



GCE

Chemistry A

H032/02: Depth in chemistry

Advanced Subsidiary 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.















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Mark Scheme

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1. Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

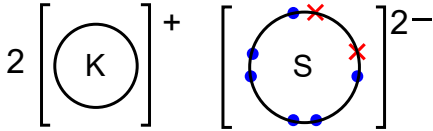
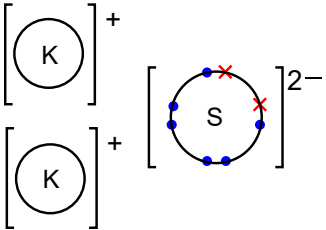
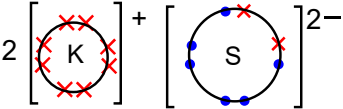
2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
✓	Separates marking points
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

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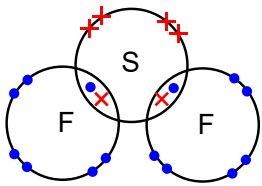
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Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	(Electrostatic) attraction between oppositely charged ions ✓	1	AO1.1	IGNORE force IGNORE references to transfer of electrons
		(ii)	<div></div> <p>Dot and cross 2 × K shown with either 8 or 0 electrons AND S shown with 8 electrons with 2 crosses and 6 dots (or vice versa) ✓</p> <p>Charges Correct charges on K⁺ AND S²⁻ ions ✓</p>	2	AO2.5 × 2	ALLOW separate K ⁺ ions, i.e. <div></div> <p>If 8 electrons are shown around K, 'extra electrons' around S must match symbol chosen for electrons around K, e.g.</p> <div></div> <p>Shell circles NOT needed IGNORE inner shell electrons</p>

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Question			Answer	Marks	AO element	Guidance
	(b)		 <p>Bonded pairs Electron pairs in covalent bonds shown correctly using dots and crosses in SF₂ molecule ✓</p> <p>Lone pairs Lone pairs correct on S and 2 F atoms ✓</p>	2	AO2.5 × 2	Shell circles NOT needed IGNORE inner shells ALLOW Non-bonding electrons shown as unpaired
	(c)		<p>K₂S: ionic bonds are strong OR has a giant ionic lattice ✓</p> <p>SF₂: London forces/ dipole-dipole forces are weak ✓ between molecules ✓</p>	3	AO1.1 × 2 AO1.2	ALLOW induced OR permanent dipole interactions ALLOW intermolecular forces are weak for 2 marks for SF ₂ IGNORE van der Waals forces, vdW
	(d)	(i)	Octahedral ✓ 90 ° ✓	2	AO1.1 × 2	
		(ii)	SF ₆ has no overall dipole OR is non polar OR S–F bonds are strong OR SF ₆ has no lone pairs ✓	1	AO2.1	
			Total	11		

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Question			Answer	Marks	AO element	Guidance
2	(a)		A species with an unpaired electron ✓	1	AO1.1	DO NOT ALLOW: species with one electron
	(b)		Homolytic (fission) ✓	1	AO1.1	
	(c)		<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}-\text{Br} \\ \\ \text{CH}_3 \end{array}$ ✓ </div> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_2\text{Br} \\ \\ \text{H}_3\text{C}-\text{C}-\text{H} \\ \\ \text{CH}_3 \end{array}$ ✓ </div> </div>	2	AO2.5 × 2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous
	(d)		<div style="text-align: center;"> </div> <p>Structure of organic product ✓</p> <p>Complete balanced equation ✓</p>	2	AO2.5 AO2.6	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous, e.g. <div style="text-align: center;"> $\begin{array}{c} \text{CH}_2\text{Br} \\ \\ \text{H}_3\text{C}-\text{C}-\text{H} \\ \\ \text{CH}_2\text{Br} \end{array}$ </div>
			Total	6		

[illegible]

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	(d)		The titre would be less ✓ Glutaric acid would be less concentrated/more dilute ✓	2	AO3.3 × 2	
			Total	12		

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Question		Answer	Marks	AO element	Guidance
4	(a) *	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) Calculates CORRECT enthalpy change with correct signs for ΔH_2 for reaction 2 AND ΔH_1 for reaction 1.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Calculates a value of ΔH_2 for reaction 2 from the: Energy change AND Amount in mol of MgCO_3.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Processes experimental data to obtain the Energy change from $mc\Delta T$ OR Amount in moles of MgCO_3 <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks <i>No response or no response worthy of credit.</i></p>	6	AO3.1 $\times 4$ AO3.2 $\times 2$	<p>Indicative scientific points may include:</p> <p>1. Processing experimental data Energy change from $mc\Delta T$</p> <ul style="list-style-type: none"> Energy in J OR kJ Using 103.01 g or 100.0 g = 103.01 $\times 4.18 \times 5.0$ = 2152.909 (J) OR 2.153 (kJ) 3SF or more (2.152909 unrounded) OR 100.0 $\times 4.18 \times 5.0$ = 2090 (J) OR 2.09 (kJ) <hr/> <p>Amount in mol of MgCO_3 $n(\text{MgCO}_3) = \frac{4.215}{84.3} = 0.0500 \text{ (mol)}$</p> <hr/> <p>2. \pm value of ΔH_2 for reaction 2 From $m = 103.01 \text{ g}$ = $\pm \frac{2.153}{0.0500} = \pm 43.06 \text{ (kJ mol}^{-1}\text{)}$ (–43.05818 unrounded) From $m = 100.0 \text{ g}$ = $\pm \frac{2.19}{0.0500} = \pm 43.8 \text{ (kJ mol}^{-1}\text{)}$</p> <hr/> <p>3. CORRECT enthalpy changes for Reaction 1 and Reaction 2 with signs (using 103.01 g ONLY) Reaction 2 = –43.06 (kJ mol^{–1}) 3SF or more with correct – sign Reaction 1 $\Delta H_1 = \Delta H_2 - \Delta H_3$ = $-43.06 - (-136.1) = \mathbf{+93.04}$ (kJ mol^{–1}) 3SF or more with correct – sign ALLOW omission of trailing zeroes, e.g. 93 for 93.0 NOTE: If 100 g used, ΔH is incorrect and L3 cannot be attained</p>
		Total	6		

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Question			Answer	Marks	AO element	Guidance
5	(a)		$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}] \times [\text{H}_2]^2} \checkmark$	1	AO1.2	Multiplication sign is not required DO NOT ALLOW curved brackets
	(b)	(i)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 1.4..... (mol dm⁻³) award 2 marks</p> <hr style="border-top: 1px dashed blue;"/> <p>$[\text{CH}_3\text{OH}] = 15.4 \times 0.57 \times 0.40^2 \checkmark$ $= 1.40448 \text{ (mol dm}^{-3}\text{)} \checkmark$</p>	2	AO2.2 × 2	<p>ALLOW ECF from incorrect expression in (a)</p> <p>ALLOW 1.4 up to calculator value of 1.40448</p>
		(ii)	To the right \checkmark	1	AO1.1	ALLOW towards the product/CH ₃ OH
	(c)		<p>Less fossil fuel used \checkmark</p> <p>Reduction in CO₂ (emissions) \checkmark</p>	2	AO3.2 × 2	ALLOW Less energy used
	(d)	(i)	d-block \checkmark	1	AO1.1	
		(ii)	<p>$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^1 \checkmark$</p> <p><i>Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake</i></p>	1	AO1.2	<p>ALLOW 4s AND/OR 4p¹ before 3d, e.g. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$</p> <p>ALLOW 1s² after answer prompt (<i>ie</i> 1s² twice) ALLOW upper case D, etc and subscripts, e.g.4S₂3D₈</p> <p>DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$</p>

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Question			Answer	Marks	AO element	Guidance
	(e)		Element A is silicon/Si ✓ AND A large increase between the 4 rd and 5 th IE 5 th electron is removed from shell closer to the nucleus OR there are 4 electrons in the outer shell ✓	2	AO3.1 AO3.2	ALLOW an indication of a different shell (from removal of 5 th electron)
			Total	10		

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Question			Answer	Marks	AO element	Guidance
6	(a)		Best fit curve ✓ Tangent drawn at approximately $t = 50$ s ✓ Gradient calculated: 0.44 ± 0.2 (cm ³ s ⁻¹) ✓	3	AO1.2 AO2.4 × 2	DO NOT ALLOW interpolation (taking a direct reading from graph), answer must be derived from taking a gradient ALLOW ECF from incorrectly drawn tangent
	(b)		Advantage: no loss of gas ✓ Disadvantage: small loss in mass ✓	2	AO3.4 × 2	IGNORE easier to set up
	(c)	(i)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 0.41 (g) award 2 marks ----- $n(\text{Ba}) = \frac{0.26}{87.6}$ OR $2.9\ldots \times 10^{-3}$ OR 3×10^{-3} ✓ mass Ba = $137.3 \times 2.9\ldots \times 10^{-3}$ = 0.41 g ✓ 2 DP required	2	AO3.3 × 2	ALLOW ECF from incorrect moles of Ba Calculator: $2.96803653 \times 10^{-3}$ NOTE 3×10^{-3} also gives 0.41 g
		(ii)	Steeper initial gradient AND levels off earlier ✓ Same volume of gas produced ✓	2	AO3.1 × 2	

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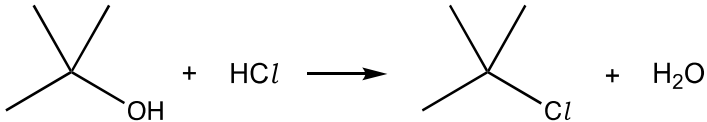
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Question			Answer	Marks	AO element	Guidance
		(iii)	Reactivity Ba is more reactive (than Sr) ✓ Atomic radius Ba has a greater atomic radius (than Sr) OR Ba has more shells OR Ba has more shielding ✓ Attraction Nuclear attraction is less in Ba OR (outer) electrons in Ba are less attracted (to nucleus) OR Increased distance / shielding in Ba outweighs increased nuclear charge ✓ Ionisation energy Ionisation energy of Ba is less OR easier to remove (outer) electrons in Ba ✓	4	AO1.1 × 4	Comparison required throughout ORA throughout For more shells, ALLOW higher energy level IGNORE more orbitals OR more sub-shells IGNORE 'different shell' or 'new shell' ALLOW Ba has less nuclear pull' OR 'Ba electrons are less tightly held' IGNORE less effective nuclear charge' IGNORE 'nuclear charge' for 'nuclear attraction' ALLOW easier to oxidise Ba
			Total	13		

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Question			Answer	Marks	AO element	Guidance
7	(a)		 <p>Correct skeletal formulae for organic compounds ✓</p> <p>Complete balanced equation ✓</p>	2	AO2.5 × 2	<p>Skeletal formulae needed for 1st marking point.</p> <p>For complete balanced equation, ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous, e.g. $(\text{CH}_3)_3\text{COH} + \text{HCl} \rightarrow (\text{CH}_3)_3\text{CCl} + \text{H}_2\text{O}$</p>

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Question		Answer	Marks	AO element	Guidance
	(b) *	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Explains the purification steps with most fine detail. AND Calculates correct mass of 2-chloro-2-methylpropane, (CH₃)₃CCl</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Describes some purification steps, with some detail. AND Calculates the mass of (CH₃)₃CCl with some errors.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Describes few purification steps. OR Attempts to calculate the mass of (CH₃)₃CCl with little progress.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks <i>No response or no response worthy of credit.</i></p>	6	AO1.2 × 2 AO2.7 × 2 AO3.3 × 2	<p>Indicative scientific points may include: <u>Main purification stages</u></p> <ul style="list-style-type: none"> Separating funnel to remove organic layer from aqueous layer Anhydrous salt to dry organic layer Distillation to purify the product <p><u>Fine detail</u></p> <ul style="list-style-type: none"> Organic layer is the top layer Name of a drying agent e.g. anhydrous MgSO₄ or CaCl₂ Collect fraction at 50 °C <p>IGNORE washing with carbonate/water <i>not in spec.</i></p> <p><u>Calculation of mass of (CH₃)₃CCl</u></p> <ul style="list-style-type: none"> $n((\text{CH}_3)_3\text{COH}) = \frac{7.70}{74.0} = 0.10405 \text{ (mol)}$ <i>expected</i> $n((\text{CH}_3)_3\text{CCl})$ $= 0.10405 \times \frac{76}{100} = 0.0791 \text{ (mol)}$ <i>expected mass</i> = $0.0791 \times 92.5 = 7.315 \text{ g}$ <p>ALLOW 7.31–7.32 for small slip/rounding</p> <p><u>Using mass</u></p> <ul style="list-style-type: none"> Theoretical mass (CH₃)₃CCl $= 7.70 \times \frac{92.5}{74.0} = 9.625 \text{ g}$ Mass of (CH₃)₃CCl = $9.625 \times \frac{76}{100} = \mathbf{7.315 \text{ g}}$

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Question			Answer	Marks	AO element	Guidance
						NOTE: Incorrect inverse ratio of $\frac{100}{76}$ gives: <ul style="list-style-type: none"> $0.10405 \times \frac{76}{100} = 0.137$ (mol) Mass = $92.5 \times 0.137 = 12.7$ g
	(c)	(i)	Butan-2-ol ✓	1	AO1.2	
		(ii)	$(\text{CH}_3)_2\text{CHCH}_2\text{OH} + 2[\text{O}] \rightarrow (\text{CH}_3)_2\text{CHCOOH} + \text{H}_2\text{O}$ B as reactant: $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$ ✓ $(\text{CH}_3)_2\text{CHCOOH}$ as product ✓ Correct equation with $2[\text{O}]$ and H_2O ✓	3	AO2.5 × 2 AO2.6	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous If structure of B is a different primary or secondary alcohol, ALLOW ECF for product and equation
			Total	12		

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