

GCE

Chemistry A

H032/02: Depth in chemistry

Advanced Subsidiary GCE

Mark Scheme for November 2020

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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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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

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

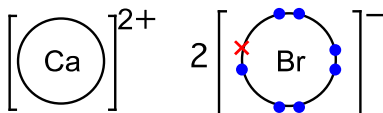
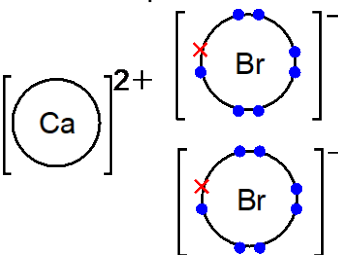
Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	Oxidised AND nickel has lost/donated two electrons ✓	1	2.1	IGNORE reference to oxidation numbers (even if incorrect)
	(b)	(i)	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 43.6 (cm³) award 3 marks $n(\text{Ni}) = \frac{0.192}{58.7} = 3.27... \times 10^{-3} \text{ (mol) } \checkmark$ $n(\text{HCl}) = 3.27 \times 10^{-3} \times 2 = 6.54... \times 10^{-3} \text{ (mol) } \checkmark$ $\text{Volume HCl} = \frac{6.54 \times 10^{-3}}{0.15} \times 1000 = 43.6 \text{ (cm}^3\text{) } \checkmark$ 3 SF required	3	1.1×1 2.4 ×2	ALLOW 3.27×10^{-3} up to calculator value of $3.270868825 \times 10^{-3}$ ALLOW 6.54×10^{-3} up to calculator value of $6.541737649 \times 10^{-3}$
		(ii)	Volume H ₂ = $3.27 \times 10^{-3} \times 24000 = 78.5 \text{ (cm}^3\text{) } \checkmark$	1	2.4 ×1	ALLOW ECF from incorrect n(Ni) from (b)(i) ALLOW 78.48 (cm ³)
		(iii)	Volume is the same ✓ Mg is in excess OR Volume of H ₂ depends on HCl/HCl is limiting reagent ✓	2	3.4 ×2	

Question	Answer	Marks	AO element	Guidance
(c)*	<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) The candidate gives a clear description of all three tests with correct observations. AND Equations are mostly correct. AND Some fine detail included in answer.</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) The candidate describes all three tests with correct observations.</p> <p>OR Describes two tests with a few omissions. AND Includes at least one correct equation.</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) The candidate attempts to describe two tests and observations, but explanations are incomplete. OR Gives a thorough description and explanation of one of the tests and attempts one equation.</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	1.2 ×2 2.7 ×2 3.4 ×2	<p>Indicative scientific points Tests for anions <i>Carbonate test:</i> Add HNO₃(aq)/HCl(aq)/H₂SO₄(aq)/H⁺(aq) fizzing/ forms CO₂(g) → Carbonate identified <i>Sulfate test:</i> Add Ba(NO₃)₂(aq) OR BaCl₂(aq) White precipitate → Sulfate identified <i>Bromide test</i> Add AgNO₃(aq) Cream precipitate → Bromide identified</p> <p>Equations (ionic or full) IGNORE state symbols (even if wrong)</p> <p><i>Carbonate</i> 2H⁺ + CO₃²⁻ → CO₂ + H₂O OR 2H⁺ + NiCO₃ → Ni²⁺ + CO₂ + H₂O OR 2HNO₃ + NiCO₃ → Ni(NO₃)₂ + H₂O + CO₂ OR 2HCl + NiCO₃ → NiCl₂ + H₂O + CO₂ OR H₂SO₄ + NiCO₃ → NiSO₄ + H₂O + CO₂</p> <p><i>Sulfate</i> Ba²⁺ + SO₄²⁻ → BaSO₄ OR Ba(NO₃)₂ + NiSO₄ → BaSO₄ + Ni(NO₃)₂ OR BaCl₂ + NiSO₄ → BaSO₄ + NiCl₂</p> <p><i>Bromide</i> Ag⁺ + Br⁻ → AgBr OR 2AgNO₃ + NiBr₂ → 2AgBr + Ni(NO₃)₂</p> <p>Fine Detail (NOT inclusive) <i>Sequence of tests on samples</i> Carbonate → Sulfate → Bromide <i>Solubility of AgBr</i> Soluble in concentrated ammonia <i>State symbols in ionic or full equations</i> e.g.</p> <ul style="list-style-type: none"> • 2H⁺(aq) + CO₃²⁻(aq) → CO₂(g) + H₂O(l) • OR 2H⁺(aq) + NiCO₃(s) → Ni²⁺(aq) + CO₂(g) + H₂O(l) • Ba²⁺(aq) + SO₄²⁻(aq) → BaSO₄(s) • Ag⁺(aq) + Br⁻(aq) → AgBr(s)

Question		Answer	Marks	AO element	Guidance
2	(a)	(The enthalpy change) for complete combustion ✓ of 1 mol (of substance) ✓	2	1.1 × 2	ALLOW energy change for combustion in excess oxygen OR reacts in excess oxygen OR reacts completely in oxygen OR energy released during complete combustion OR energy change for combustion in excess air IGNORE energy required ALLOW element OR compound OR reactant DO NOT ALLOW atoms
	(b)	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = – 2680 (kJ mol⁻¹) award 4 marks If answer = (+) 2680 (kJ mol⁻¹) award 3 marks Energy released in J OR kJ = 200 × 4.18 × 20.0 = 16720 (J) OR 16.72 (kJ) ✓ $n(\text{C}_6\text{H}_{12}) = \frac{0.525}{84} = 0.00625 \text{ (mol)} \checkmark$ Energy per mole = $\frac{16.72}{0.00625}$ OR (-)2675.2 (kJ mol ⁻¹) ✓ $\Delta_c H = -2680 \text{ (kJ mol}^{-1}\text{)}$ Value to 3SF AND ‘-’ sign ✓	4	3.1 × 2 3.2 × 1 1.2 × 1	ALLOW 16700 J or 16.7 kJ up to calculator value of 16720 J (Must be at least 3 SF) ALLOW ECF from incorrect $M(\text{C}_6\text{H}_{12})$ or energy change IF energy released above rounded to 16700, Energy per mole = (-)2672 by ECF 3 marks $\Delta_c H = -2670$ to 3SF 4 marks COMMON ERROR -7.02 (kJ mol ⁻¹) award 3 marks
	(c)	(i) % uncertainty in temp. rise = $\frac{1}{20} \times 100 = 5\% \checkmark$ % uncertainty in volume = $\frac{2}{200} \times 100 = 1\%$ AND temp rise has greater % uncertainty ✓	2	2.8 × 2	Award 1 mark if uncertainties are given as 0.05 AND 0.01 with correct statement

Question		Answer	Marks	AO element	Guidance
	(ii)	<p>Any two from: Heat released to the surroundings ✓</p> <p>Incomplete combustion OR incomplete reaction OR not everything burns ✓</p> <p>Non-standard conditions ✓</p>	2	3.2 ×2	<p>ALLOW heat loss</p> <p>IGNORE reference to evaporation</p>
	(iii)	<p>Less accurate due to greater heat losses ✓</p> <p>More accurate due to smaller % uncertainty in temperature change OR mass of fuel burnt ✓</p>	2	3.4 ×2	<p>ALLOW less accurate due to evaporation of water</p> <p>ALLOW error for uncertainty</p> <p>ALLOW for both marks May not change as increase in temperature change OR increase in mass of fuel burned would decrease % uncertainty BUT may be outweighed by increased heat loss to surroundings</p> <p>OWTTE</p>

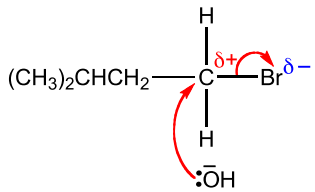
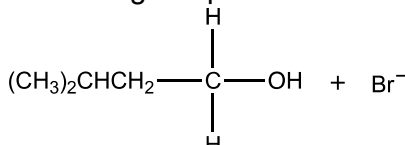
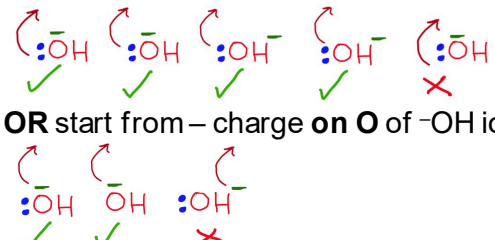
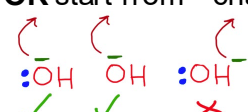
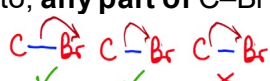
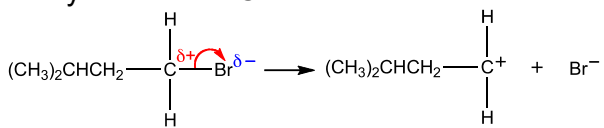
Question		Answer	Marks	AO element	Guidance
3	(a)	<p>Ca: metallic bonding OR giant metallic lattice ✓</p> <p>Br₂: simple molecular OR simple covalent ✓</p> <p>Induced dipole(–dipole) forces/interactions OR London forces ✓</p> <p>Conductivity linked to mobile electrons In Ca electrons are mobile OR electrons are delocalised OR electrons can move AND in Br₂ charge carriers/electrons are not mobile ✓</p> <p>Melting point linked to bond strengths Metallic bonds are strong AND London forces are weak OR Metallic bonds need a large amount of energy to break AND London forces need little energy to break ✓</p>	5	<p>1.1 × 2</p> <p>2.1 × 1</p> <p>3.2 × 2</p>	<p>ALLOW Metallic structure DO NOT ALLOW reference to molecules or intermolecular forces for calcium</p> <p>ALLOW ‘are molecules’</p> <p>IGNORE</p> <ul style="list-style-type: none"> • permanent dipole(–dipole) forces • IDID and LDF • van der Waals <p>DO NOT ALLOW ‘free electrons’ for mobile electrons</p> <p>ALLOW comparison, e.g.</p> <ul style="list-style-type: none"> • Metallic bonds are stronger than London forces <p>OR</p> <ul style="list-style-type: none"> • Metallic bonds need more energy to break than London forces ✓ <p>ALLOW intermolecular forces instead of London forces for this mark</p>

Question		Answer	Marks	AO element	Guidance
(b)	(i)	 <p>Ca shown with either 8 or 0 electrons AND Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓ Correct charges on both ions ✓</p>	2		<p>ALLOW separate Br⁻ ions, i.e.</p>  <p>1.2 × 1 2.5 × 1</p> <p>For first mark, if eight electrons are shown around Ca, the 'extra' electrons around Br must match the symbol chosen for the electrons for Na. IGNORE inner shells Circles or brackets not required</p>
	(ii)	<p>Atomic radius Ba has a greater atomic radius than Ca OR Ba has more shells OR Ba has more shielding ✓</p> <p>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 ✓</p> <p>Ionisation energy Ionisation energy of Ba is less OR easier to remove (outer) electrons in Ba ✓</p>	3		<p>Comparison required throughout ORA throughout</p> <p>1.1 × 1</p> <p>For more shells, ALLOW higher energy level IGNORE more orbitals OR more sub-shells IGNORE 'different shell' or 'new shell'</p> <p>ALLOW Ba has less nuclear pull' OR 'Ba electrons are less tightly held'</p> <p>2.3 × 2</p> <p>IGNORE less effective nuclear charge' IGNORE 'nuclear charge' for 'nuclear attraction'</p> <p>ALLOW easier to oxidise Ba</p>

Question		Answer	Marks	AO element	Guidance	
	(c)	(i)	$\text{Al}_2\text{Se}_3 + 6\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + 3\text{H}_2\text{Se}$	1	2.6 × 1	
		(ii)	<p>H_2O has hydrogen/H-bonds (between molecules) ✓</p> <p>H_2Se has induced dipole(-dipole) interactions OR London forces ✓</p> <p>H-bonds are stronger (than other intermolecular forces) OR more energy needed to overcome H-bonds ✓</p>	3	1.1 × 2 2.1 × 1	ALLOW permanent dipole-dipole interactions
	(d)	(i)	Sodium bromate(V) ✓	1	2.5 × 1	
		(ii)	<p>Br is oxidised AND reduced OR Br oxidation number is increased and decreased ✓</p> <p>Br is oxidised from 0 to +5 ✓</p> <p>Br is reduced from 0 to -1 ✓</p>	3	1.1 × 1 2.2 × 2	<p>ALLOW same element is both oxidised and reduced</p> <p>ALLOW 1 mark if all 3 oxidation numbers are correct (even if oxidation/reduction incorrectly assigned)</p>

Question		Answer	Marks	AO element	Guidance
4	(a)	Bond angle 112–120° ✓ Explanation Around N, there is a double bond, a single bond and a lone pair ✓ Electron pairs repel ✓ <i>Seen anywhere</i>	3	1.1 × 1 2.1 × 2	ALLOW 3 bonding pairs and 1 lone pair OR 2 bonding region and 1 lone pair ALLOW bonding pairs or lone pairs
	(b)	(i)	1	1.2 × 1	DO NOT ALLOW curved brackets
		(ii)	1	3.1 × 1	Response MUST refer to stoichiometry of equation and compare molar ratio of both NO and Cl ₂
		(iii)	2	2.6 × 2	ALLOW 1.1 up to calculator value of 1.144552314 ALLOW ECF from inverted K_c expression in b(ii) 2.9(478) × 10 ⁻⁴ 1 mark 0.017(1691584) 2 marks
		(iv)	2	2.5 × 2	ALLOW 'favours the right', for 'shifts to right' ALLOW moves to right in endothermic direction

Question		Answer	Marks	AO element	Guidance
5	(a)	C, E AND F ✓✓ Three correct alcohols → 2 marks Two correct alcohols → 1 mark	2	1.1 × 1 2.1 × 1	If >2 alcohols are shown lose 1 mark for each incorrect response
	(b)	$(\text{CH}_3\text{CH}_2\text{CHOHCH}_3 +) 6\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O} \checkmark$	1	2.6 × 1	DO NOT ALLOW [O]
	(c)	2-methylbutan-2-ol ✓	1	1.2 × 1	
	(d) (i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF atom economy = 46.1(%) award 2 marks ----- Atom economy $= \frac{M_r \text{ of } (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}}{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH} + M_r \text{ NaBr}} \times 100$ OR $= \frac{88}{190.9} \times 100 \checkmark$ $= 46.1(\%) \checkmark$	2	1.2 × 1 2.2 × 1	ALLOW $\frac{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}}{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{Br} + M_r \text{ NaOH}} \times 100$ ALLOW 46% up to calculator value (46.09743321) ALLOW ECF from incorrect M_r values

Question	Answer	Marks	AO element	Guidance
(ii)	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <hr/> <p>Curly arrows 2 marks curly arrow from OH⁻ to C atom of C-Br bond ✓</p> <p>dipole shown on C-Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C-Br bond to Br atom ✓</p>  <p>IGNORE incorrect R groups for curly arrow marks</p> <p>IGNORE presence of Na⁺ but OH⁻ needed i.e. Na⁺OH⁻ can be allowed if criteria met</p> <hr/> <p>Products 1 mark correct organic product AND Br⁻ ✓</p>  <p>IGNORE presence of Na⁺ but Br⁻ needed i.e. Na⁺Br⁻ can be allowed BUT NaBr does NOT show Br⁻</p> <p>NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows</p>	3	<p>2.5 × 1</p> <p>1.1 × 1</p> <p>2.5 × 1</p>	<p>1st curly arrow must</p> <ul style="list-style-type: none"> go to the C of C-Br <p>AND</p> <ul style="list-style-type: none"> start from, OR be traced back to any point across width of lone pair on O of OH⁻  <ul style="list-style-type: none"> OR start from - charge on O of -OH ion  <p>(Lone pair NOT needed if curly arrow shown from O⁻)</p> <p>2nd curly arrow must start from, OR be traced back to, any part of C-Br bond and go to Br</p>  <hr/> <p>ALLOW S_N1 mechanism for 2 curly arrow marks</p> <p>First mark Dipole shown on C-Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C-Br bond to Br atom ✓</p>  <p>Second mark Curly arrow from OH⁻ AND to correct carbocation</p>

Question			Answer	Marks	AO element	Guidance
						<p>Use curly arrow criteria in guidance above</p>
	(iii)		Nucleophilic substitution ✓	1	1.1 × 1	
	(e)		Rate slower with chloroalkane ORA ✓ C–Cl bond is stronger than C–Br bond OR C–Cl bond has greater bond enthalpy OR more energy needed to break C–Cl bond ✓	2	3.1 × 1 2.5 × 1	IGNORE reference to bond polarity

Question	Answer	Marks	AO element	Guidance
(f)	<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) The candidate gives thorough explanations of both spectra, and correctly identifies X and Y with a correct equation.</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) The candidate attempts all three scientific points but explanations are incomplete.</p> <p>OR Explains two scientific points thoroughly with few omissions.</p> <p>AND Attempts a feasible structure based on deduction from correct M_r. <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) The candidate gives a simple description based on at least two of the main scientific points.</p> <p>OR Gives a thorough description and explanation of one of the scientific points.</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	2.5 ×1 3.1 ×2 3.2 ×3	<p>Indicative scientific points</p> <p>LOOK AT THE SPECTRA for labelled peaks</p> <p>Mass Spectrum</p> <ul style="list-style-type: none"> • M^+ or molecular ion of 86 • $m/z = 43$ shows CH_3CO^+ OR C_3H_7^+ <p>IR Spectrum</p> <ul style="list-style-type: none"> • IR shows no broad absorption at $2500\text{--}3300\text{ cm}^{-1}$ so no O–H bond AND not a carboxylic acid • IR shows absorption at 1700 cm^{-1} for C=O bond OR indicates a ketone/aldehyde present <p>Identification and Equation</p> <ul style="list-style-type: none"> • X must be a secondary alcohol, since refluxing a secondary alcohol with acidified potassium dichromate (VI) forms a ketone OR primary alcohol → carboxylic acid AND tertiary alcohol would not be oxidised. • X is $(\text{CH}_3)_2\text{CHCHOHCH}_3$ OR compound E OR 3-methylbutan-2-ol • Y is $(\text{CH}_3)_2\text{CHCOCH}_3$ OR 3-methylbutan-2-one <p><i>Equation</i> $(\text{CH}_3)_2\text{CHCHOHCH}_3 + [\text{O}] \rightarrow (\text{CH}_3)_2\text{CHCOCH}_3 + \text{H}_2\text{O}$</p>

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