Oxford Cambridge and RSA

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.

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

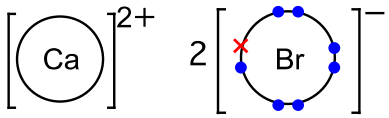
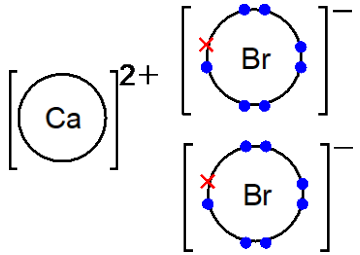
Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	Oxidised **AND** nickel has lost/donated **two** electrons ✓	1	2.1	**IGNORE** reference to oxidation numbers (even if incorrect)
	(b)	(i)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 43.6 (cm³) award 3 marks** $n(\text{Ni}) = \frac{0.192}{58.7} = 3.27\ldots \times 10^{-3}$ (mol) ✓ n(HCl) = $3.27 \times 10^{-3} \times 2 = 6.54\ldots \times 10^{-3}$ (mol) ✓ Volume HCl = $\frac{6.54 \times 10^{-3}}{0.15} \times 1000 = 43.6$ (cm³) ✓ **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 $H_2 = 3.27 \times 10^{-3} \times 24000 = 78.5$ (cm³) ✓	1	2.4 ×1	**ALLOW** ECF from incorrect n(Ni) from (b)(i) **ALLOW** 78.48 (cm³)
		(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)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **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. *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)** The candidate describes all three tests with correct observations. **OR** Describes two tests with a few omissions. **AND** Includes at least one correct equation. *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)** 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. *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**	1.2 ×2 2.7 ×2 3.4 ×2	**Indicative scientific points** **Tests for anions** *Carbonate test*: Add $HNO_3(aq)/HCl(aq)/H_2SO_4(aq)/H^+(aq)$ fizzing/ forms $CO_2(g) \rightarrow$ Carbonate identified *Sulfate test:* Add $Ba(NO_3)_2(aq)$ **OR** $BaCl_2(aq)$ White precipitate $\rightarrow$ Sulfate identified *Bromide test* Add $AgNO_3(aq)$ Cream precipitate $\rightarrow$ Bromide identified **Equations (ionic or full)** **IGNORE** state symbols (even if wrong) *Carbonate* $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$ **OR** $2H^+ + NiCO_3 \rightarrow Ni^{2+} + CO_2 + H_2O$ **OR** $2HNO_3 + NiCO_3 \rightarrow Ni(NO_3)_2 + H_2O + CO_2$ **OR** $2HCl + NiCO_3 \rightarrow NiCl_2 + H_2O + CO_2$ **OR** $H_2SO_4 + NiCO_3 \rightarrow NiSO_4 + H_2O + CO_2$ *Sulfate* $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ **OR** $Ba(NO_3)_2 + NiSO_4 \rightarrow BaSO_4 + Ni(NO_3)_2$ **OR** $BaCl_2 + NiSO_4 \rightarrow BaSO_4 + NiCl_2$ *Bromide* $Ag^+ + Br^- \rightarrow AgBr$ **OR** $2AgNO_3 + NiBr_2 \rightarrow 2AgBr + Ni(NO_3)_2$ **Fine Detail (NOT inclusive)** *Sequence of tests on samples* Carbonate $\rightarrow$ Sulfate $\rightarrow$ Bromide *Solubility of AgBr* Soluble in concentrated ammonia *State symbols in ionic or full equations* *e,g.* • $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$ **OR** $2H^+(aq) + NiCO_3(s) \rightarrow Ni^{2+}(aq) + CO_2(g) + H_2O(l)$ • $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ • $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

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 e**lement 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) ✓ $n(C_6H_{12}) = \frac{0.525}{84} = 0.00625$ (mol) ✓ Energy per mole = $\frac{16.72}{0.00625}$ **OR** (–)2675.2 (kJ mol^{-1})✓ $\Delta_c H$ = – 2680 (kJ mol^{-1}) 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 $M(C_6H_{12})$ 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 = $\frac{1}{20}$ × 100 = 5% ✓ % uncertainty in volume = $\frac{2}{200}$ × 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)	**Any two from:** Heat released to the surroundings ✓ Incomplete combustion **OR** incomplete reaction **OR** not everything burns ✓ Non-standard conditions ✓	**2**	3.2 ×2	**ALLOW** heat loss **IGNORE** reference to evaporation
		(iii)	**Less** accurate due to greater heat losses ✓ **More** accurate due to smaller % uncertainty in temperature change **OR** mass of fuel burnt ✓	**2**	3.4 ×2	**ALLOW** less accurate due to evaporation of water **ALLOW** error for uncertainty **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 OWTTE

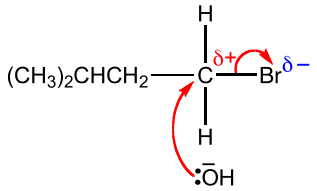
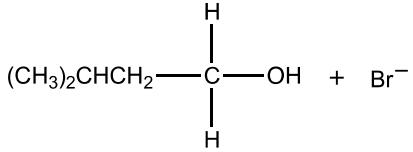
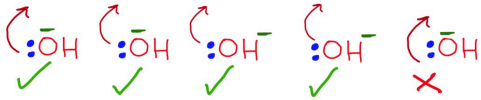
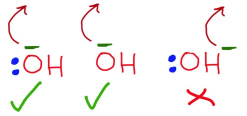
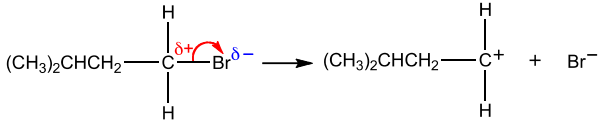
Question	Answer	Marks	AO element	Guidance
3 (a)	Ca: metallic bonding **OR** giant metallic lattice ✓	5	1.1 ×2	**ALLOW** Metallic structure **DO NOT ALLOW** reference to molecules or intermolecular forces for calcium
	Br_2: simple molecular **OR** simple covalent ✓			**ALLOW** 'are molecules'
	Induced dipole(–dipole) forces/interactions **OR** London forces ✓		2.1×1	**IGNORE** • permanent dipole(–dipole) forces • IDID and LDF • van der Waals
	Conductivity linked to mobile electrons In Ca electrons are mobile **OR** electrons are delocalised **OR** electrons can move **AND** in Br_2 charge carriers/electrons are not mobile ✓		3.2 ×2	**DO NOT ALLOW** 'free electrons' for mobile electrons
	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 ✓			**ALLOW** comparison, e.g. • Metallic bonds are stronger than London forces **OR** • Metallic bonds need more energy to break than London forces ✓ **ALLOW** intermolecular forces instead of London forces for this mark

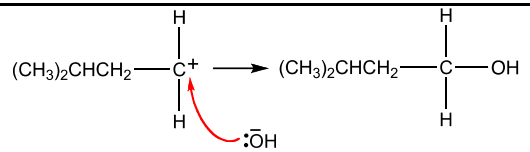
Question			Answer	Marks	AO element	Guidance
	(b)	(i)	 Ca shown with either 8 or 0 electrons **AND** Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓ Correct charges on both ions ✓	**2**	1.2 ×1 2.5 ×1	**ALLOW** separate Br^- ions, i.e.  For first mark, if eight electrons are shown 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
		(ii)	**Atomic radius** Ba has a **greater** atomic radius than Ca **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 ✓	**3**	1.1 ×1 2.3 ×2	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

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

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 ✓ *Seen anywhere*	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)	$(K_c =) \frac{[NO]^2[Cl_2]}{[NOCl]^2}$ ✓	1	1.2 ×1	**DO NOT ALLOW** curved brackets
		(ii)	From equation, n(NO) is $2 \times n(Cl_2)$ **OR** Ratio NO:Cl_2 is 2:1	1	3.1 ×1	Response **MUST** refer to stoichiometry of equation and compare molar ratio of both NO and Cl_2
		(iii)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = $\sqrt{1.31}$ = 1.1 (mol dm^{-3}) award 2 marks** $[NOCl]^2 = \frac{[NO]^2[Cl_2]}{K_c}$ **OR** $\frac{0.34^2 \times 0.17}{0.015}$ **OR** 1.3 ✓ $[NOCl] = \sqrt{1.3}$ = 1.1 (mol dm^{-3}) ✓	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) x 10^{-4} 1 mark 0.017(1691584) 2 marks
		(iv)	As T increases, equilibrium (position) shifts to right **AND** (forward) reaction is endothermic ✓ Equilibrium concentration of NO increases ✓	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)		$(CH_3CH_2CHOHCH_3 +) 6O_2 \rightarrow 4CO_2 + 5H_2O$ ✓	**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 $= \frac{M_r \text{ of } (CH_3)_2CHCH_2CH_2OH}{M_r\ (CH_3)_2CHCH_2CH_2OH + M_r\ NaBr} \times 100$ **OR** $= \frac{88}{190.9} \times 100$ ✓ $= 46.1(\%)$ ✓	**2**	1.2 ×1 2.2 ×1	**ALLOW** $\frac{M_r\ (CH_3)_2CHCH_2CH_2OH}{M_r\ (CH_3)_2CHCH_2CH_2Br + M_r\ NaOH} \times 100$ **ALLOW** 46% up to calculator value (46.09743321) **ALLOW ECF** from incorrect M_r values

Question	Answer	Marks	AO element	Guidance
(ii)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** --- **Curly arrows 2 marks** curly arrow from OH^- to C atom of C–Br bond ✓ dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓  **IGNORE** incorrect R groups for curly arrow marks **IGNORE** presence of Na^+ but OH^- needed i.e. Na^+OH^- can be allowed if criteria met --- **Products 1 mark** correct organic product **AND** Br^- ✓  **IGNORE** presence of Na^+ but Br^- needed i.e. Na^+Br^- can be allowed **BUT** NaBr does **NOT** show Br^- **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows	3	2.5 ×1 1.1 ×1 2.5 ×1	**1st curly arrow** must • go to the C of C–Br **AND** • 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

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

Question	Answer	Marks	AO element	Guidance
(f)	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** The candidate gives thorough explanations of both spectra, and correctly identifies **X** and **Y** with a correct equation. *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)** The candidate attempts all three scientific points but explanations are incomplete. **OR** Explains two scientific points thoroughly with few omissions. **AND** Attempts a feasible structure based on deduction from correct M_r. *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)** The candidate gives a simple description based on at least two of the main scientific points. **OR** Gives a thorough description and explanation of one of the scientific points. *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**	2.5 ×1 3.1 ×2 3.2 ×3	**Indicative scientific points** **LOOK AT THE SPECTRA** for labelled peaks **Mass Spectrum** • M^+ or molecular ion of 86 • m/z = 43 shows CH_3CO^+ **OR** $C_3H_7^+$ **IR Spectrum** • IR shows no broad absorption at 2500–3300 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 **Identification and Equation** • **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 $(CH_3)_2CHCHOHCH_3$ **OR** compound **E** **OR** 3-methylbutan-2-ol • **Y** is $(CH_3)_2CHCOCH_3$ **OR** 3-methylbutan-2-one *Equation* $(CH_3)_2CHCHOHCH_3 + [O] \rightarrow (CH_3)_2CHCOCH_3 + H_2O$

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