Question	Answer	Marks
4(a)	**M1:** correct use of stoichiometry **M2:** answer + 189	2
4(b)	**M1:** States or uses correct form of Gibbs equation $\Delta G = \Delta H - T\Delta S$ **M2:** appreciates / includes $\Delta G = 0$ at temperature required **M3:** uses 1000 correctly and answer +624(.339) Award 3 marks for correct answer	3
4(c)	negative **and** decrease in number / amount of gas molecules	1

Question	Answer	Marks
3(a)(i)	• enthalpy change / energy change • one mole of electrons • (gained by) **one mole** of **gaseous atoms** two for one mark, three for two marks	2
3(a)(ii)	(energy required to overcome) the repulsion between the electron and anion / negative ion	1

Question	Answer	Marks
3(a)(iii)	• less negative / less exothermic down the group • greater the distance between the nucleus and (the shells of the) electrons **OR** atomic radii increases **OR** more shielding by inner shells • the less **attraction** between nucleus and incoming electron (and the less energy released) two for one mark, three for two marks	2
3(b)	**M1** use of correct seven numbers only in calculation / energy cycle **M2** only 2 × used correctly **M3** correct signs and evaluation ecf –208 = 131 + 906 + 1733 + 62 + 151 + 2x – 2605 2x = –586 x = –293 kJ mol^{-1}	3
3(c)	first box ticked **AND** Cd^{2+} larger / Cd^{2+} lower charge density **AND** less attraction between the ions / weaker ionic bonds	1

Question	Answer	Marks
3(a)	**M1** $\Delta S^{\circ} = (213.8 + 2 \times 248.2) - (237.8 + 3 \times 205.2)$ $\Delta S^{\circ} = -143.2$ (J K^{-1} mol^{-1}) **M2** $\Delta H^{\circ} = (-393.5 + 2 \times -296.8) - (116.7)$ $\Delta H^{\circ} = -1103.8$ (kJ mol^{-1}) **M3** $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ $\Delta G^{\circ} = -1103.8 - (298 \times -0.1432) = -1061.1$ to -1061.4 (kJ mol^{-1}) ecf min 3sf	3
3(b)	**M1** $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ **AND** $\Delta G^{\circ} = 0$ **OR** $T = \Delta H^{\circ} / \Delta S^{\circ}$ [1] **M2** $T = 261.6 \div 0.3655 = 715.7 / 716 / 715$ K min 3sf	2

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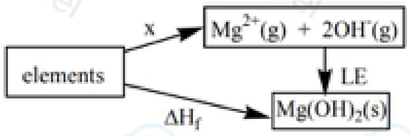
Question	Answer	Marks
1(a)(i)	**M1** (a species) that donates/uses a many lone pairs/more than one lone pair **M2** to form a dative/coordinate to a metal atom/metal ion/TM/TE/metal **OR** **M1** (a species) that donates/uses lone pairs to form many/more than one **M2** dative/coordinate bond to a metal atom/metal ion/TM/TE/metal	2
1(a)(ii)	structure of EDTA any **six** atoms circled of 2 N & 4 O	1
1(a)(iii)	**M1** $K_{stab1} = \dfrac{[[CdEDTA]^{2-}]}{[[Cd(H_2O)_6]^{2+}][EDTA^{4-}]}$ **M2** units = mol^{-1} dm^3	2
1(b)(i)	$K_{eq4} = K_{stab3}/K_{stab2}$	1
1(b)(ii)	**M1** $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ $\Delta G^{\circ} = 0.84 - (298*0.0809)$ **M2** $\Delta G^{\circ} = -23.3$ (kJ mol^{-1}) **3sf min**	2
1(b)(iii)	more negative as $T\Delta S$ increases **OR** more negative as ΔS is positive	1

2(a)(i)	**M1** ΔH_{latt} and ΔH_{hyd} both decrease OR ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermi [redacted] **M2** ΔH_{latt} decreases more than ΔH_{hyd} (as OH^- being smaller than M^{2+}) **M3** ΔH_{sol} becomes more exothermic / more negative	[redacted]
2(a)(ii)	(for MCO_3) change / decrease in ΔH_{hyd} is larger than decrease in ΔH_{latt}	1
2(a)(iii)	**M1** Sr and Ba could be used **AND** Mg could not be used **M2** solubility of $MgCO_3$ is more than $Mg(OH)_2$ OR $SrCO_3$ / $BaCO_3$ is less than $Sr(OH)_2$ / $Ba(OH)_2$	2

Question	Answer	Marks
2(b)(i)	K_{sp} = $[Mg^{2+}(aq)][OH^-(aq)]^2$ OR $K_{sp} = (2.0 \times 10^{-4})(4.0 \times 10^{-4})^2$ $= 3.2 \times 10^{-11}$	2
2(b)(ii)	**M1** (white) ppt. / solid (of $BaCO_3$) will appear **M2** due to the common ion effect OR the $BaCO_3(s) \rightleftharpoons Ba^{2+}(aq) + CO_3^{2-}(aq)$ equilibrium shifts to the left	2
2(c)	 $-2993 + 148 + 736 + 1450 + 2\Delta H_f(OH^-(g)) = -925$ $2\Delta H_f(OH^-(g)) = -266$ $\Delta H_f(OH^-(g)) = -133$ (kJ mol^{-1})	3

Question	Answer	Marks
2(a)(i)	• conjugate base of acid I = OH^- • acid II = HNO_2 • conjugate base of acid II = NO_2^-	1
2(a)(ii)	lone pair on the **N** can be donated to a proton / H^+ **OR** lone pair on the **N** can accept / gain a proton / H^+ **OR** lone pair on the **N** can form a dative bond to a proton / H^+	1
2(a)(iii)	$H_2O + CH_3COOH \rightarrow H_3O^+ + CH_3COO^-$	1
2(b)(i)	$(K_w) = [H^+][OH^-]$ **ALLOW** $(K_w) = K_a \times K_b$	1
2(b)(ii)	endothermic **AND** equilibrium position moves right **OR** as water dissociates more **OR** K_w increases with temperature	1
2(b)(iii)	M1 (K_w increases with temperature so) pH of neutral solution decreases **OR** (from graph) $K_w = 1.50 \times 10^{-14} = [H^+]^2$ $\therefore$ neutral pH = $-½ \log (1.50 \times 10^{-14}) = 6.91$ **OR** $[H^+] = 10^{-7.00}$ $\therefore [OH^-] = 1.50 \times 10^{-14} / 10^{-7.00} = 1.50 \times 10^{-7}$	1
	M2 pH 7 is therefore above neutral pH / is alkaline **OR** $[OH^-] > [H^+]$ (so alkaline)	1
2(c)(i)	$H_2O(l)$ **particles / molecules** has **more** randomness / disorder **OR** $H_2O(l)$ has more ways to arrange **particles / energy** (than in solid)	1
2(c)(ii)	$H_2O(g)$ **particles / molecules** has **much more** randomness / disorder **OR** $H_2O(g)$ has **many** more ways to arrange **particles / energy** (than in liquid)	1
2(c)(iii)	+6030 / (70.1 – 48.0) = 272.85 / 272.9 / 273 K (which is 0 °C)	1
2(d)(i)	(+)1.62 V	1

Question	Answer	Marks
2(d)(ii)	$[OH^-] = 10^{-14}/10^{-11} = 1 \times 10^{-3}$	1
	$E = +0.40 - ½ \times 0.059 \times \log (10^{-3})^2 = +0.40 - 0.059(-3) =$ **+0.577 (V)** min 2sf	1

Question	Answer	Marks
5(a)	energy change / always positive / always negative / either negative or positive lattice energy: always negative ✓ enthalpy of neutralisation: always negative ✓ **both** [1]	
5(b)	(energy change) when **1 mole** of solute is dissolved in an infinite amount of **water** to form a dilute solution	1
5(c)	calculation of ΔH°_{sol} with –251, –1284 and –2035 only and two correct signs [1] calculation of ΔH°_{sol} with –251, –1284 and –2035 only and correct signs **OR** calculation of ΔH°_{sol} with (–251 × 3), –1284 and –2035 only and two correct signs [2] ΔH°_{sol} = (3 × –251) + (–1284) – (–2035) = **–2** (kJ mol⁻¹) [3]	3
5(d)	Ca^{2+} have a higher charge / greater charge density [1] **ora** **stronger** electrostatic forces between Br^{-} and Ca^{2+} [1]	2
5(e)(i)	$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ [1]	1
5(e)(ii)	TΔS is more positive **OR** –TΔS becomes more negative [1]	1

Question	Answer	Marks
3(e)(ii)	states / uses correct Gibbs equation [1] answer = 190 / 191 / 190.0 [1]	2
3(e)(iii)	Becomes less feasible / less spontaneous / **AND** because ΔS is negative / TΔS becomes more negative / –TΔS becomes more positive [1]	1