Oxford Cambridge and RSA

GCE

Chemistry A

H032/01: Breadth 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.

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
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

SECTION A

Question	Answer	Marks	AO element	Guidance
1	C	1	AO1.2	
2	A	1	AO2.1	
3	D	1	AO1.1	
4	C	1	AO1.2	
5	C	1	AO2.2	
6	D	1	AO2.4	
7	B	1	AO2.3	
8	C	1	AO1.2	
9	D	1	AO1.2	
10	A	1	AO2.6	
11	A	1	AO1.1	
12	C	1	AO1.1	
13	B	1	AO2.5	**ALLOW** 4
14	B	1	AO1.1	
15	D	1	AO2.1	
16	B	1	AO1.2	
17	B	1	AO1.2	
18	C	1	AO2.2	
19	B	1	AO1.1	
20	A	1	AO2.1	
	Total	**20**		

SECTION B

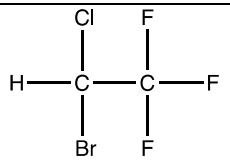
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>21</td><td>(a)</td><td></td><td>
<table>
<tr><th rowspan="2">Shell</th><th rowspan="2">Total number of electrons</th><th colspan="3">Sub-shell</th></tr>
<tr><th>s</th><th>p</th><th>d</th></tr>
<tr><td>1st</td><td>2</td><td>2</td><td></td><td></td></tr>
<tr><td>2nd</td><td>8</td><td>2</td><td>6</td><td></td></tr>
<tr><td>3rd</td><td>18</td><td>2</td><td>6</td><td>10</td></tr>
</table>
1st 2 rows correct → 1 mark ✓

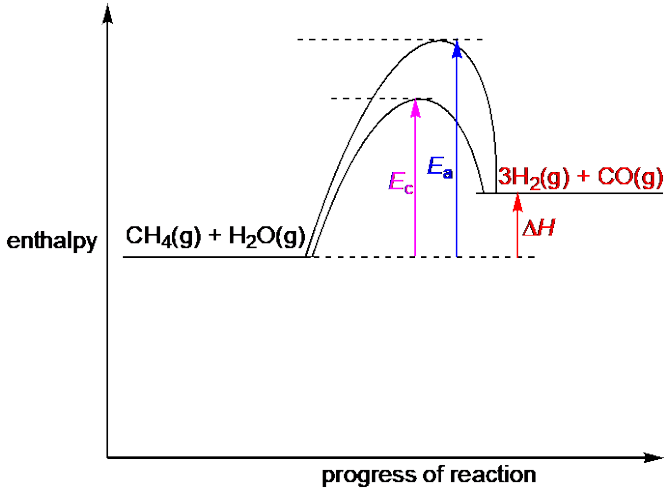
3rd row correct → 1 mark ✓
</td><td>2</td><td>AO1.1
×2</td><td>ALLOW
(1)s^2
(2)s^2 (2)p^6
(3)s^2 (3)p^6 (3)d^{10}

DO NOT ALLOW extra numbers</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
<table>
<tr><th></th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr>
<tr><td>^{76}Se</td><td>34</td><td>42</td><td>34</td></tr>
<tr><td>^{82}Se</td><td>34</td><td>48</td><td>34</td></tr>
</table>
ALL 6 entries correct for mark ✓
</td><td>1</td><td>AO1.2</td><td></td></tr>
<tr><td></td><td>(c)</td><td></td><td>FIRST CHECK ANSWER ON THE ANSWER LINE
IF answer = 32.094 (to 3 DP) award 2 marks

$\frac{(32 \times 94.93) + (33 \times 0.78) + (34 \times 4.29)}{100}$
OR 32.0936 ✓

= 32.094 (to 3 DP) ✓</td><td>2</td><td>AO1.2
×2</td><td>For 1 mark: ALLOW ECF → to 2 DP if:
• %s used with wrong isotopes ONCE
OR
• transposed decimal places for ONE %</td></tr>
</table>

Question			Answer	Marks	AO element	Guidance
	(d)	(i)	 ✓	1	AO2.5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. $CF_3CHClBr$
		(ii)	**FIRST, CHECK ANSWER** **IF answer = 7.224×10^{22}, award 2 marks** --- $n(C_2HBrClF_3) = \frac{7.896}{197.4}$ **OR** 0.04(00) (mol) ✓ F atoms $= 3 \times 0.0400 \times 6.02 \times 10^{23}$ $= 7.224 \times 10^{22}$ ✓ Minimum **3** SF required	2	AO2.2 ×2	**Alternative approaches** n(F atoms) $= \frac{7.896}{197.4} \times 3 = 0.12$ ✓ F atoms $= 0.12 \times 6.02 \times 10^{23}$ $= 7.224 \times 10^{22}$ ✓ **OR** 3 mol F atoms $= 3 \times 6.02 \times 10^{23} = 1.806 \times 10^{24}$ ✓ F atoms $= 1.806 \times 10^{24} \times 0.04$ $= 7.224 \times 10^{22}$ ✓ **OR** Mass F in 7.896 g $= \frac{57}{197.4} \times 7.896 = 2.28$ (g) ✓ F atoms $= \frac{2.28}{19} \times 6.02 \times 10^{23}$ $= 7.224 \times 10^{22}$ ✓ **ALLOW ECF** from incorrect $n(C_2HBrClF_3)$ **ALLOW** use of 6.022×10^{23} **OR** 6.023×10^{23} --- **Common error** 2.408×10^{22} **OR** $2.41 \times 10^{22} \rightarrow$ 1 mark No × 3 $1.806 \times 10^{24} \rightarrow$ 1 mark No $n(C_2HBrClF_3)$
			Total	**8**		

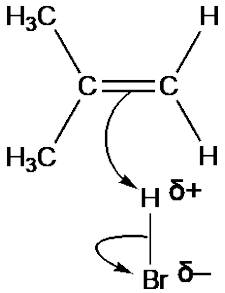
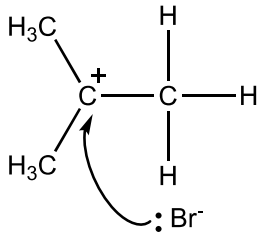
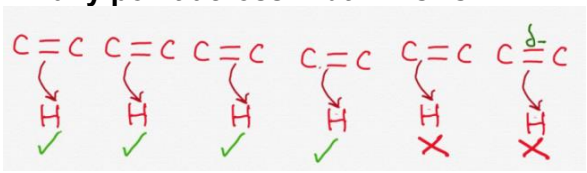
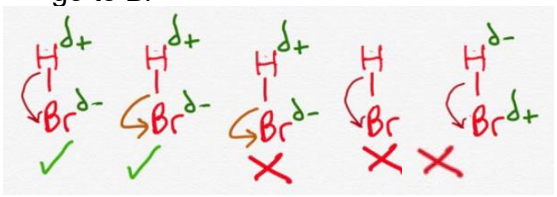
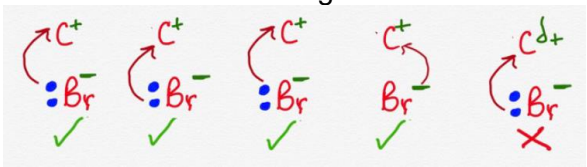
Question			Answer	Marks	AO element	Guidance
22	(a)		 **ΔH and products above reactants** **1 mark** **3**H_2(g) + CO(g) on RHS **IGNORE** state symbols **AND** ΔH labelled with product **above** reactant **AND** **ΔH arrow upwards** ✓ **E_a and E_c and curves** **2 marks** **ONE** curve shown with arrow labelled E_a **OR** E_c from reactants to top of curve → 1 mark ✓ **TWO** curves shown with E_c arrow lower than E_a **AND** each arrow from reactants to top of curve → 2 marks ✓	**3**	AO1.1 ×3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** --- **IGNORE** state symbols. **ΔH label** **ALLOW** arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line **E_a and E_c labels** L SEP **ALLOW** no arrowhead(s) at both ends of activation energy line **ALLOW** double headed arrows L SEP BUT **DO NOT ALLOW** arrowhead down E_a and E_c lines must point to maximum (or near to the maximum) on the curve **OR** span approximately 80% of the distance between reactants and maximum regardless of position

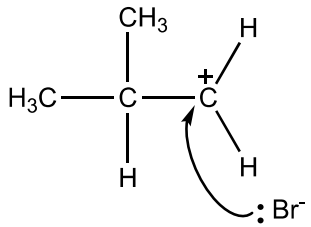
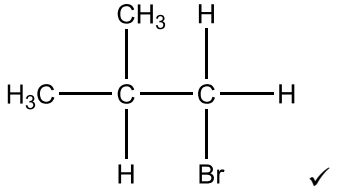
Question			Answer	Marks	AO element	Guidance
	(b)			4		***FULL ANNOTATIONS MUST BE USED***
			Pressure:			
			Right-hand side has more (gaseous) moles **OR** 2 (gaseous) moles form 4 (gaseous) moles ✓		AO1.2	**ALLOW** suitable alternatives for right-hand side, e.g. towards H_2/products **OR** forward direction
			Low pressure **OR** decrease pressure ✓		AO2.1	**OR** increases yield For moles, **ALLOW** molecules/particles
			Temperature:			
			(Forward) reaction is endothermic/ΔH is positive **OR** (Forward) reaction takes in heat ✓		AO1.2	**ORA for** reverse reaction, e.g. **ALLOW reverse** reaction is exothermic
			High temperature **OR** increase temperature ✓		AO2.1	/ΔH is negative**/**gives out heat

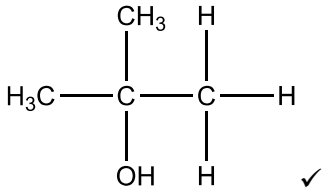
Question			Answer	Marks	AO element	Guidance
	(c)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)432 (kJ mol^{-1}) award 3 marks** --- *Energy for bonds broken (4 × C–H + 2 × O–H)* 4 × 413 + 2 × 464 **OR** 1652 + 928 **OR** 2580 (kJ) ✓ *H–H bond enthalpy correctly calculated* 3 × H–H bond enthalpy = 2580 – 1077 – 206 = 1297 (kJ mol^{-1}) ✓ H–H bond enthalpy = $\frac{1297}{3}$ = (+)432/432.3…. kJ mol^{-1} ✓ *Mark is for answer*	**3**	AO2.6 ×3	**FULL ANNOTATIONS MUST BE USED** --- **IGNORE** sign **IGNORE** sign **ALLOW ECF** **DO NOT ALLOW** – sign --- **COMMON ERRORS** **570/569.66** (Allow 6 or 7 at end) → 2 marks 2580 – 1077 + 206 = **1709** ✓ *Wrong sign for 206* Then 1709/3 = **570** ✓ **1150/1150.3**… → 2 marks 2580 + 1077 – 206 = **3451** ✓ *Wrong sign for 1077* 3451/3 = **1150** ✓ **501** → 2 marks 2580 – 1077 = **1503** ✓ *Missing 206* 1503/3 = **501** ✓
			Total	**10**		

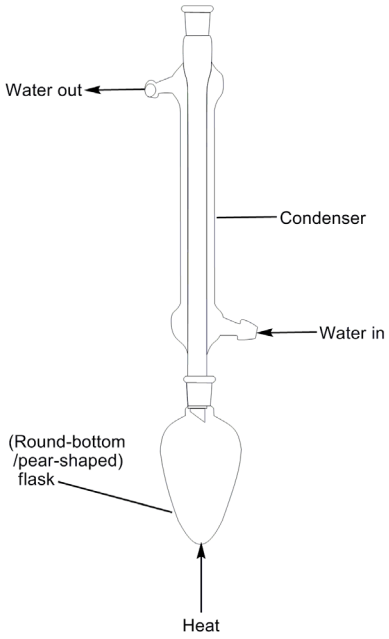
Question			Answer	Marks	AO element	Guidance
23	(a)		toxic/poisonous **OR** forms chlorinated hydrocarbons **OR** forms carcinogenic compounds / toxic compounds ✓	**1**	AO1.1	**IGNORE** 'harmful'/'dangerous' **IGNORE** chlorine is carcinogenic/causes cancer dangerous for health/causes breathing problems
	(b)		Element **oxidised**: Chlorine/C*l* Change from: –1 to 0 ✓ Element **reduced**: Manganese/Mn Change from +4 to +2 ✓	**2**	AO1.2 ×2	**MAX** 1 mark if no '+' sign for oxidation number **ALLOW** Cl_2 for chlorine **ALLOW** 1– **ALLOW** 4+ **AND** 2+ **ALLOW** 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around **IGNORE** numbers around equation i.e. treat as rough working
	(c)		$3KClO_4 + 8Al \rightarrow 3KCl + 4Al_2O_3$ ✓	**1**	AO2.6	**ALLOW** multiples

Question			Answer	Marks	AO element	Guidance
	(d)			5 max		**IGNORE** additions of halogen to same halide e.g. Chlorine to chloride.
			Plan Mix (solution of) halogen and (solution of) halide ✓		AO3.3	**ALLOW** within text if it is clear that halogen is added to halide
			Observation with chlorine bromide → orange/yellow ✓		AO2.7	Check observations in a presented table.
			Observation with bromine iodide → violet/purple/pink ✓		AO2.7	
			Observation with iodine No colour change/no reaction ✓		AO2.7	
			Equation $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ **OR** $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ **OR** $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓		AO2.6	**ALLOW** multiples, e.g. $\frac{1}{2}Cl_2 + Br^- \rightarrow \frac{1}{2}Br_2 + Cl^-$
			Reactivity trend $Cl_2 > Br_2 > I_2$ /decreases down the group ✓		AO1.1	
			Total	**9**		

Question			Answer	Marks	AO element	Guidance
24	(a)		Curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1. Curly arrow from C=C to HBr and H–Br** ***2 marks***  **DO NOT ALLOW** partial charge on C=C Curly arrow from C=C bond to H of H–Br ✓ Correct dipole shown on H–Br **AND** curly arrow that breaks H–Br bond ✓ **2. Curly arrow from Br^- to carbocation** ***1 mark***  **DO NOT ALLOW** δ+ on C of carbocation Correct carbocation **AND** curly arrow from Br^- to C^+ of **CORRECT** carbocation ✓ **3. Name of mechanism** ***1 mark*** Electrophilic addition ✓	**4**	AO1.2 AO1.2 AO2.5 AO1.1	**1st curly arrow must** • go to the H atom of H–Br **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow must** • start from, **OR** be traced back to **any part of** $^{\delta+}$H–Br$^{\delta-}$ bond **AND** • go to $Br^{\delta-}$  **3rd curly arrow must** • go to the C+ of carbocation **AND** • start from, **OR** be traced back to any point across width of lone pair on $:Br^-$ • **OR** start from – charge of Br^- ion 

Question			Answer	Marks	AO element	Guidance
						*(Lone pair **NOT** needed if curly arrow shown from – charge of Br^- ion)* **IF** Br_2 is used instead of HBr contact your Team Leader **DO NOT ALLOW incorrect carbocation, i.e.** 
	(b)	**(i)**	Same **molecular** formula **AND** Different **structural** formulae ✓	**1**	AO1.1	Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient *(no reference to structure/structural)* For structural formulae, **ALLOW** structure/displayed/skeletal formulae
	(b)	**(ii)**	 ✓	**1**	AO2.5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

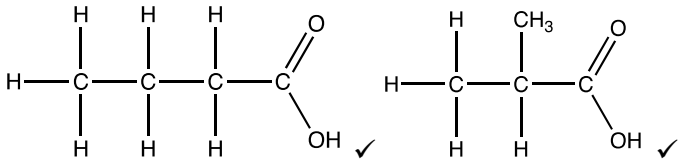
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>
<table>
<tr><th>Alcohol C</th><th>Reagent AND product</th></tr>
<tr><td> 

✓</td><td>NaOH AND NaBr
OR
KOH AND KBr
OR
OH^- AND Br^- ✓</td></tr>
</table>
</td><td>2</td><td>AO2.5
×2</td><td>ALLOW Reagent: H_2O/water
AND Product: HBr</td></tr>
<tr><td></td><td>(c)</td><td>(ii)</td><td>
<table>
<tr><td> 
</td><td>1st mark:
Labelled condenser above a flask ✓

2nd mark:
Only available if 1st mark has been awarded

Flask
AND
heat labelled ✓</td></tr>
</table>
</td><td>2</td><td>AO3.3
×2</td><td>For condenser label,
ALLOW ‘condenser’
OR
water in AND water out (May be implied by connection to tap and sink).</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>10</td><td></td><td></td></tr>
</table>

Question			Answer	Marks	AO element	Guidance
25	(a)	(i)	**Moles Sc OR moles O** $n(\text{Sc}) = \frac{\mathbf{0.27}}{45} = 6 \times 10^{-3}$ (mol) **OR** $n(\text{O}) = \frac{\mathbf{0.144}}{16.0} = 9 \times 10^{-3}$ (mol) ✓ **Empirical formula** Sc_2O_3 ✓	**2**	AO2.8 ×2	**NO ECF**
	(a)	**(ii)**	Heat to constant mass ✓	**1**	AO3.4	**ALLOW** response that implies heating to constant mass, e.g. Heat again until mass does not change **IGNORE** 'heat for longer' *No link to constant mass*
	(b)		***Rearranging ideal gas equation*** $n = \frac{pV}{RT}$ ✓ ***Unit conversion AND substitution into*** $\boldsymbol{n = \frac{pV}{RT}}$**:** • R = 8.314 **OR** 8.31 • $V = 9.39 \times 10^{-3}$ m^3 • *T in K:* 293 K *e.g.* $n = \frac{1.37 \times 10^7 \times 9.39 \times 10^{-3}}{8.314 \times 293}$ ✓ ***Calculation of n*** n = 52.80906994 (mol) ✓ ***Calculation of M*** $M = \frac{1.69 \times 10^3}{52.80906994} = 32.00207847$ ✓ **ALLOW** 2 SF or more ***Gas*** O_2 **OR** oxygen ✓	**5**	AO1.2 AO2.4 ×3 AO3.2	**ALLOW ECF throughout** **IF** $n = \frac{pV}{RT}$ is omitted, **ALLOW** when values are substituted into rearranged ideal gas equation. **ALLOW ECF** from incorrectly rearranged ideal gas equation, e.g. $n = \frac{RT}{pV} \rightarrow 0.0189361411$ $M \rightarrow 89247$ *(Likely to be 3/5 max)* **ALLOW** use of 8.31 for R, which gives: n = 52.83448947 M = 31.98668175 **ALLOW** 3 SF or more, e.g. 52.8 Using 52.8, M = 32.00757576 **ALLOW ECF** for a 'reasonable gas' that matches calculated molar mass

Question			Answer	Marks	AO element	Guidance
26			**Mass spectrum:** *M* = 88 ✓ **IR:** Peak at 1630-1820 (cm^{-1}) is C=O ✓ Peak at 2500–3500 (cm^{-1}) is O–H **AND** carboxylic acid ✓ **Structures**  ✓	**5**	AO3.1 ×3 AO3.2 ×2	**ALLOW** stated values within stated ranges **ALLOW** 'acid O–H **IGNORE** references to C–O peaks **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**13**		

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