

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.

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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).

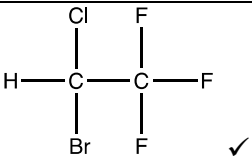
Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording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

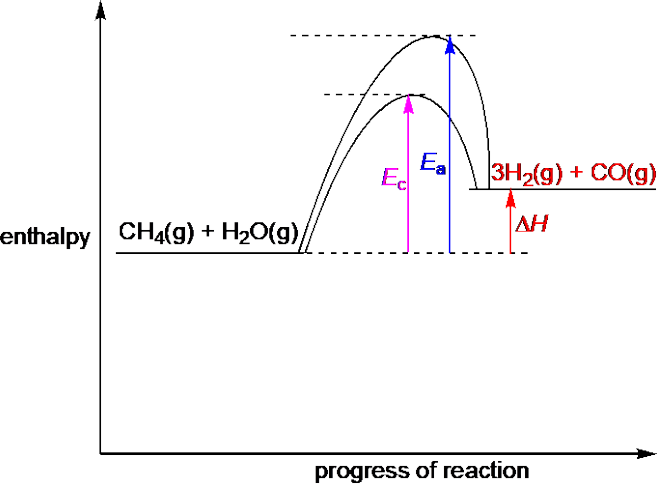
SECTION A

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

Question		Answer				Marks	AO element	Guidance																							
21	(a)	<table border="1"> <thead> <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> </thead> <tbody> <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> </tbody> </table> <p>1st 2 rows correct → 1 mark ✓</p> <p>3rd row correct → 1 mark ✓</p>				Shell	Total number of electrons	Sub-shell			s	p	d	1st	2	2			2nd	8	2	6		3rd	18	2	6	10	2	AO1.1 ×2	<p>ALLOW</p> <p>(1)s²</p> <p>(2)s² (2)p⁶</p> <p>(3)s² (3)p⁶ (3)d¹⁰</p> <p>DO NOT ALLOW extra numbers</p>
Shell	Total number of electrons	Sub-shell																													
		s	p	d																											
1st	2	2																													
2nd	8	2	6																												
3rd	18	2	6	10																											
	(b)	<table border="1"> <thead> <tr> <th></th> <th>Protons</th> <th>Neutrons</th> <th>Electrons</th> </tr> </thead> <tbody> <tr> <td>⁷⁶Se</td> <td>34</td> <td>42</td> <td>34</td> </tr> <tr> <td>⁸²Se</td> <td>34</td> <td>48</td> <td>34</td> </tr> </tbody> </table> <p>ALL 6 entries correct for mark ✓</p>					Protons	Neutrons	Electrons	⁷⁶ Se	34	42	34	⁸² Se	34	48	34	1	AO1.2												
	Protons	Neutrons	Electrons																												
⁷⁶ Se	34	42	34																												
⁸² Se	34	48	34																												
	(c)	<p>FIRST CHECK ANSWER ON THE ANSWER LINE</p> <p>IF answer = 32.094 (to 3 DP) award 2 marks</p> $\frac{(32 \times 94.93) + (33 \times 0.78) + (34 \times 4.29)}{100}$ <p>OR 32.0936 ✓</p> <p>= 32.094 (to 3 DP) ✓</p>				2	AO1.2 ×2	<p>For 1 mark: ALLOW ECF → to 2 DP if:</p> <ul style="list-style-type: none"> • %s used with wrong isotopes ONCE OR • transposed decimal places for ONE % 																							

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 ₃ CHClBr
	(ii)	<p>FIRST, CHECK ANSWER IF answer = 7.224×10^{22}, award 2 marks</p> <hr/> <p>$n(\text{C}_2\text{HBrClF}_3) = \frac{7.896}{197.4}$ OR 0.04(00) (mol) ✓</p> <p>F atoms = $3 \times 0.0400 \times 6.02 \times 10^{23}$ = 7.224×10^{22} ✓ Minimum 3 SF required</p>	2	AO2.2 ×2	<p>Alternative approaches</p> <p>$n(\text{F atoms}) = \frac{7.896}{197.4} \times 3 = 0.12$ ✓</p> <p>F atoms = $0.12 \times 6.02 \times 10^{23}$ = 7.224×10^{22} ✓</p> <p>OR</p> <p>3 mol F atoms = $3 \times 6.02 \times 10^{23} = 1.806 \times 10^{24}$ ✓</p> <p>F atoms = $1.806 \times 10^{24} \times 0.04$ = 7.224×10^{22} ✓</p> <p>OR</p> <p>Mass F in 7.896 g = $\frac{57}{197.4} \times 7.896 = 2.28$ (g) ✓</p> <p>F atoms = $\frac{2.28}{19} \times 6.02 \times 10^{23}$ = 7.224×10^{22} ✓</p> <p>ALLOW ECF from incorrect $n(\text{C}_2\text{HBrClF}_3)$ ALLOW use of 6.022×10^{23} OR 6.023×10^{23}</p> <hr/> <p>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 $n(\text{C}_2\text{HBrClF}_3)$</p>
Total			8		

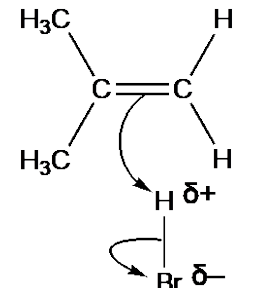
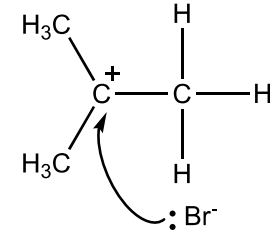
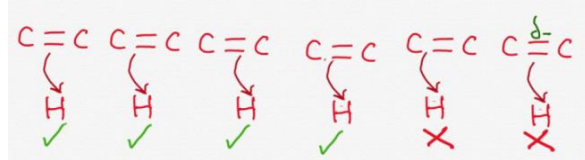
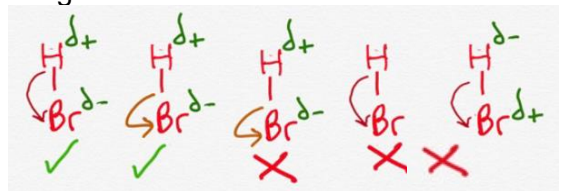
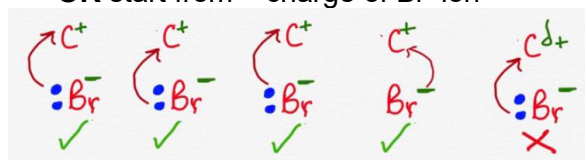
Question	Answer	Marks	AO element	Guidance
22 (a)	 <p>ΔH and products above reactants 1 mark $3\text{H}_2(\text{g}) + \text{CO}(\text{g})$ on RHS IGNORE state symbols AND ΔH labelled with product above reactant AND ΔH arrow upwards ✓</p> <p>E_a and E_c and curves 2 marks ONE curve shown with arrow labelled E_a OR E_c from reactants to top of curve → 1 mark ✓</p> <p>TWO curves shown with E_c arrow lower than E_a AND each arrow from reactants to top of curve → 2 marks ✓</p>	3	AO1.1 ×3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <hr/> <p>IGNORE state symbols.</p> <p>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</p> <p>E_a and E_c labels^[SEP] ALLOW no arrowhead(s) at both ends of activation energy line</p> <p>ALLOW double headed arrows^[SEP] BUT DO NOT ALLOW arrowhead down</p> <p>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</p>

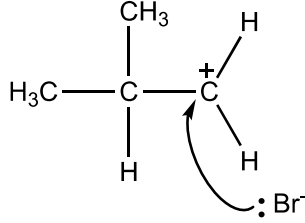
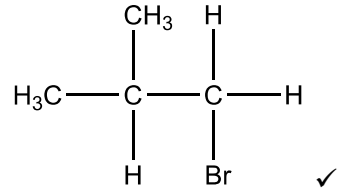
Question		Answer	Marks	AO element	Guidance
(b)		<p>Pressure: Right-hand side has more (gaseous) moles OR 2 (gaseous) moles form 4 (gaseous) moles ✓ Low pressure OR decrease pressure ✓</p> <p>Temperature: (Forward) reaction is endothermic/ΔH is positive OR (Forward) reaction takes in heat ✓ High temperature OR increase temperature ✓</p>	4	 AO1.2 AO2.1 AO1.2 AO2.1	<p><i>FULL ANNOTATIONS MUST BE USED</i></p> <hr style="border-top: 1px dashed blue;"/> <p>ALLOW suitable alternatives for right-hand side, e.g. towards H₂/products OR forward direction OR increases yield</p> <p>For moles, ALLOW molecules/particles</p> <p>ORA for reverse reaction, e.g. ALLOW reverse reaction is exothermic /ΔH is negative/gives out heat</p>

Question		Answer	Marks	AO element	Guidance
(c)		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF bond enthalpy = (+)432 (kJ mol⁻¹) award 3 marks</p> <hr/> <p><i>Energy for bonds broken (4 × C–H + 2 × O–H)</i> $4 \times 413 + 2 \times 464$ OR 1652 + 928 OR 2580 (kJ) ✓</p> <p><i>H–H bond enthalpy correctly calculated</i> $3 \times \text{H–H bond enthalpy} = 2580 - 1077 - 206$ $= 1297 \text{ (kJ mol}^{-1}\text{)} \checkmark$</p> <p>H–H bond enthalpy = $\frac{1297}{3}$ $= (+)432/432.3\dots \text{ kJ mol}^{-1} \checkmark$ <i>Mark is for answer</i></p>	3	AO2.6 ×3	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>IGNORE sign</p> <p>IGNORE sign</p> <p>ALLOW ECF</p> <p>DO NOT ALLOW – sign</p> <hr/> <p>COMMON ERRORS</p> <p>570/569.66 (Allow 6 or 7 at end) → 2 marks $2580 - 1077 + 206 = \mathbf{1709} \checkmark$ <i>Wrong sign for 206</i> Then 1709/3 = 570 ✓</p> <p>1150/1150.3... → 2 marks $2580 + 1077 - 206 = \mathbf{3451} \checkmark$ <i>Wrong sign for 1077</i> 3451/3 = 1150 ✓</p> <p>501 → 2 marks $2580 - 1077 = \mathbf{1503} \checkmark$ <i>Missing 206</i> 1503/3 = 501 ✓</p>
		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/Cl 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)	<p>Plan Mix (solution of) halogen and (solution of) halide ✓</p> <p>Observation with chlorine bromide → orange/yellow ✓</p> <p>Observation with bromine iodide → violet/purple/pink ✓</p> <p>Observation with iodine No colour change/no reaction ✓</p> <p>Equation $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ OR $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ OR $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓</p> <p>Reactivity trend $Cl_2 > Br_2 > I_2$ /decreases down the group ✓</p>	5 max	<p>AO3.3</p> <p>AO2.7</p> <p>AO2.7</p> <p>AO2.7</p> <p>AO2.6</p> <p>AO1.1</p>	<p>IGNORE additions of halogen to same halide e.g. Chlorine to chloride.</p> <p>ALLOW within text if it is clear that halogen is added to halide</p> <p>Check observations in a presented table.</p> <p>ALLOW multiples, e.g. $\frac{1}{2}Cl_2 + Br^- \rightarrow \frac{1}{2}Br_2 + Cl^-$</p>
		Total	9		

Question	Answer	Marks	AO element	Guidance
24 (a)	<p>Curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows</p> <p>1. Curly arrow from C=C to HBr and H-Br 2 marks</p>  <div style="border: 1px solid black; padding: 5px; display: inline-block;">DO NOT ALLOW partial charge on C=C</div> <p>Curly arrow from C=C bond to H of H-Br ✓</p> <p>Correct dipole shown on H-Br AND curly arrow that breaks H-Br bond ✓</p> <p>2. Curly arrow from Br- to carbocation 1 mark</p>  <div style="border: 1px solid black; padding: 5px; display: inline-block;">DO NOT ALLOW delta+ on C of carbocation</div> <p>Correct carbocation AND curly arrow from Br- to C+ of CORRECT carbocation ✓</p> <p>3. Name of mechanism 1 mark</p> <p>Electrophilic addition ✓</p>	4	AO1.2 AO1.2 AO2.5 AO1.1	<p>1st curly arrow must</p> <ul style="list-style-type: none"> go to the H atom of H-Br AND start from, OR be traced back to any point across width of C=C  <p>2nd curly arrow must</p> <ul style="list-style-type: none"> start from, OR be traced back to any part of $\delta^+H-Br\delta^-$ bond AND go to Brδ^-  <p>3rd curly arrow must</p> <ul style="list-style-type: none"> 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
					<p>(Lone pair NOT needed if curly arrow shown from – charge of Br⁻ ion)</p> <p>IF Br₂ is used instead of HBr contact your Team Leader</p> <p>DO NOT ALLOW incorrect carbocation, i.e.</p> 
(b)	(i)	Same molecular formula AND Different structural formulae ✓	1	AO1.1	Same formula is not sufficient (<i>no reference to molecular</i>) Different arrangement of atoms is not sufficient (<i>no reference to structure/structural</i>) 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

Question		Answer	Marks	AO element	Guidance				
(c)	(i)	<table border="1"> <tr> <td>Alcohol C</td> <td>Reagent AND product</td> </tr> <tr> <td> $\begin{array}{c} \text{CH}_3 \quad \text{H} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \quad \text{H} \quad \checkmark \end{array}$ </td> <td> NaOH AND NaBr OR KOH AND KBr OR OH⁻ AND Br⁻ ✓ </td> </tr> </table>	Alcohol C	Reagent AND product	$ \begin{array}{c} \text{CH}_3 \quad \text{H} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \quad \text{H} \quad \checkmark \end{array} $	NaOH AND NaBr OR KOH AND KBr OR OH ⁻ AND Br ⁻ ✓	2	AO2.5 ×2	ALLOW Reagent: H ₂ O/water AND Product: HBr
Alcohol C	Reagent AND product								
$ \begin{array}{c} \text{CH}_3 \quad \text{H} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \quad \text{H} \quad \checkmark \end{array} $	NaOH AND NaBr OR KOH AND KBr OR OH ⁻ AND Br ⁻ ✓								
(c)	(ii)	<table border="1"> <tr> <td> </td> <td> <p>1st mark: Labelled condenser above a flask ✓</p> <p>2nd mark: <i>Only available if 1st mark has been awarded</i></p> <p>Flask AND heat labelled ✓</p> </td> </tr> </table>		<p>1st mark: Labelled condenser above a flask ✓</p> <p>2nd mark: <i>Only available if 1st mark has been awarded</i></p> <p>Flask AND heat labelled ✓</p>	2	AO3.3 ×2	For condenser label, ALLOW 'condenser' OR water in AND water out (May be implied by connection to tap and sink).		
	<p>1st mark: Labelled condenser above a flask ✓</p> <p>2nd mark: <i>Only available if 1st mark has been awarded</i></p> <p>Flask AND heat labelled ✓</p>								
Total			10						

Question			Answer	Marks	AO element	Guidance
25	(a)	(i)	<p>Moles Sc OR moles O</p> $n(\text{Sc}) = \frac{0.27}{45} = 6 \times 10^{-3} \text{ (mol)}$ <p>OR</p> $n(\text{O}) = \frac{0.144}{16.0} = 9 \times 10^{-3} \text{ (mol) } \checkmark$ <p>Empirical formula Sc₂O₃ ✓</p>	2	AO2.8 ×2	NO ECF
	(a)	(ii)	Heat to constant mass ✓	1	AO3.4	<p>ALLOW response that implies heating to constant mass, e.g. Heat again until mass does not change</p> <p>IGNORE 'heat for longer' <i>No link to constant mass</i></p>
	(b)		<p>Rearranging ideal gas equation</p> $n = \frac{pV}{RT} \checkmark$ <p>Unit conversion AND substitution into $n = \frac{pV}{RT}$:</p> <ul style="list-style-type: none"> • R = 8.314 OR 8.31 • V = 9.39 × 10⁻³ m³ • T in K: 293 K <p>e.g. $n = \frac{1.37 \times 10^7 \times 9.39 \times 10^{-3}}{8.314 \times 293} \checkmark$</p> <p>Calculation of n n = 52.80906994 (mol) ✓</p> <p>Calculation of M</p> $M = \frac{1.69 \times 10^3}{52.80906994} = 32.00207847 \checkmark$ <p>ALLOW 2 SF or more</p> <p>Gas O₂ OR oxygen ✓</p>	5	AO1.2 AO2.4 ×3 AO3.2	<p>ALLOW ECF throughout</p> <p>IF $n = \frac{pV}{RT}$ is omitted, ALLOW when values are substituted into rearranged ideal gas equation.</p> <p>ALLOW ECF from incorrectly rearranged ideal gas equation, e.g. $n = \frac{RT}{pV} \rightarrow 0.0189361411$ M → 89247 (Likely to be 3/5 max)</p> <p>ALLOW use of 8.31 for R, which gives: n = 52.83448947 M = 31.98668175</p> <p>ALLOW 3 SF or more, e.g. 52.8</p> <p>Using 52.8, M = 32.00757576</p> <p>ALLOW ECF for a 'reasonable gas' that matches calculated molar mass</p>

Question	Answer	Marks	AO element	Guidance
26	<p>Mass spectrum: $M = 88$ ✓</p> <p>IR: Peak at 1630-1820 (cm^{-1}) is C=O ✓ Peak at 2500–3500 (cm^{-1}) is O–H AND carboxylic acid ✓</p> <p>Structures</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\begin{array}{c} \text{H} & \text{H} & \text{H} & \text{O} \\ & & & // \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C} \\ & & & \backslash \\ \text{H} & \text{H} & \text{H} & \text{OH} \end{array}$ ✓ </div> <div style="text-align: center;"> $\begin{array}{c} \text{H} & \text{CH}_3 & \text{O} \\ & & // \\ \text{H}-\text{C} & -\text{C} & -\text{C} \\ & & \backslash \\ \text{H} & \text{H} & \text{OH} \end{array}$ ✓ </div> </div>	5	AO3.1 ×3 AO3.2 ×2	<p>ALLOW stated values within stated ranges</p> <p>ALLOW 'acid O–H</p> <p>IGNORE references to C–O peaks</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p>
	Total	13		

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