

GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

Advanced 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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Tuesday 5 October 2021 –Afternoon

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

MARK SCHEME

Duration: 2 hours 15 minutes

MAXIMUM MARK 100

**Last updated: 17/10/2021
Post-standardisation**

This document consists of 27 pages

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
/	alternative and acceptable answers for the same marking point
✓	Separates marking points
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
<u>—</u>	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

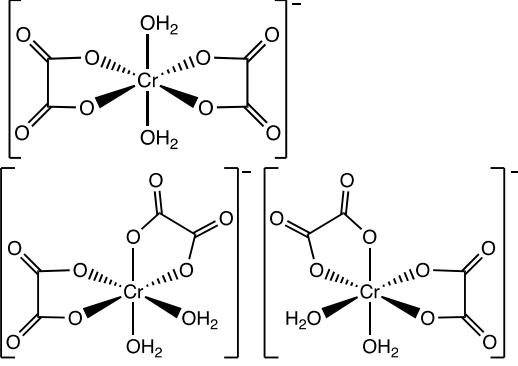
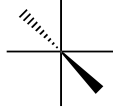
Question	Answer	Marks	AO element	Guidance
1	C	1	AO1.1	
2	B	1	AO1.2	
3	D	1	AO2.6	
4	B	1	AO2.2	
5	D	1	AO2.6	
6	C	1	AO2.6	
7	A	1	AO1.1	
8	B	1	AO2.2	
9	B	1	AO2.2	
10	A	1	AO2.6	
11	A	1	AO1.2	
12	C	1	AO1.2	
13	D	1	AO1.1	Accept 1
14	B	1	AO2.1	
15	C	1	AO2.3	
	Total	15		

Question			Answer	Marks	AO element	Guidance																								
16	(a)		2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ (delocalised) electrons Diagram with regular arrangement of labelled 'Mg²⁺ ions' OR '2+ ions' AND attempt to show electrons ✓ Labelled electrons between other species AND statement anywhere of delocalised electrons (can be in text or in diagram) Electrons move ✓	3		Regular arrangement must have at least two rows of correctly charged ions and a minimum of two ions per row ALLOW as label: +2 ions OR + 2 cations OR +2/2+ seen within circle ALLOW e⁻ or 'e' as a label for electron IGNORE “–” for electron label ALLOW mobile/flow for move IGNORE 'carry charge'																								
	(b)	(i)	Mg ³⁺ (g) → Mg ⁴⁺ (g) + e ⁻ ✓	1	AO1.2	State symbols required (ignore states on electrons) ALLOW Mg³⁺(g) – e⁻ → Mg⁴⁺(g) ALLOW Mg⁺³(g) ALLOW e for e⁻																								
	(b)	(ii)	Big jump/larger difference between 2 and 3 ✓	1	AO1.2	IGNORE big jump between 10 and 11 DO NOT ALLOW other combinations.																								
	(b)	(iii)	1st AND 3rd AND 4th AND 5th AND 9th AND 11th ✓ i.e. <table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr><tr><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr></table>	1	2	3	4	5	6	7	8	9	10	11	12	✓		✓	✓	✓				✓		✓		1	AO2.1	
1	2	3	4	5	6	7	8	9	10	11	12																			
✓		✓	✓	✓				✓		✓																				

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	(enthalpy change for) 1 mole of a compound/substance/solid/solute dissolving ✓	1	AO1.1	IGNORE 'energy released' OR 'energy required' For dissolving, ALLOW forms aqueous/hydrated ions IGNORE ionic OR covalent DO NOT ALLOW dissolving elements DO NOT ALLOW response that implies formation of 1 mole of aqueous ions
	(c)	(ii)	$\underline{\text{Mg}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{g})} \quad \checkmark$ $\underline{\text{Mg}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})} \quad \checkmark$	2	AO2.2 ×2	ALLOW $\text{Mg}^{2+}(\text{g}) + 2\text{F}^{-}(\text{aq})$ ALLOW $\text{MgF}_2(\text{aq})$
	(c)	(iii)	$-6 \text{ (kJ mol}^{-1}\text{)}$ ✓ $\Delta_{\text{sol}}H (\text{MgF}_2) = -(-2926) + (2 \times -506) + (-1920)$	1	AO2.2	1 mark ONLY
	(c)	(iv)	Ionic radius Halide ion gets larger down the group ✓ Lattice enthalpy Lattice enthalpy is less exothermic down group OR halide ion has less attraction for Mg^{2+} ✓ Hydration enthalpy Hydration enthalpy is less exothermic down group OR halide ion has less attraction for H_2O ✓ Enthalpy of solution Difficult to predict whether lattice enthalpy or hydration enthalpy has bigger effect ✓	4	AO1.2 ×3 AO3.2	ALLOW ORA throughout ALLOW ions closer together in MgF_2 OR further apart in MgI_2 DO NOT ALLOW atomic radius ALLOW MgI_2 is less exothermic than MgF_2 for LE and hydration enthalpy -as trend 'down the group'. ALLOW less negative/more positive BUT IGNORE is smaller/less
			Total	14		

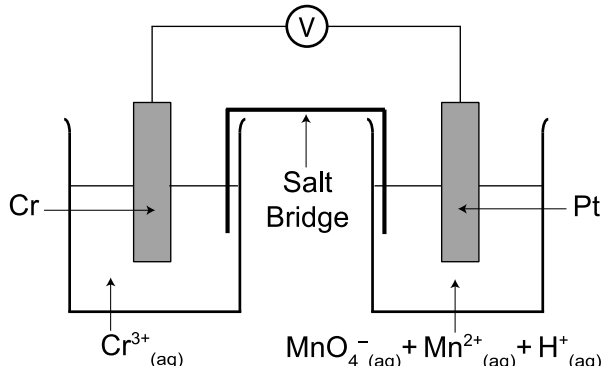
Question			Answer	Marks	AO element	Guidance
17	(a)		Transition element: Has an ion with an incomplete/partially-filled d sub-shell/d-orbital ✓ d-block d sub-shell/d-orbital is being filled/has highest energy OR Electron configurations shown for Sc: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$ AND Zn: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ ✓ <i>Electron configurations of ions</i> Sc³⁺: $1s^2 2s^2 2p^6 3s^2 3p^6$ AND d sub-shell empty / d orbital(s) empty ✓ Zn²⁺: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ AND d sub-shell full / d-orbitals full ✓	4	AO1.1 x4	FULL ANNOTATIONS MUST BE USED ----- DO NOT ALLOW d shell IGNORE d block IGNORE outer electron electron configurations ALLOW $4s^0$ ALLOW $4s^2$ before 3d, i.e.$4s^2 3d^1$; $4s^2 3d^{10}$ IGNORE other Sc and Zn ions ALLOW ECF for short hand notation. For Sc³⁺, ALLOW Sc⁺³ OR Sc forms a 3+ ion; For Zn²⁺, ALLOW Zn⁺² OR Zn forms a 2+ ion;
	(b)	(i)	Donates two electron pairs (to a metal ion) AND forms two coordinate bonds (to a metal ion) ✓	1	AO1.1 x1	ALLOW lone pairs for electron pairs ALLOW dative (covalent) bonds for coordinate bonds TWO is only needed once if bonds are plural, e.g. Donates 2 electron pairs to form coordinate bonds Donates electron pairs to form 2 coordinate bonds

Question			Answer	Marks	AO element	Guidance																					
		(ii)*	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Reaches a comprehensive conclusion with most detail and few errors to obtain: the formulae of A and B AND ionic equation for ligand substitution AND the 3D structures of B stereoisomers <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a sound conclusion with some detail and some errors for the formula of A OR B AND ionic equation for ligand substitution OR the 3D structures of B stereoisomers <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Obtains the correct formula of A OR B OR 3D structures of B stereoisomers which are mostly correct. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	AO2.2 ×2 AO2.6 ×2 AO3.1 ×2	Indicative scientific points: <u>1. Formula of the hydrated salt A</u> Formula of A: $\text{Cr}_2\text{H}_{24}\text{O}_{24}\text{S}_3$ <i>Example of working</i> <table> <tr> <td>Cr</td><td>:</td><td>H</td><td>:</td><td>O</td><td>:</td><td>S</td> </tr> <tr> <td>17.10</td><td>:</td><td>3.94</td><td>:</td><td>63.13</td><td>:</td><td>15.83</td> </tr> <tr> <td>52.0</td><td>:</td><td>1.0</td><td>:</td><td>16.0</td><td>:</td><td>32.1</td> </tr> </table> There may be other methods Detail <i>Hydrated salt = $\text{Cr}_2(\text{SO}_4)_3 \cdot 12\text{H}_2\text{O}$</i> <u>2. Formula of B and ionic equation</u> Formula of B: $[\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]^-$ Ionic equation $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 2\text{C}_2\text{O}_4^{2-} \rightarrow [\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]^- + 4\text{H}_2\text{O}$ ALLOW ligands in any order, e.g. $[\text{Cr}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$ Detail <i>Use of charges and brackets</i> <u>3. 3D structures of B stereoisomers</u>	Cr	:	H	:	O	:	S	17.10	:	3.94	:	63.13	:	15.83	52.0	:	1.0	:	16.0	:	32.1
Cr	:	H	:	O	:	S																					
17.10	:	3.94	:	63.13	:	15.83																					
52.0	:	1.0	:	16.0	:	32.1																					

Question			Answer	Marks	AO element	Guidance
						 - Consistent use of 2 'out wedges', 2 'in wedges', 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge' ALLOW following orientations  Detail - Most bonding shown from Cr to O of H₂O and O⁻ C₂O₄²⁻
			Total	11		

Question			Answer	Marks	AO element	Guidance
18	(a)		Formula: CuCO_3 ✓ $\text{CuCO}_3 + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O}$ ✓	2	AO1.2 AO2.6	IGNORE state symbols ALLOW formula within equation. ALLOW other copper(II) compounds which can react with nitric acid to form a gas e.g. CuS , CuSO_3 for mark 1, with correct equation for mark 2. e.g. $\text{CuSO}_3 + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{SO}_2 + \text{H}_2\text{O}$
	(b)		$2\text{Cu}^{2+}(\text{aq}) + 4\text{I}^{-}(\text{aq}) \rightarrow 2\text{CuI}(\text{s}) + \text{I}_2(\text{aq})$ ✓	1	AO2.6	ALLOW multiples State symbols are required
	(c)		starch (solution) AND blue-black to colourless ✓	1	AO1.2	ALLOW blue OR black OR purple for colour of mixture ALLOW blue colour disappears (to colourless) IGNORE 'clear' IGNORE 'colorimetry'
	(d)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 1.35 award 4 marks ----- $n(\text{S}_2\text{O}_3^{2-}) = 0.0200 \times \frac{26.55}{1000}$ $= 5.31 \times 10^{-4} \text{ (mol) } \checkmark$ $n(\text{I}_2) = 2.655 \times 10^{-4}$ OR $n(\text{Cu}^{2+}) = 5.31 \times 10^{-4} \text{ (mol) } \checkmark$ $m(\text{Cu}/\text{Cu}^{2+}) \text{ in ore} = 63.5 \times 5.31 \times 10^{-4}$ $= 0.0337 \dots \text{ (g) } \checkmark$ $\text{percentage} = \frac{0.0337 \dots}{2.50} \times 100$ $= 1.35 \text{ (\%)} \checkmark$ (3SF required)	4	AO2.8 ×5	FULL ANNOTATIONS MUST BE USED ----- ALLOW ECF throughout If 1:2 ratio for $\text{I}_2:\text{Cu}^{2+}$ not used check ratio in b) and allow ECF IGNORE rounding errors after 3 SF Calculator: 0.0337185 ALLOW 3 SF (0.0337) up to calculator value ECF dependent on the use of a calculated mass of Cu/Cu^{2+}

Question			Answer	Marks	AO element	Guidance
	(e)	(i)	Lower AND smaller titre ✓	1	AO3.4	ALLOW less I ₂ produced / less Cu ²⁺ reacts
		(ii)	The same AND burette measures by difference ✓	1	AO3.4	ALLOW AW
	(f)		Any two of the following: Make up a (standard solution) from Step 2 to a stated volume (e.g. 250 cm³) OR Repeat titrations AND Take mean of concordant/closest titres/ identify anomalies OR lower [S₂O₃]²⁻ to increase titre volume (to reduce the percentage error). OR higher [S₂O₃]²⁻ so not to refill the burette. OR Use a 3 dec place balance (to reduce the percentage error).	2	AO3.4 x 2	
			Total	12		

Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	Complete circuit with voltmeter AND labelled salt bridge linking two half-cells ✓  Cr electrode in Cr^{3+} ✓ Pt electrode in MnO_4^- AND H^+ AND Mn^{2+} ✓	3	AO1.2 ×3	Half cells can be drawn in either order Half cells must show electrodes dipping into solutions ALLOW small gaps in circuit IGNORE any stated concentrations IGNORE state symbols In salt bridge, ALLOW any stated ion that may be present, e.g. Cr^{3+}, MnO_4^-, Mn^{2+}, H^+
	(a)	(ii)	$5\text{Cr} + 3\text{MnO}_4^- + 24\text{H}^+ \rightarrow 5\text{Cr}^{3+} + 3\text{Mn}^{2+} + 12\text{H}_2\text{O}$ ✓	1	AO2.6	IGNORE state symbols ALLOW multiples
	(b)	(i)	Mn is oxidised from +6 (in MnO_4^{2-}) to +7 (in MnO_4^-) ✓ Mn is reduced from +6 (in MnO_4^{2-}) to +4 (in MnO_2) ✓	2	AO2.1 ×2	IGNORE '6' (signs required) ALLOW after number, e.g. 5+ ALLOW 1 mark for correct oxidation numbers but not linked to oxidation/reduction. IGNORE any reference to electron loss/gain (even if wrong)

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	<i>Explanation using E° values</i> $(E^\circ \text{ of) system 3 (MnO}_4^-/\text{MnO}_4^{2-})$ is less positive / more negative than system 5 ($\text{MnO}_4^{2-}/\text{MnO}_2$) ✓ <i>Equilibrium shift related to E° values</i> system 3 ($\text{MnO}_4^-/\text{MnO}_4^{2-}$) shifts left AND system 5 ($\text{MnO}_4^{2-}/\text{MnO}_2$) shifts right ✓	2	AO3.1 ×2	IGNORE 'lower/higher' ALLOW reverse argument: System 5 more positive than system 3, etc Must be comparative ALLOW response in terms of E_{cell} $E = (+)1.14 \text{ V}$ for system 5 – system 3 Shift dependent on systems 3 and 5 correctly identified
	(c)	(i)	$\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ ✓	1	AO2.6	ALLOW multiples ALLOW $\text{H}_2 + 2\text{OH}^- - 2\text{e}^- \rightarrow 2\text{H}_2\text{O}$ ALLOW equation with equilibrium sign
	(c)	(ii)	$(0.40 - 1.23 =) -0.83 \text{ (V)}$ ✓	1	AO1.2	
	(c)	(iii)	Fuel reacts with oxygen/oxidant to give electrical energy/voltage ✓	1	AO1.1	ALLOW named fuel. e.g. hydrogen/H_2; ethanol; methanol, etc ALLOW fuel cell requires <u>continuous</u> supply of fuel AND oxygen/an oxidant OR fuel cell operates <u>continuously</u> as long as a fuel AND oxygen/an oxidant are added IGNORE 'reactants' 'products' and comments about pollution and efficiency
			Total	11		

Question			Answer	Marks	AO element	Guidance
20	(a)		rate of forwards reaction = rate of backwards reaction OR concentrations/pressure/temperature are constant /do not change ✓	1	AO1.1	DO NOT ALLOW “are the same”
	(b)	(i)	$\Delta G = \Delta H - T\Delta S = -114 - (298 \times -0.147)$ ✓ = -70.194 (kJ mol ⁻¹) AND statement of $\Delta G < 0$ OR ΔG is -ve OR $\Delta H < T\Delta S$ ✓	2	AO2.2 ×2	ALLOW -114000 – (298 × -147) ALLOW -70 up to calculator value of -70.194 correctly rounded, i.e. -70 OR -70.2 OR -70.19 ALLOW -70000 up to -70194 (J mol ⁻¹) ALLOW ECF for an incorrectly calculated negative value of ΔG linked to feasibility statement IGNORE rounding after 3 SF ORA for comment about – sign required for feasibility
	(b)	(ii)	776 (K) ✓ i.e. Maximum temperature = $\frac{\Delta H}{\Delta S} = \frac{-114}{-0.147} = 776$ (K) 3 SF required (appropriate from supplied data)	1	AO2.2	

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	FIRST, CHECK FOR VALUE OF K_p. IF answer = 20.7 (MPa⁻¹), award 4 marks <i>Equilibrium amounts</i> $n(\text{NO}) = 0.4 \text{ (mol)}$ AND $n(\text{O}_2) = 0.9 \text{ (mol)}$ AND $n(\text{NO}_2) = 1.2 \text{ (mol)}$ ✓ <i>Total moles at equilibrium</i> $n_{\text{tot}} = 2.5 \text{ (mol)}$ ✓ <i>Partial pressures</i> $p(\text{NO}) = \frac{0.4}{2.5} \times 1.21 = 0.1936 \text{ (MPa)}$ AND $p(\text{O}_2) = \frac{0.9}{2.5} \times 1.21 = 0.4356 \text{ (MPa)}$ AND $p(\text{NO}_2) = \frac{1.2}{2.5} \times 1.21 = 0.5808 \text{ (MPa)}$ ✓ <i>K_p value</i> $K_p = \frac{0.5808^2}{0.1936^2 \times 0.4356} = 20.7 \text{ to 3 SF (MPa}^{-1}\text{)}$ ✓	4	AO2.4 ×4	FULL ANNOTATIONS MUST BE USED ALLOW ECF throughout ALLOW 20.6 from 3 SF partial pressures, 0.194, 0.436 and 0.581 IF there is an alternative answer, check to see if there is any ECF credit possible using working below Look for values to 3 SF here: 0.194, 0.436 and 0.581 ALLOW 25.0 as ECF (from omission of partial pressures for 3 marks)

Question			Answer	Marks	AO element	Guidance																				
	(c)	(ii)	<table><tr><th>Change</th><th>K_p</th><th>Equilibrium amount of NO₂</th><th>Initial rate</th></tr><tr><td>Temperature increased</td><td>smaller</td><td>smaller</td><td>greater</td></tr><tr><td>Pressure increase</td><td>same</td><td>greater</td><td>greater</td></tr><tr><td>Catalyst added</td><td>same</td><td>same</td><td>greater</td></tr><tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr></table>	Change	K_p	Equilibrium amount of NO ₂	Initial rate	Temperature increased	smaller	smaller	greater	Pressure increase	same	greater	greater	Catalyst added	same	same	greater		✓	✓	✓	3	AO1.2 ×3	Mark by COLUMN ALLOW obvious alternatives for greater/smaller/same, e.g. increases/decreases/more/less
Change	K_p	Equilibrium amount of NO ₂	Initial rate																							
Temperature increased	smaller	smaller	greater																							
Pressure increase	same	greater	greater																							
Catalyst added	same	same	greater																							
	✓	✓	✓																							
			Total	11																						

Question			Answer	Marks	AO element	Guidance
21	(a)	(i)	(Expt 1 and 2) $[S_2O_3^{2-}]$ halves, $[H^+]$ constant, AND rate halves AND first order (with respect to $[S_2O_3^{2-}]$) ✓ (Expt 2 and 3) $[S_2O_3^{2-}]$ quarter AND $[H^+]$ halves, AND rate quarters AND zero order (with respect to $[H^+]$) ✓	2	AO3.1 ×2	ALLOW ORA i.e. (Expt 2 and 1) $[S_2O_3^{2-}]$ doubles, $[H^+]$ constant, AND rate doubles AND first order with respect to $[S_2O_3^{2-}]$ ALLOW comparison of Expt 1 and 3: $[S_2O_3^{2-}] \times 1/8$ AND $[H^+]$ halves, AND rate $\times 1/8$ AND zero order with respect to $[H^+]$
	(a)	(ii)	$S_2O_3^{2-}$ as only reactant species in step 1 ✓ Rest of mechanism correct ✓	2	AO3.2 ×2	Step 1: $S_2O_3^{2-} \rightarrow S + SO_3^{2-}$ Step 2: $SO_3^{2-} + 2H^+ \rightarrow SO_2 + H_2O$ OR Step 1: $S_2O_3^{2-} \rightarrow SO_2 + SO^{2-}$ Step 2: $SO^{2-} + 2H^+ \rightarrow S + H_2O$ Check with Team Leader for other equations
	(b)	(i)	Gradient gradient in range of -5700 to -6100 ✓ E_a calculation $E_a = (-) \text{ gradient} \times 8.314$ e.g. from -5900, $E_a = (+) 49052.6 \text{ (J mol}^{-1}\text{)}$ ✓ E_a to 3SF and in kJ mol^{-1} ✓ e.g. $49.1 \text{ (kJ mol}^{-1}\text{)}$	3	AO2.8 ×3	FULL ANNOTATIONS MUST BE USED ----- Marks are for intermediate calculations ALLOW ECF from an incorrect gradient ALLOW ECF on missing $\times 10^{-3}$, e.g. ALLOW 2 marks for: gradient = -5.9, leading to $E_a = 49.0526 \text{ (J mol}^{-1}\text{)}$ AND $0.0491 \text{ (kJ mol}^{-1}\text{)}$ DO NOT ALLOW a negative E_a

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	ln A is intercept at 0 when $1/T$ OR x axis is 0 ✓	1	AO3.2	
		(iii)	<i>ln k</i> $\ln k = -2.59$ ✓ <i>Temperature</i> $1/T = 3.10 \times 10^{-3} \text{ (s}^{-1}\text{)}$ $T = 49.6 \text{ }^{\circ}\text{C}$ ✓	2	AO3.1 AO3.2	Correct T scores 2 marks ALLOW ECF for $1/T$ from incorrect lnK shown on the graph ALLOW in the range $1/T = 3.09 - 3.11 (\times 10^{-3} \text{ s}^{-1})$ $T = 48.5 \text{ to } 50.6 \text{ }^{\circ}\text{C}$ ALLOW $T = 50 \text{ }^{\circ}\text{C}$
			Total	10		

Question			Answer	Marks	AO element	Guidance
22	(a)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 13.15 award 2 marks $[H^+] = \frac{1.00 \times 10^{-14}}{0.140} = 7.14 \dots \times 10^{-14} \text{ (mol) } \checkmark$ $pH = -\log (7.14 \dots \times 10^{-14}) = 13.15 \checkmark$ 2 DP required	2	AO2.2 ×2	ALLOW ECF providing $pH > 7$ Calculator: $7.142857143 \times 10^{-14}$ ALLOW pOH method $pOH = -\log(0.14) = 0.85 \dots \checkmark$ $pH = 14.00 - (0.85 \dots) = 13.15 \checkmark$
	(b)	(i)	$n(H_2SO_4) = 1.60 \times \frac{25.0}{1000} = 0.04(00) \text{ (mol)}$ AND $n(NaOH) = 1.50 \times \frac{55.0}{1000} = 0.0825 \text{ (mol) } \checkmark$ 0.04(00) mol H_2SO_4 reacts with 0.08(00) mol NaOH OR 1 mol H_2SO_4 reacts with 2 mol NaOH $\checkmark$	2	AO2.2 ×2	ALLOW 0.0825 > 0.08

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	$q = mc\Delta T = 80.0 \times 4.18 \times 13.0$ $= 4347.2 \text{ (J) OR } 4.3472 \text{ (kJ) } \checkmark$ $\Delta H_1 = (-) \frac{4.3472}{0.0400} = (-)108.68 \text{ kJ mol}^{-1} \checkmark$ $\Delta_{\text{neut}}H = (-) \frac{108.68}{2} = (-)54.34 \text{ kJ mol}^{-1} \checkmark$ – sign for ΔH value(s) $\checkmark$	4	AO2.4 ×4	FULL ANNOTATIONS MUST BE USED ALLOW 3 SF up to calculated answer throughout ALLOW ECF from q DO NOT ALLOW division by $n(\text{NaOH})$ ALLOW $\Delta_{\text{neut}}H$ from $\Delta H_1 / 2$ ALLOW alternative methods
	(b)	(iii)	The same OR $13^\circ\text{C} \checkmark$ (Double the moles so) double the energy is spread over double the volume	2	AO3.1 ×2	ALLOW explanation that uses a calculation based on moles, volumes ALLOW mass for volume

Question		Answer	Marks	AO element	Guidance
	(c)*	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Reaches a comprehensive conclusion with most detail and few errors for the formation of the buffer AND Calculation of the correct buffer pH AND Correct mass of N₂O₃. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a sound conclusion with some detail and some errors for Formation of buffer AND Calculation of the buffer pH OR Formation of buffer AND Mass of N₂O₃. OR Calculation of the buffer pH AND Mass of N₂O₃. OR Partial explanations of formation of the buffer AND buffer pH AND Mass of N₂O₃. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts, with some success, to: Describe formation of buffer OR Calculate buffer pH OR Obtain mass of N₂O₃. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	AO1.2 ×2 AO2.6 ×2 AO3.1 ×2	Indicative scientific points may include: 1. Formation of buffer - Acid / HNO₂ is in excess - HNO₂ + NaOH → NaNO₂ + H₂O - Partial neutralisation of HNO₂ → formation of NO₂⁻/ NaNO₂ - Buffer contains HNO₂ AND NO₂⁻/NaNO₂ 2. Calculation of buffer pH - n(HNO₂) added = 0.0500 (mol) - n(NaOH) added = 0.0150 (mol) - n(NO₂⁻) formed = 0.0150 (mol) - n(HNO₂) remaining = 0.0500 – 0.0150 = 0.0350 (mol) - K_a = 10^{-3.34} = 4.57... × 10⁻⁴ (mol dm⁻³) - Concentrations = mol (volume 1 dm³) [H⁺] = $\frac{4.57... \times 10^{-4} \times 0.0350}{0.0150}$ = 1.0665... × 10⁻³ (mol dm⁻³) - pH = 2.97 - pH to 2 dec places 3. Calculation of mass of N₂O₃ 1 mol N₂O₃ → 2 mol HNO₂ OR N₂O₃ + H₂O → 2HNO₂ - n(HNO₂) = 0.0500 (mol) - n(N₂O₃) = 0.0500/2 = 0.0250 (mol) - m(N₂O₃) = 0.0250 × 76 = 1.9(0) g
		Total	16		

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