



**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
	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



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

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



Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	Oxidised <b>AND</b> nickel has lost/donated <b>two</b> electrons ✓	1	2.1	<b>IGNORE</b> reference to oxidation numbers (even if incorrect)
	(b)	(i)	<b>FIRST CHECK ANSWER ON THE ANSWER LINE</b> <b>If answer = 43.6 (cm<sup>3</sup>) award 3 marks</b>  $n(\text{Ni}) = \frac{0.192}{58.7} = 3.27\dots \times 10^{-3} \text{ (mol) } \checkmark$ $n(\text{HCl}) = 3.27 \times 10^{-3} \times 2 = 6.54\dots \times 10^{-3} \text{ (mol) } \checkmark$ $\text{Volume HCl} = \frac{6.54 \times 10^{-3}}{0.15} \times 1000 = 43.6 \text{ (cm}^3\text{) } \checkmark$ <p style="text-align: center;"><b>3 SF required</b></p>	3	1.1×1 2.4 ×2	<b>ALLOW</b> $3.27 \times 10^{-3}$ up to calculator value of $3.270868825 \times 10^{-3}$  <b>ALLOW</b> $6.54 \times 10^{-3}$ up to calculator value of $6.541737649 \times 10^{-3}$
		(ii)	Volume H <sub>2</sub> = $3.27 \times 10^{-3} \times 24000 = 78.5 \text{ (cm}^3\text{) } \checkmark$	1	2.4 ×1	<b>ALLOW</b> ECF from incorrect n(Ni) from (b)(i) <b>ALLOW</b> 78.48 (cm <sup>3</sup> )
		(iii)	Volume is the <b>same</b> ✓  Mg is in excess <b>OR</b> Volume of H <sub>2</sub> 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><b>Level 3 (5–6 marks)</b> The candidate gives a clear description of all three tests with correct observations. <b>AND</b> Equations are mostly correct. <b>AND</b> 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><b>Level 2 (3–4 marks)</b> The candidate describes all three tests with correct observations.</p> <p><b>OR</b> Describes two tests with a few omissions. <b>AND</b> 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><b>Level 1 (1–2 marks)</b> The candidate attempts to describe two tests and observations, but explanations are incomplete. <b>OR</b> 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><b>0 marks</b> <i>No response or no response worthy of credit.</i></p>	6	1.2 x2 2.7 x2 3.4 x2	<p><b>Indicative scientific points</b></p> <p><b>Tests for anions</b></p> <p><i>Carbonate test:</i> Add HNO<sub>3</sub>(aq)/HCl(aq)/H<sub>2</sub>SO<sub>4</sub>(aq)/H<sup>+</sup>(aq) fizzing/ forms CO<sub>2</sub>(g) → Carbonate identified</p> <p><i>Sulfate test:</i> Add Ba(NO<sub>3</sub>)<sub>2</sub>(aq) <b>OR</b> BaCl<sub>2</sub>(aq) White precipitate → Sulfate identified</p> <p><i>Bromide test</i> Add AgNO<sub>3</sub> (aq) Cream precipitate → Bromide identified</p> <p><b>Equations (ionic or full)</b> <b>IGNORE</b> state symbols (even if wrong)</p> <p><i>Carbonate</i> 2H<sup>+</sup> + CO<sub>3</sub><sup>2-</sup> → CO<sub>2</sub> + H<sub>2</sub>O <b>OR</b> 2H<sup>+</sup> + NiCO<sub>3</sub> → Ni<sup>2+</sup> + CO<sub>2</sub> + H<sub>2</sub>O <b>OR</b> 2HNO<sub>3</sub> + NiCO<sub>3</sub> → Ni(NO<sub>3</sub>)<sub>2</sub> + H<sub>2</sub>O + CO<sub>2</sub> <b>OR</b> 2HCl + NiCO<sub>3</sub> → NiCl<sub>2</sub> + H<sub>2</sub>O + CO<sub>2</sub> <b>OR</b> H<sub>2</sub>SO<sub>4</sub> + NiCO<sub>3</sub> → NiSO<sub>4</sub> + H<sub>2</sub>O + CO<sub>2</sub></p> <p><i>Sulfate</i> Ba<sup>2+</sup> + SO<sub>4</sub><sup>2-</sup> → BaSO<sub>4</sub> <b>OR</b> Ba(NO<sub>3</sub>)<sub>2</sub> + NiSO<sub>4</sub> → BaSO<sub>4</sub> + Ni(NO<sub>3</sub>)<sub>2</sub> <b>OR</b> BaCl<sub>2</sub> + NiSO<sub>4</sub> → BaSO<sub>4</sub> + NiCl<sub>2</sub></p> <p><i>Bromide</i> Ag<sup>+</sup> + Br<sup>-</sup> → AgBr <b>OR</b> 2AgNO<sub>3</sub> + NiBr<sub>2</sub> → 2AgBr + Ni(NO<sub>3</sub>)<sub>2</sub></p> <p><b>Fine Detail (NOT inclusive)</b></p> <p><i>Sequence of tests on samples</i> Carbonate → Sulfate → Bromide</p> <p><i>Solubility of AgBr</i> Soluble in concentrated ammonia</p> <p><i>State symbols in ionic or full equations</i> e.g.</p> <ul style="list-style-type: none"> <li>• 2H<sup>+</sup>(aq) + CO<sub>3</sub><sup>2-</sup>(aq) → CO<sub>2</sub>(g) + H<sub>2</sub>O(l)</li> <li>• <b>OR</b> 2H<sup>+</sup>(aq) + NiCO<sub>3</sub>(s) → Ni<sup>2+</sup>(aq) + CO<sub>2</sub>(g) + H<sub>2</sub>O(l)</li> <li>• Ba<sup>2+</sup>(aq) + SO<sub>4</sub><sup>2-</sup>(aq) → BaSO<sub>4</sub>(s)</li> <li>• Ag<sup>+</sup>(aq) + Br<sup>-</sup>(aq) → AgBr(s)</li> </ul>



Question		Answer	Marks	AO element	Guidance
2	(a)	(The enthalpy change) for complete combustion ✓  of 1 mol (of substance) ✓	2	1.1 x2	<b>ALLOW</b> energy change for combustion in excess oxygen <b>OR</b> reacts in excess oxygen <b>OR</b> reacts completely in oxygen <b>OR</b> energy released during complete combustion <b>OR</b> energy change for combustion in excess air  <b>IGNORE</b> energy required  <b>ALLOW</b> element OR compound OR reactant <b>DO NOT ALLOW</b> atoms
	(b)	<b>FIRST CHECK ANSWER ON THE ANSWER LINE</b> <b>If answer = - 2680 (kJ mol<sup>-1</sup>) award 4 marks</b> <b>If answer = (+) 2680 (kJ mol<sup>-1</sup>) award 3 marks</b>  Energy released in J <b>OR</b> kJ = 200 × 4.18 × 20.0 = 16720 (J) <b>OR</b> 16.72 (kJ) ✓ $n(\text{C}_6\text{H}_{12}) = \frac{0.525}{84} = 0.00625 \text{ (mol)} \checkmark$  Energy per mole = $\frac{16.72}{0.00625}$ <b>OR</b> (-)2675.2 (kJ mol <sup>-1</sup> ) ✓  $\Delta_c H = - 2680 \text{ (kJ mol}^{-1}\text{)}$ Value to 3SF <b>AND</b> '-' sign ✓	4	3.1 x2  3.2 x1  1.2 x1	<b>ALLOW</b> 16700 J or 16.7 kJ up to calculator value of 16720 J (Must be at least 3 SF)  <b>ALLOW ECF</b> from incorrect $M(\text{C}_6\text{H}_{12})$ or energy change  <b>IF</b> energy released above rounded to 16700, Energy per mole = (-)2672 by ECF 3 marks $\Delta_c H = - 2670$ to 3SF 4 marks  <b>COMMON ERROR</b> -7.02 (kJ mol <sup>-1</sup> ) award 3 marks
	(c)	(i) % uncertainty in temp. rise = $\frac{1}{20} \times 100 = 5\% \checkmark$  % uncertainty in volume = $\frac{2}{200} \times 100 = 1\%$  <b>AND</b> temp rise has greater % uncertainty ✓	2	2.8 x2	<b>Award 1 mark if uncertainties are given as 0.05 AND 0.01 with correct statement</b>

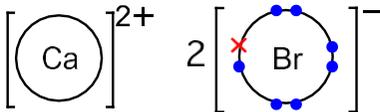
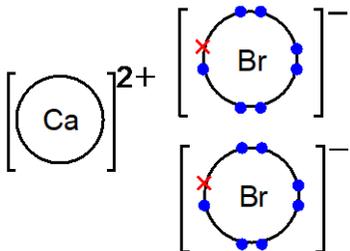


Question		Answer	Marks	AO element	Guidance
	(ii)	<p><b>Any two from:</b> Heat released to the surroundings ✓</p> <p>Incomplete combustion <b>OR</b> incomplete reaction <b>OR</b> not everything burns ✓</p> <p>Non-standard conditions ✓</p>	2	3.2 x2	<p><b>ALLOW</b> heat loss</p> <p><b>IGNORE</b> reference to evaporation</p>
	(iii)	<p><b>Less</b> accurate due to greater heat losses ✓</p> <p><b>More</b> accurate due to smaller % uncertainty in temperature change <b>OR</b> mass of fuel burnt ✓</p>	2	3.4 x2	<p><b>ALLOW</b> less accurate due to evaporation of water</p> <p><b>ALLOW</b> error for uncertainty</p> <p><b>ALLOW</b> for both marks <b>May not change</b> as increase in temperature change <b>OR</b> increase in mass of fuel burned would decrease % uncertainty <b>BUT</b> 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 <b>OR</b> giant metallic lattice ✓</p> <p>Br<sub>2</sub>: simple molecular <b>OR</b> simple covalent ✓</p> <p>Induced dipole(–dipole) forces/interactions <b>OR</b> London forces ✓</p> <p><b>Conductivity linked to mobile electrons</b>            In Ca electrons are mobile                <b>OR</b> electrons are delocalised                <b>OR</b> electrons can move  <b>AND</b> in Br<sub>2</sub> charge carriers/electrons are not mobile ✓</p> <p><b>Melting point linked to bond strengths</b>            Metallic bonds are strong  <b>AND</b> London forces are weak  <b>OR</b>            Metallic bonds need a large amount of energy to break  <b>AND</b> 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><b>ALLOW</b> Metallic structure  <b>DO NOT ALLOW</b> reference to molecules or intermolecular forces for calcium</p> <p><b>ALLOW</b> ‘are molecules’</p> <p><b>IGNORE</b></p> <ul style="list-style-type: none"> <li>• permanent dipole(–dipole) forces</li> <li>• IDID and LDF</li> <li>• van der Waals</li> </ul> <p><b>DO NOT ALLOW</b> ‘free electrons’ for mobile electrons</p> <p><b>ALLOW</b> comparison, e.g.</p> <ul style="list-style-type: none"> <li>• Metallic bonds are stronger than London forces</li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• Metallic bonds need more energy to break than London forces ✓</li> </ul> <p><b>ALLOW</b> 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  <b>AND</b>            Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓            Correct charges on both ions ✓</p>	2		<p><b>ALLOW</b> separate Br<sup>-</sup> ions, i.e.</p>  <p>1.2 x1 2.5 x1</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.</p> <p><b>IGNORE</b> inner shells</p> <p>Circles or brackets not required</p>
	(ii)	<p><b>Atomic radius</b>            Ba has a <b>greater</b> atomic radius than Ca  <b>OR</b> Ba has <b>more</b> shells  <b>OR</b> Ba has <b>more</b> shielding ✓</p> <p><b>Attraction</b>            Nuclear attraction is less in Ba  <b>OR</b> (outer) electrons in Ba are less attracted (to nucleus)  <b>OR</b> Increased distance / shielding in Ba outweighs increased nuclear charge ✓</p> <p><b>Ionisation energy</b>            Ionisation energy of Ba is less  <b>OR</b> easier to remove (outer) electrons in Ba ✓</p>	3		<p>Comparison required throughout  <b>ORA</b> throughout</p> <p>For <b>more</b> shells, <b>ALLOW</b> higher energy level  <b>IGNORE</b> more orbitals <b>OR</b> more sub-shells  <b>IGNORE</b> 'different shell' or 'new shell'</p> <p><b>ALLOW</b> Ba has less nuclear pull'  <b>OR</b> 'Ba electrons are less tightly held'</p> <p><b>IGNORE</b> less effective nuclear charge'  <b>IGNORE</b> 'nuclear charge' for 'nuclear attraction'</p> <p><b>ALLOW</b> easier to oxidise Ba</p>



Question		Answer	Marks	AO element	Guidance	
	(c)	(i)	$Al_2Se_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2Se$	1	2.6 x1	
		(ii)	H <sub>2</sub> O has hydrogen/H-bonds (between molecules) ✓ H <sub>2</sub> Se has induced dipole(-dipole) interactions <b>OR</b> London forces ✓ H-bonds are stronger (than other intermolecular forces) <b>OR</b> more energy needed to overcome H-bonds ✓	3	1.1 x2  2.1 x1	<b>ALLOW</b> permanent dipole-dipole interactions
	(d)	(i)	Sodium bromate(V) ✓	1	2.5 x1	
		(ii)	Br is oxidised <b>AND</b> reduced <b>OR</b> Br oxidation number is increased and decreased ✓ Br is oxidised from 0 to +5 ✓ Br is reduced from 0 to -1 ✓	3	1.1 x1  2.2 x2	<b>ALLOW</b> same element is both oxidised and reduced  <b>ALLOW 1 mark</b> if all 3 oxidation numbers are correct (even if oxidation/reduction incorrectly assigned)



Question		Answer	Marks	AO element	Guidance
4	(a)	<p><b>Bond angle</b> 112–120° ✓</p> <p><b>Explanation</b> Around N, there is a double bond, a single bond and a lone pair ✓</p> <p>Electron pairs repel ✓ Seen anywhere</p>	3	1.1 x1  2.1 x2	<p><b>ALLOW</b> 3 bonding pairs and 1 lone pair <b>OR</b> 2 bonding region and 1 lone pair</p> <p><b>ALLOW</b> bonding pairs or lone pairs</p>
	(b)	(i)	1	1.2 x1	<b>DO NOT ALLOW</b> curved brackets
		(ii)	1	3.1 x1	Response <b>MUST</b> refer to stoichiometry of equation and compare molar ratio of both NO and Cl <sub>2</sub>
		(iii)	2	2.6 x2	<p><b>ALLOW</b> 1.1 up to calculator value of 1.144552314</p> <p><b>ALLOW ECF</b> from inverted <math>K_c</math> expression in <b>b(ii)</b> 2.9(478) x 10<sup>-4</sup> 1 mark 0.017(1691584) 2 marks</p>
		(iv)	2	2.5 x2	<p><b>ALLOW</b> 'favours the right', for 'shifts to right' <b>ALLOW</b> moves to right in endothermic direction</p>



Question		Answer	Marks	AO element	Guidance
5	(a)	<b>C, E AND F ✓✓</b> Three correct alcohols → 2 marks Two correct alcohols → 1 mark	2	1.1 x1 2.1 x1	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 x1	<b>DO NOT ALLOW</b> [O]
	(c)	2-methylbutan-2-ol ✓	1	1.2 x1	
	(d) (i)	<b>FIRST, CHECK THE ANSWER ON ANSWER LINE IF atom economy = 46.1(%) award 2 marks</b> ----- Atom economy $= \frac{M_r \text{ of } (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}}{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH} + M_r \text{ NaBr}} \times 100$ <b>OR</b> $= \frac{88}{190.9} \times 100 \checkmark$ $= 46.1(\%) \checkmark$	2	1.2 x1 2.2 x1	<b>ALLOW</b> $\frac{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}}{M_r (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{Br} + M_r \text{ NaOH}} \times 100$ <b>ALLOW</b> 46% up to calculator value (46.09743321) <b>ALLOW ECF</b> from incorrect $M_r$ values





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 <b>ORA</b> ✓ C–Cl bond is stronger than C–Br bond <b>OR</b> C–Cl bond has greater bond enthalpy <b>OR</b> more energy needed to break C–Cl bond ✓	2	3.1 ×1 2.5 ×1	<b>IGNORE</b> 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><b>Level 3 (5–6 marks)</b> The candidate gives thorough explanations of both spectra, and correctly identifies <b>X</b> and <b>Y</b> 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><b>Level 2 (3–4 marks)</b> The candidate attempts all three scientific points but explanations are incomplete.</p> <p><b>OR</b> Explains two scientific points thoroughly with few omissions.</p> <p><b>AND</b> Attempts a feasible structure based on deduction from correct <math>M_r</math>. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence</i></p> <p><b>Level 1 (1–2 marks)</b> The candidate gives a simple description based on at least two of the main scientific points.</p> <p><b>OR</b> 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><b>0 marks</b> <i>No response or no response worthy of credit.</i></p>	6	2.5 ×1 3.1 ×2 3.2 ×3	<p><b>Indicative scientific points</b></p> <p><b>LOOK AT THE SPECTRA</b> for labelled peaks</p> <p><b>Mass Spectrum</b></p> <ul style="list-style-type: none"> <li>• <math>M^+</math> or molecular ion of 86</li> <li>• <math>m/z = 43</math> shows <math>\text{CH}_3\text{CO}^+</math> <b>OR</b> <math>\text{C}_3\text{H}_7^+</math></li> </ul> <p><b>IR Spectrum</b></p> <ul style="list-style-type: none"> <li>• IR shows no broad absorption at <math>2500\text{--}3300\text{ cm}^{-1}</math> so no O–H bond <b>AND</b> not a carboxylic acid</li> <li>• IR shows absorption at <math>1700\text{ cm}^{-1}</math> for C=O bond <b>OR</b> indicates a ketone/aldehyde present</li> </ul> <p><b>Identification and Equation</b></p> <ul style="list-style-type: none"> <li>• <b>X</b> must be a secondary alcohol, since refluxing a secondary alcohol with acidified potassium dichromate (VI) forms a ketone <b>OR</b> primary alcohol → carboxylic acid <b>AND</b> tertiary alcohol would not be oxidised.</li> <li>• <b>X</b> is <math>(\text{CH}_3)_2\text{CHCHOHCH}_3</math> <b>OR</b> compound <b>E</b> <b>OR</b> 3-methylbutan-2-ol</li> <li>• <b>Y</b> is <math>(\text{CH}_3)_2\text{CHCOCH}_3</math> <b>OR</b> 3-methylbutan-2-one</li> </ul> <p><i>Equation</i>  <math>(\text{CH}_3)_2\text{CHCHOHCH}_3 + [\text{O}] \rightarrow (\text{CH}_3)_2\text{CHCOCH}_3 + \text{H}_2\text{O}</math></p>

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