly linked to initial rate **OR** half-life: $k = \frac{rate}{[I_2]}$ **OR** $k = \frac{\ln 2}{t_{1/2}}$ • *k* determined correctly from measured initial rate or measured half life with units of s^{-1}, e.g. $k = \frac{5.5 \times 10^{-6}}{0.02} = 2.75 \times 10^{-4}\ s^{-1}$ from initial rate of 5.5×10^{-6} mol dm^{-3} s^{-1} **OR** from $t_{1/2}$ of 2500 s • *Typical range 2.25–3.25 × 10^{-4}*
	(c)	**(i)**	Reactants for 1st step: $CH_3CH_2CH_2CH=CH_2 + I_2$ ✓ 2 steps that add up to overall equation: $CH_2CH_2CH=CH_2 + I_2 \rightarrow CH_3CH_2CH_2CHICH_2I$ ✓ e.g. $CH_3CH_2CH_2CH=CH_2 + I_2 \rightarrow CH_3CH_2CH_2CHICH_2^+ + I^-$ $CH_3CH_2CH_2CHICH_2^+ + I^- \rightarrow CH_3CH_2CH_2CHICH_2I$	**2**	AO2.5 × 2	**ALLOW** mechanism for electrophilic addition shown. **IGNORE** state symbols Must be based on slow step, i.e. 2nd mark dependent on correct slow step: $CH_3CH_2CH_2CH=CH_2 + I_2$ **IGNORE** actual positioning of + charge **ALLOW** $\rightarrow CH_3CH_2CH_2CHICH_2 + I$ (no charge) $CH_3CH_2CH_2CHICH_2 + I \rightarrow$
		(ii)	Repeat experiment with $[I_2]$ constant/kept the same **OR** use (large) excess of I_2 ✓ Monitor/measure/plot $[CH_3CH_2CH_2CH=CH_2]$ over time **OR** Monitor/measure how $[CH_3CH_2CH_2CH=CH_2]$ affects rate ✓	**2**	AO3.4 ×2	**ALLOW** I_2 in (great) excess **ALLOW** initial rates approach of running several experiments with different concentrations of $CH_3CH_2CH_2CH=CH_2$ i.e. Measure initial rates for each experiment **AND** double concentration → rate doubles

Question			Answer	Marks	AO element	Guidance
5	(a)	(i)	**Reduction**: $Na^+ + e^- \rightarrow Na$ ✓ **Oxidation**: $2N_3^- \rightarrow 3N_2 + 2e^-$ ✓ **ALLOW** 1 mark for 2 correct equations but wrong way round	**2**	AO1.2	**ALLOW multiples** **e.g.** $2Na^+ + 2e^- \rightarrow 2Na$ **IGNORE** state symbols
		(ii)	**FIRST CHECK ANSWER ON ANSWER LINE** **IF** mass = 34.5 (g) **AND** working using ideal gas equation Award **5 marks** for calculation --- ***Rearranging ideal gas equation*** $n = \frac{pV}{RT}$ ✓ ***Unit conversion AND substitution into*** $n = \frac{pV}{RT}$ **:** • *R = 8.314* ***OR*** *8.31* • *V* = 16(.0) × 10^{-3} • *T in K: 290 K* *e.g.* $\frac{1.20 \times 10^5 \times 16.0 \times 10^{-3}}{8.314 \times 290}$ ✓ ***Calculation of n*** *n* = 0.796 (mol) ✓ ***Calculation of mass*** $n(NaN_3) = \frac{2}{3} \times 0.796 = 0.531$ (mol) ✓ mass NaN_3 = 0.531 × 65 = 34.5 (g) ✓ **3 SF required**	**5**	AO2.4 ×5	**TAKE CARE** as value written down may be truncated value stored in calculator. **IF** $n = \frac{pV}{RT}$ is omitted, **ALLOW** when values are substituted into rearranged ideal gas equation. Calculator: 0.7963302448 From unrounded 0.7963302448, $n(NaN_3)$ = 0.5308868299 mass = 0.5308868299 × 65 = 34.50764394 → 34.5 to 3 SF **COMMON ERROR** **51.7 OR 51.8** → 4 marks (2/3 omitted *depending on intermediate rounding* 0.796 × 65 = 51.7 **OR** 51.8 **54.4** → 4 marks (*inverted gas equation)* $n = \frac{RT}{pV}$ →1.255760417→ 0.8371736111 → 54.4 (g) CARE with intermediate rounding **81.6 OR 81.7** → 3 mks *(as above but no 2/3)*

Question			Answer	Marks	AO element	Guidance
	(b)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.75 award 2 marks** --- $[H^+]^2 = K_a \times [HN_3]) = 2.51 \times 10^{-5} \times 0.125$ $[H^+] = \sqrt{(K_a \times [HN_3])}$ $[H^+]^2 = 2.51 \times 10^{-5} \times 0.125$ **OR** $[H^+] = \sqrt{(2.51 \times 10^{-5} \times 0.125)}$ **OR** $[H^+] = 1.77\ldots. \times 10^{-3}$ (mol dm^{-3}) ✓ pH = –log $1.77\ldots. \times 10^{-3}$ = 2.75 (Must be to **2DP**) ✓	**2**	AO2.2 ×2	**ALLOW ECF** throughout **IGNORE** error with HN_3 shown as NH_3 **ALLOW** pH mark by **ECF** **ONLY** if $2.51 \times 10^{-5} \times 0.125$ used **AND** pH <7 --- **Common errors (Must be to 2 DP)** pH = 5.50 → 1 mark (*No square root)* $[H^+] = 6.26 \times 10^{-4}$ from $\sqrt{(2.51 \times 10^{-5})} \times 0.125$ pH = 3.20 → 1 mark $[H^+] = 8.87 \times 10^{-6}$ from $\sqrt{(0.125)} \times 2.51 \times 10^{-5}$ pH = 5.05 → 1 mark
		(ii)	• Correct equation ✓ • Correct acid–base pair labels for correct equation ✓ $HN_3 + H_2O \rightleftharpoons N_3^- + H_3O^+$ ✓ **A1 B2 B1 A2** ✓ **OR** **A2 B1 B2 A1**	**2**	AO1.2 ×2	**ALLOW** 1 mark for one correct acid–base pair **WITH** correct labels e.g. H_2O H_3O^+ **WITH** B1 A1 **OR** B2 A2

Question			Answer	Marks	AO element	Guidance
		(iii)	Structure of 2-methylbutanoic acid ✓ Structure of organic product (primary amine) ✓ CO_2 **AND** N_2 as products ✓  	**3**	AO3.2 ×2 AO2.6	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous **Common error** With NH_3, $\rightarrow CO_2 + H_2$ **ALLOW ECF** for equation using a different amine isomer of the organic product *e.g.* $(CH_3)_2CHCH_2NH_2$ **DO NOT ALLOW ECF** from unbranched species, e.g. $CH_3CH_2CH_2NH_2$ **IGNORE** HN_3 in equation, even if missing **IGNORE** poor connectivity to all groups

Question	Answer	Marks	AO element	Guidance
(c)*	*Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Reaches a comprehensive conclusion to determine the correct formulae of **almost all** of **E**, **F**, **G**, **H**, **I** and **J** *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)** Reaches a sound conclusion to determine the correct formulae of **at least half** of **E**, **F**, **G**, **H**, **I** and **J** *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)** Reaches a simple conclusion to determine the correct formulae of **some** of **E**, **F**, **G**, **H**, **I** and **J** *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.*	**6**	AO3.1 ×2 AO3.2 ×4	**Indicative scientific points may include:** **Identify of E, F, G, H, I and J** • **E** Cu/copper • **F**: H_2O/water • **G**: N_2/nitrogen • **H**: CH_3COCl **OR** $ClCH_2CHO$ **OR** C_2H_3OCl • **I**: CH_3CONH_2 **OR** H_2NCH_2CHO • **J**: NH_4Cl/ammonium chloride ***Examples of reasoning*** **Working** $n(CuO) = \frac{4.77}{(63.5 + 16)} = 0.06$ (mol) M(**E**) = 3.81 ÷ 0.06 = 63.5 n(**G**) $= \frac{480}{24000} = 0.02$ M(**G**) $= \frac{0.560}{0.02} = 28$ (g mol^{-1}) **Infrared spectrum** **I** contains • C=O (~1700 cm^{-1}) • NH_2 (~3200–3400 cm^{-1}) **Equations** $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$ $CH_3COCl + 2NH_3 \rightarrow CH_3CONH_2 + NH_4Cl$ **OR** $ClCH_2CHO + 2NH_3 \rightarrow H_2NCH_2CHO + NH_4Cl$

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