1.

Question	Answer	Mark
3(a)(i)	(entropy) increases / is positive **and** H_2 / gas is formed	1 **1**
3(a)(ii)	(entropy) increases / is positive **and** (KC*l* (aq)) solution has (free) moving / mobile ions / aqueous ions	1 **1**
3(a)(iii)	(entropy) decreases / is negative **and** decrease in **gas**	1 **1**
3(b)(i)	$\Delta S^{\ominus} = 26.9 + 214 - 65.7 = (+)\,175.2$ (J K^{-1} mol^{-1}) $\Delta G^{\ominus} = 117 - (298 \times 175.2 / 1000)$ **OR** $\Delta G^{\ominus} = 117\,000 - (298 \times 175.2)$ $\Delta G^{\ominus} = +64.8$ (kJ mol^{-1})	1 1 1 **3**
3(b)(ii)	TΔS is more positive than ΔH / TΔS increases / –TΔS more negative **and** ΔG is negative / decrease / less positive	1 **1**
3(c)	use of $\Delta G = 0$ or $\frac{T\Delta S}{\Delta H} = 1$ T = 130 / (316 / 1000) = **410 / 411 / 412 / 411.4** (K)	1 1 **2**

Question	Answer	Mark
3(d)	hydration enthalpy and lattice energy **both** more endothermic / more positive / less exothermic / less negative (down the group) ΔH_{hyd} decreases more / faster **and** ΔH_{sol} becomes (more) endothermic / (more) positive / less exothermic / less negative	1 1 **2**
	Total:	**11**

2.

Question	Answer	Marks
2(c)(iii)	use of ΔH_{i1} 494 (kJ mol^{-1}) $\Delta H^{\ominus}_f$ = +107+494+142–732 $\Delta H^{\ominus}_f$ = **+**11 (kJ mol^{-1})	1 1 1 **3**
2(c)(iv)	(ionic) radius / size of Na^+ is smaller (so stronger attraction to azide ion) **OR** ionic radius increases down the group	1 **1**
	Total:	**11**

3.

Question	Answer	Marks
3(c)(i)	(entropy is a measure / degree of the) disorder of a **system / substance**	1 **1**
3(c)(ii)	$\Delta S^{\ominus} = (2\times27) + (3\times214) - (90) - (3\times198)$ **OR** 696 – 684 $\Delta S^{\ominus} = (+)\,12$ (J K^{-1} mol^{-1})	1 1 **2**
3(c)(iii)	$\Delta G^{\ominus} = -43.6 - (298 \times 12 / 1000)$ $\Delta G^{\ominus} = -47.2$ (kJ mol^{-1})	1 1 **2**
3(c)(iv)	high E_a **and** to speed up the rate	1 **1**
	Total:	**13**

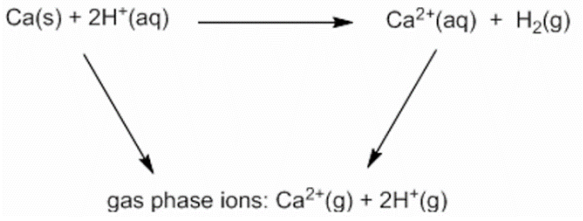
4.

8 (a)	ΔH = [2(–580) + 3(–286) + 3(–1438)] – [–2061 + 4(–437) + 3(–814)] = **–81** kJ mol^{-1}	[2]

5.

(b) (i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds ***or*** same types of / similar bonds forming / breaking ***or*** same number of bonds forming / breaking	1
(ii)	$\Delta S = (\Delta H - \Delta G) / T = (60.7 - 56.5) \times 1000 / 298 =$ (+)**14** / (+)**14.1**	1
(iii)	fewer moles (of solutes) are forming (one mole of) the complex (so less loss of disorder) ***or*** one *en* displaces two H_2O whereas one CH_3NH_2 only displaces one H_2O	1
(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or $\Delta G^{\ominus}$ is more negative.	1

6.

(ii)	 ***x*** = ΔH_{at}(Ca) + IE(1) + IE(2) – 2Δ**H**$_{hyd}$(H^+) + Δ**H**$_{hyd}$(Ca^{2+}) – 2IE(H) – E(H-H) ***x*** = 178 + 590 + 1150 + 2(1090) – 1576 – 2(1310) – 436 ***x*** = **–534** kJ mol^{-1}	4
(c)	CH_3CO_2H is incompletely ionised / weak acid / weaker acid enthalpy change of ionisation (of CH_3COOH) is +2 kJ mol^{-1} **or** energy needed to ionise / dissociate (CH_3COOH)	2

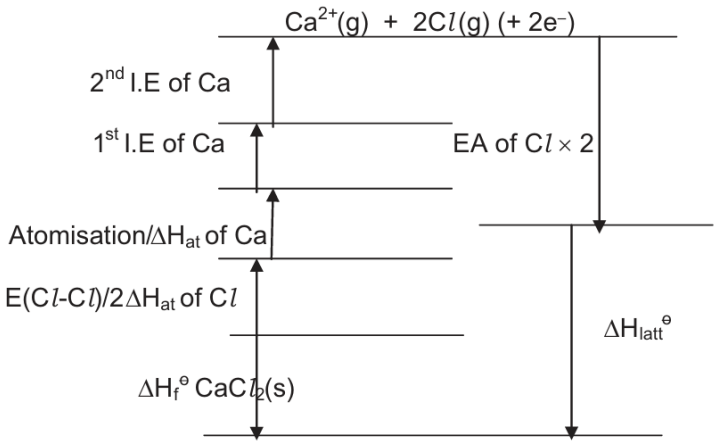
7.

(c) (i)	$\Delta S^{\ominus}$ will be positive, because more gas moles on the RHS / products	[1]
(ii)	$\Delta S^{\ominus} = (\Delta H^{\ominus} - \Delta G^{\ominus}) / T = (241 - 51)/1000 = 0.19$ OR 190 kJ mol^{-1} K^{-1} OR J mol^{-1} K^{-1}	[1] [1]
(d)	$\Delta G^{\ominus}$ will become less positive/more negative as T increases, …because $\Delta S^{\ominus}$ is positive (*or* $-T\Delta S^{\ominus}$ is more negative) …therefore the reaction becomes more feasible / spontaneous as T increases	[2]

8.

8 (a)	ΔH = [2(–580) + 3(–286) + 3(–1438)] – [–2061 + 4(–437) + 3(–814)] = –81 kJ mol^{-1}	[2]

9.

2 (a) (i)	$Ca^{2+}(g) + 2Cl^{-}(g) \rightarrow CaCl_2(s)$ (state symbols required)	1
(ii)		2
(iii)	$\Delta H_{latt}^{\ominus} = -796 - 242 - 178 - 590 - 1150 + (2 \times 349) = -2258$ kJ mol^{-1}	3
(b)	(higher temperature means that) particles have more energy; entropy (of the gas / system) increases because of an increase in the amount of disorder / randomness;	2
(c) (i)	<table><tr><th>reaction</th><th>sign of $\Delta S^{\ominus}$</th></tr><tr><td>$CO(g) + O_2(g) \rightarrow CO_2(g)$</td><td>negative</td></tr><tr><td>$Mg(s) + ½O_2(g) \rightarrow MgO(s)$</td><td>negative</td></tr><tr><td>$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4.5H_sO(s)$</td><td>negative</td></tr><tr><td>$NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + CO_2(g) + H_2O(l)$</td><td>positive</td></tr></table>	2
(ii)	there is a reduction in the overall number of gaseous molecules	1
(d)	$\Delta S_f^{\ominus} = 386 - (192 + (3 \times 131))$ $= -199$ (J K^{-1} mol^{-1})	2
(e) (i)	$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ $= 117 - ((298 \times 175) / 1000)$ = (+) 64.85 (kJ mol^{-1})	2
(ii)	$\Delta G^{\ominus}$ is positive and so the reaction is not spontaneous (at 298 K)	1

10.

Question	Answer	Marks
5(a)	(Na^+) 0.095 / 0.181 = 0.525 **and** octahedral **and** co-ordination no. = 6	**1**
	(Mg^{2+}) 0.065 / 0.181 = 0.359 **and** tetrahedral **and** co-ordination no. = 4	**1**
5(b)	enthalpy change = (–642) – (2 × –106) = **–430**	**1**
5(c)(i)	–106 = 147 + 121 + 736 + (–349) + lattice energy lattice energy = –761	**3**
5(c)(ii)	$MgCl_2$ more exothermic / negative / bigger than $MgCl$ **and** $NaCl$ more exothermic / negative / bigger than $MgCl$	**1**
	(reason for $MgCl_2$) higher charge / lower radius of Mg^{2+} cation	**1**
	(reason for $NaCl$) smaller radius of Na^+ cation	**1**
5(d)	energy change when 1 mole of atoms / ions each gain an electron **or** energy change when 1 mole of atoms / ions gain 1 mole of electrons	**1**
	gaseous	**1**

11.

Question	Answer	Marks
1(a)	solubility increases down the group	**1**
	ΔH_{latt} and ΔH_{hyd} both **decrease** **or** ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermic	**1**
	ΔH_{latt} decreases / changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+})	**1**
	ΔH_{sol} becomes more exothermic / more negative / less endothermic / less positive	**1**
1(b)(i)	ΔH_{r1} – (538 + 2x230 + 394) = –(1216 + 286) ΔH_{r1} – 1392 = –1502	**1**
	ΔH_{r1} = **–110**	**1**
1(b)(ii)	let $\Delta H_f(HCO_3^-(aq))$ = y 2y – 538 = –1216 – 394 – 286 – 26	**1**
	y = **–692**	**1**
1(b)(iii)	ΔH_{r3} –538 – 2(230 + 394) = –538 – 2(692) ΔH_{r3} = **–136**	**1**
1(b)(iv)	ΔH_{r3} will be identical to ΔH_{r4}, / unchanged	**1**
	as the reaction is the same, or: $2OH^-(aq) + 2CO_2(g) \longrightarrow 2HCO_3^-(aq)$ or metal ions stay in solution/metal ions are unchanged / are spectators	**1**

Question	Answer	Marks
1(c)	more **gaseous moles** are being consumed (in reaction 3) **or** more **CO_2 moles** are being consumed (in reaction 3)	**1**
	ΔS is therefore expected to be **more negative/less positive** for reaction 3.	**1**
	Total:	**13**

12.

Question	Answer	Marks
1(a)(i)	increases down the group	1
	radius / size of (cat)ion/M^{2+} increases	1
	less polarisation / distortion of anion / carbonate **ion** / CO_3^{2-}	1
1(a)(ii)	Na^+ has smaller ionic charge **and** larger ionic radii OR the **charge density** of the **Na^+** is **lower**	1
1(b)(i)	$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$	1
1(b)(ii)	$NaHCO_3$ because Na^+ is **smaller** OR charge density Na^+ is **larger**	1
1(c)(i)	LE = $\Delta H_f - 2(\Delta H_{at} + IE) - ½(O=O) - (EA_1 + EA_2)$ = –361 – 2(89) **–** 2(418) – 496/2 – (–141+798) = **–2280** (kJ mol^{-1}) correct answer scores [3]	3 1 1 1
1(c)(ii)	LE of Na_2O will be **more negative** AND as $Na^{(+)}$ is smaller / larger charge density / smaller radii AND so greater attraction (between the ions) OR (ionic) bonds will be stronger	1
	Total:	**10**

13.

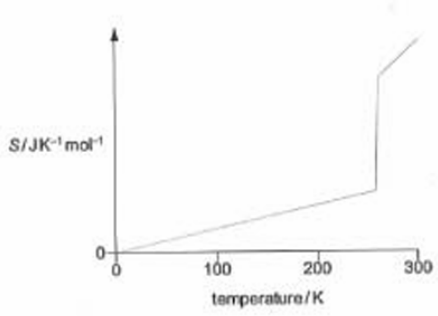
Question	Answer	Marks
1(a)	solubility increases down the group	1
	ΔH_{latt} and ΔH_{hyd} both **decrease** **or** ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermic	1
	ΔH_{latt} decreases / changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+})	1
	ΔH_{sol} becomes more exothermic / more negative / less endothermic / less positive	1
1(b)(i)	ΔH_{r1} – (538 + 2x230 + 394) = –(1216 + 286) ΔH_{r1} – 1392 = –1502	1
	ΔH_{r1} = **–110**	1
1(b)(ii)	let $\Delta H_f(HCO_3^-(aq))$ = y 2y – 538 = –1216 – 394 – 286 – 26	1
	y = **–692**	1
1(b)(iii)	ΔH_{r3} –538 – 2(230 + 394) = –538 – 2(692) ΔH_{r3} = **–136**	1
1(b)(iv)	ΔH_{r3} will be identical to ΔH_{r4}, / unchanged	1
	as the reaction is the same, or: $2OH^-(aq) + 2CO_2(g) \longrightarrow 2HCO_3^-(aq)$ or metal ions stay in solution/metal ions are unchanged / are spectators	1

Question	Answer	Marks
1(c)	more **gaseous moles** are being consumed (in reaction 3) **or** more **CO_2 moles** are being consumed (in reaction 3)	1
	ΔS is therefore expected to be **more negative/less positive** for reaction 3.	1
	Total:	**13**

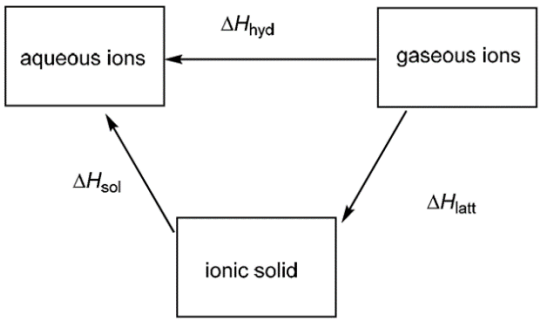
14.

Question	Answer	Marks
2(a)	<table><tr><td>enthalpy change</td><td>positive</td><td>negative</td><td>either positive or negative</td></tr><tr><td>electron affinity</td><td></td><td></td><td>✓</td></tr><tr><td>enthalpy change of atomisation</td><td>✓</td><td></td><td></td></tr><tr><td>enthalpy change of ionisation</td><td>✓</td><td></td><td></td></tr><tr><td>lattice enthalpy</td><td></td><td>✓</td><td></td></tr></table>	**2**
2(b)(i)	the second electron is removed from a (more) positively charged ion	**1**
2(b)(ii)	ΔH_6 is lattice (energy / enthalpy) **AND** ΔH_7 is (energy / enthalpy of) formation	**1**
2(c)	the electron affinity becomes less exothermic / negative down the Group 17	**1**
	electron affinity depends (mainly) on the electron-nucleus distance which increases down Group 17	**1**
2(d)	**M1** correct use of $\Delta G = \Delta H - T\Delta S$	**1**
	M2 $\Delta S = 26.9 - (32.7 + 102.5) = -108.3\,J\,K^{-1}\,mol^{-1}$ **OR** $-0.1083\,kJ\,K^{-1}\,mol^{-1}$	**1**
	M3 $\Delta G = -602 - (298 \times (-0.1083)) = -570$	**1**
	M4 units: $kJ\,mol^{-1}$	**1**

15.

Question	Answer	Marks
8(a)	 **M1** continuous increase in *S* from 0–300 K (excluding m.p.) [1] **M2 steep** vertical increase in *S* **ONLY** at the m.p. **AND** continuous increase in *S* after m.p. [1]	**2**
8(b)	[1] for each correct tick <table><tr><td></td><td>negative $\Delta S^{\ominus}$</td><td>positive $\Delta S^{\ominus}$</td></tr><tr><td>solid dissolving in water</td><td></td><td>✓</td></tr><tr><td>water boiling to steam</td><td></td><td>✓</td></tr></table>	**1**
8(c)	$\Delta H^{\ominus} = (2 \times C{=}O) + (3 \times H\text{-}H) - (3 \times C\text{-}H) - (C\text{-}O) - (3xO\text{-}H)$ $\Delta H^{\ominus} = (2 \times 805) + (3 \times 436) - (3 \times 410) - (1 \times 360) - (3 \times 460)$ [1] $\Delta H^{\ominus} = 1610 + 1308 - 1230 - 360 - 1380 =$ **– 52** ($kJ\,mol^{-1}$) [1] ecf correct answer scores [2]	**2**
8(d)(i)	$\Delta S^{\ominus} = 127 + 70 - (214 + 3 \times 131)$ [1] = – 410 ($J\,K^{-1}\,mol^{-1}$) [1] ecf correct answer scores [2]	**2**
8(d)(ii)	$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ [1] $\Delta G^{\ominus} = -131 - (298 \times -0.41) =$ **– 8.8(2)** ($kJ\,mol^{-1}$) [1] correct answer scores [2]	**2**
8(d)(iii)	(as temperature increases) feasibility decreases	**1**

16.

4(c)	 arrow label and direction correct [1] x 3	**3**

17.

8(c)(i)	(entropy) is a measure of the disorder/randomness of a system	**1**
8(c)(ii)	$\Delta S^{\ominus} = 237 + 187 - (241 + 198) = -15.0$ (J K^{-1} mol^{-1})	**1**
8(c)(iii)	$\Delta H^{\ominus} = 95.4–92.3 - (80.1–45.9) = -31.1$ (kJ mol^{-1})	**1**
8(c)(iv)	$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ [1] $\Delta G^{\ominus} = -31.1 - (298 \times -0.015) = -26.6$ (kJ mol^{-1}) [1]	**2**
8(c)(v)	(at higher temperatures) $T\Delta S^{\ominus}$ becomes more negative so $\Delta G^{\ominus}$ becomes more positive **OR** (at high temperatures) $-T\Delta S^{\ominus}$ is becomes more positive so $\Delta G^{\ominus}$ becomes more positive	**1**

18.

1(d)	use of (2×109) or 218 and (2×494) or 988	**1**
	use of (0.5×496) or 248	**1**
	use of 416, 142, 844	**1**
	evaluation of expression correctly $\Delta H_{lat} = -416 - (2 \times 109) - (0.5 \times 496) - (2 \times 494) - (-142 + 844) = -2572$	**1**
1(e)	the lattice energy of Na_2S is less exothermic	**1**
	the sulfide ion is larger than the oxide ion / S^{2-} larger than O^{2} / ionic radii quoted 0.184 nm and 0.140 nm **AND** less attraction (between the ions)/bonds are weaker	**1**

19.

1(c)(i)	$-225.7 = 239.0 - (18.7 + 2x)$	**1**
	$x = +223$	**1**
1(c)(ii)	decrease in number of **moles** of **gas** /more **moles** of **gas** on left / reactants (ora)	**1**
1(d)	use of $\Delta G = \Delta H - T\Delta S$ with $\Delta G = 0$ / $\Delta G > 0$ **or** $T = \Delta H / \Delta S$ or $T = (640\,000 / 225.7)$	**1**
	2836 / 2840 (2835.6)	**1**

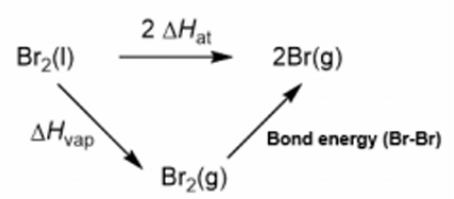
20.

Question	Answer	Marks
3(a)	a **measure / degree** of **disorder / randomness** of a system	**1**
3(b)	**M1:** negative – molecules have less energy in the system **M2:** positive – solid being converted into an aqueous solution **M3:** negative – gaseous ions being converted into a solid	**3**
3(c)(i)	(standard) Gibbs free energy change	**1**
3(c)(ii)	**M1:** $(\Delta)G = \Delta H - T\Delta S$ **M2:** description of calculating the minimum value of T for which ΔG is zero / becomes negative **OR** $T = \Delta H / \Delta S$ [1]	**2**

21.

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**

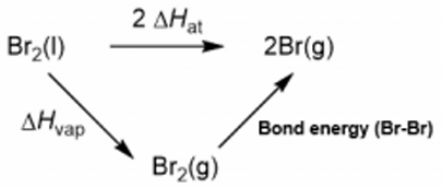
22.

Question	Answer	Marks
6(a)	<table><tr><td>energy change</td><td>always positive</td><td>always negative</td><td>either negative or positive</td></tr><tr><td>bond energy</td><td>✓</td><td></td><td></td></tr><tr><td>enthalpy of formation</td><td></td><td></td><td>✓</td></tr></table> **both** ticks correct	**1**
6(b)	(energy change) when **1 mole** of **gaseous atoms** are formed (from an element in its standard state)	**1**
6(c)	 **M1**: correct cycle: formulae and state symbols **M2**: use of 1 × 193 **and** 2 × (112) **M3**: for the correct sum and answer ecf from M2 $\Delta H^{\ominus}_{vap}$ (= (2 × 112) – (193)) = **+31** kJ mol^{-1} [scores M2 and M3]	**3**
6(d)	more endothermic **and** greater Van der Waals / London / induced dipole-dipole forces **both**	**1**
6(e)(i)	(energy change) when **1 mole** of **gaseous ions** is dissolved in (an excess of) water	**1**
6(e)(ii)	**M1**: Br^- has a smaller ionic radii **M2**: stronger (ion-dipole) attractions with water molecules	**2**

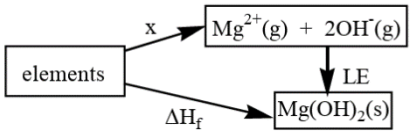
23.

Question	Answer	Marks
5(a)	<table><tr><th>energy change</th><th>always positive</th><th>always negative</th><th>either negative or positive</th></tr><tr><td>lattice energy</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of neutralisation</td><td></td><td>✓</td><td></td></tr></table> **both** [1]	**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 $\Delta H^{\ominus}_{sol}$ with –251, –1284 and –2035 only and two correct signs [1] calculation of $\Delta H^{\ominus}_{sol}$ with –251, –1284 and –2035 only and correct signs **OR** calculation of $\Delta H^{\ominus}_{sol}$ with (–251 × 3), –1284 and –2035 only and two correct signs [2] $\Delta H^{\ominus}_{sol}$ = (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)	$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ [1]	**1**
5(e)(ii)	TΔS is more positive **OR** –TΔS becomes more negative [1]	**1**

24.

Question	Answer	Marks
6(a)	<table><tr><th>energy change</th><th>always positive</th><th>always negative</th><th>either negative or positive</th></tr><tr><td>bond energy</td><td>✓</td><td></td><td></td></tr><tr><td>enthalpy of formation</td><td></td><td></td><td>✓</td></tr></table> **both** ticks correct	**1**
6(b)	(energy change) when **1 mole** of **gaseous atoms** are formed (from an element in its standard state)	**1**
6(c)	 **M1**: correct cycle: formulae and state symbols **M2**: use of 1 × 193 **and** 2 × (112) **M3**: for the correct sum and answer ecf from M2 $\Delta H^{\ominus}_{vap}$ (= (2 × 112) – (193)) = **+31** kJ mol^{-1} [scores M2 and M3]	**3**
6(d)	more endothermic **and** greater Van der Waals / London / induced dipole-dipole forces **both**	**1**
6(e)(i)	(energy change) when **1 mole** of **gaseous ions** is dissolved in (an excess of) water	**1**
6(e)(ii)	**M1**: Br^- has a smaller ionic radii **M2**: stronger (ion-dipole) attractions with water molecules	**2**

25.

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**

26.

2(c)	**M1:** Use of 2×-348 (EA F) and +158 (bond energy of F_2) [1] **M2:** Use of +147 (at Mg) and +736 and +1450 (IEs of Mg) [1] **M3:** evaluation and calculation of their answer $(-1102 - (147 + 158 + 736 + 1450 - 696))$ = **–2897** (kJ mol^{-1}) [1] ecf	**3**

27.

Question	Answer	Marks
3(a)(i)	(+193 + 242 + 590 + 1150 + (2 × –349)) [1] answer (+)1477 [1]	**2**
3(a)(ii)	(–795 – 83 – 1477) [1] –2355 [1]	**2**
3(a)(iii)	(–2355 –(2 × –364)) [1] –1627 [1]	**2**
3(a)(iv)	Z–Y or X–W [1]	**1**
3(a)(v)	less (exothermic) and both ions (in $CaCl_2$) are larger [1]	1
3(b)(i)	soluble barium salt **AND** soluble sulfate [1]	1
3(b)(ii)	less soluble (down the group) [1] ΔH_{lat} and ΔH_{hyd} both decrease down the group [1] ΔH_{hyd} decreases more / faster / is dominant factor [1] ΔH_{sol} gets less exo / more endo [1]	**4**

28.

Question	Answer	Marks
7(a)(i)	• energy change • when one electron is added • to each atom /ion in one mole of • gaseous atoms /ions Award one mark for two correct statements. Award two marks for four correct statements	**2**
7(a)(ii)	**M1** energy change when 1 mole of an ionic compound is formed **M2** from gas phase ions/ gaseous ions	**2**

Question	Answer	Marks
7(b)	**M1** use of data (with no multipliers) 31, 131, -2678 **M2** extraction of data 908, 1730, 193 **M3** use of (2 x-325) **M4** evaluation of <u>their</u> expression correctly, as shown $\Delta H_f(ZnBr_2)$ = 131 + (908 +1730) + 193 + 31 + (2 x-325) + (-2678) = **-335** kJ mol^{-1} [4]	**4**
7(c)(i)	Br^- is a largest ion/larger ion than Cl^- so attraction between Br^- and Zn^{2+} is smaller	**1**
7(c)(ii)	O^{2-} is a smallest ion/smaller ion than Cl^- **AND** O^{2-} has the highest charge/ higher charge than Cl^- (so attraction between O^{2-} and Zn^{2+} is larger)	**1**

29.

7(b)(i)	$\Delta S^\ominus$ = 72.7 + 56.5 -96.2 = **+33.0** J K^{-1} mol^{-1}	**1**
7(b)(ii)	**M1** $\Delta G = \Delta H^\ominus - T\Delta S^\ominus$ **M2** ΔG = (65.5)- (298x0.033) = **+55.7** kJ mol^{-1} min 3sf **M3** ΔG = positive so not feasible/spontaneous	**3**

30.

3(c)(i)	ΔH_4 = (3 ×) electron affinity of fluorine / F ΔH_6 = (enthalpy change of) formation of AlF_3	**2**
3(c)(ii)	**M1** +326 + 1½ × 158 + 5137 + 3 × –328 + ΔH_{latt} = –1504 **M2** ΔH_{latt} = –6220 (kJ mol^{-1})	**2**
3(c)(iii)	**M1** lattice energy of ScF_3 should be less exothermic ora **M2** Sc ion / Sc^{3+} larger than Al ion / Al^{3+} **AND** lesser attraction between the ions / ionic bonds are weaker	**2**
3(d)(i)	$K_{sp} = [Al^{3+}][F^-]^3$	**1**
3(d)(ii)	$K_{sp} = 6.5 \times 10^{-2} \times (3 \times 6.5 \times 10^{-2})^3 = 4.8 \times 10^{-4}$	**1**

31.

Question	Answer	Marks
3(a)	• enthalpy/energy change • one mole of electrons gained • by one mole of atoms • gaseous (atoms)	**2**
3(b)	$Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ [1]	**1**

Question	Answer	Marks
3(c)	M1: selecting correct data 951, 844, 142 only M2: evaluation to give 249 (ΔH_{atom}) **OR** 2(951) = BE – 2(142) + 2(844) M3: evaluation to 498 (2 × 249) ecf M2 951 = ΔH_{atom} –142 + 844 ΔH_{atom} = 249 BE = **498** (kJ mol^{-1}) [3]	**3**
3(d)(i)	**attraction** between nucleus / protons / nuclear charge **and** electron [1]	**1**
3(d)(ii)	**repulsion** between 1– ion / electrons of O^- **and** electron [1]	**1**
3(e)	M1: selecting correct data 951, 1933, 3517 only (ignore signs) M2: evaluation to give –633 (ΔH_f) ecf ΔH_f = 951 + 1933 – 3517 = **–633** (kJ mol^{-1}) [2]	**2**
3(f)	ionic charge / charge density (of the ions) [1] greater (attractive) force between the ion**s** [1]	**2**

32.

Question	Answer	Marks
1(a)	• enthalpy / energy change / given out / evolved / released • one mole is formed / made [1] • of compound / solid / lattice / crystal • (from) **gas**eous **ions** [1]	**2**
1(b)b	$S^-(g) + e^- \rightarrow S^{2-}(g)$ [1]	**1**
1(c)c	(555 + 200 – 532 = 223, 223 × 8 = 1784) M1 selecting correct data 555, 200, 532 **only**, (ignore signs and multipliers) [1] M2 evaluation to give +223 [1] M3 multiplying M2 by 8 and evaluation ans (+) 1784 [1]	**3**
1(d)	(1619 + 555 – 2612 = –438) M1 selecting correct data 1619 555 2612 only, (ignore signs and multipliers) [1] M2 evaluation to give –438 [1]	**2**
1(e)(i)	ionic radius / size / sum of ionic radii [1] ionic charge / product of ionic charges [1]	**2**
1(e)(ii)	M1 (size tends to make $\Delta H^{\ominus}_{latt}$ of radium sulfide) less exothermic since the ions are larger [1] M2 (charge tends to make $\Delta H^{\ominus}_{latt}$ of radium sulfide) less exothermic since the ions are more highly charged [1]	**2**
1(e)(iii)	(ionic) charge (since) **AND** $\Delta H^{\ominus}_{latt}$ of radium sulfide is more exothermic [1]	**1**

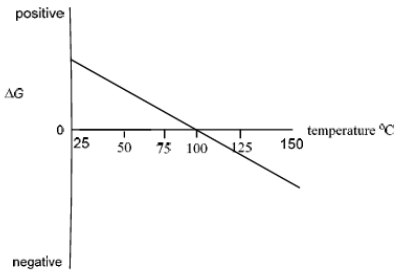
33.

3(e)(i)	–20 [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 / $T\Delta S$ becomes more negative / $-T\Delta S$ becomes more positive [1]	**1**

34.

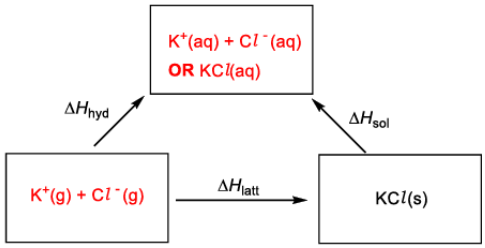
Question	Answer	Marks
4(a)(i)	**M1:** energy change when 1 mole of a ionic compound is formed **M2:** from its gaseous ions under standard conditions	**2**
4(a)(ii)	$\Delta H_{sol} = (-2099) + (2\times - 378) - (-2824)$ $\Delta H_{sol} = -31$ kJ mol^{-1} **M1:** use of $\times 2$ as only multiplier **M2:** correct signs and evaluation	**2**
4(a)(iii)	**M1:** Cu^{2+} is smaller **OR** Cu^{2+} has a higher charge density **M2:** Cu^{2+} attracts water molecules more / stronger **OR** (Cu^{2+}) forms stronger ion-dipole forces to water molecules	**2**

Question	Answer	Marks
4(c)(i)	measure / degree of (dis)order / randomness (of a system) **OR** the number of possible arrangements of the particles and their energy (in a given system)	**1**
4(c)(ii)	<table><tr><th></th><th>ΔS is negative</th><th>ΔS is zero</th><th>ΔS is positive</th></tr><tr><td>solid dissolving in water</td><td></td><td></td><td>✓</td></tr><tr><td>water solidifying to ice</td><td>✓</td><td></td><td></td></tr></table>	**1**
4(c)(iii)	 *two correct for 1 mark, three correct for two marks:* • starting at +8.6 kJ / in positive region close to the *y*-axis • line passes through *x*-axis around 100°C • negative gradient straight / curve line through the *x*-axis (no clear positive inflexions)	**2**
4(d)	**M1:** ΔH negative / –, ΔS negative / – **M2:** as temperature increase, ΔG becomes (more) positive / less negative ora **OR** at low(er) T, (ΔH more negative than $T\Delta S$) so ΔG is negative **OR** at high(er) T, (ΔH less negative than $T\Delta S$) so ΔG is positive	**2**

35.

Question	Answer	Marks
2(a)(i)	**M1** the only number extracted: 762, 1560, 496 **M2** correct multiplier, other four numbers used and calculation to the answer $-272 = +416 + ½(496) + 762 + 1560 - 141 + 798 + \Delta H_{lattice}$ $\therefore \Delta H_{lattice}$ = **–3915** (kJ mol^{-1}) ecf	**2**
2(a)(iii)	• FeO more exothermic/more negative • Fe^{2+} has smaller radius/higher charge density (also same charge) • greater attraction/ stronger ionic bonds (between Fe^{2+} and O^{2-}) **All three for two marks**	**2**

36.

Question	Answer	Marks
1(a)	 M1 K^+ (g) and Cl^- (g) **AND** KCl (aq) **OR** K^+ (aq) + Cl^- (aq) M2 three correct directional arrows COND M1	**2**
1(b)	use of data –155, –2493 **AND** 2 × –364 [1] ΔH_{hyd} Mg^{2+} = **–1920** (kJ mol^{-1}) [1] min 3sf	**2**
1(c)	• Mg^{2+} is **smaller** (than K^+) • Mg^{2+} is **greater charge** (than K^+) • greater **attraction** between Mg^{2+} and Cl^-/**between the ions** (in $MgCl_2$) **OR** stronger ionic bonds (in $MgCl_2$)	**2**
1(d)(i)	enthalpy change when **one mole** of **gaseous atoms** formed from the **element** (in its standard state at 298 K)	**1**
1(d)(ii)	enthalpy change when every atom in one mole of gaseous atoms gains one electron **OR** one mole of gaseous atoms gains one mole of electrons	**1**
1(e)(i)	number of possible arrangements of particles and energy in a system	**1**

Question	Answer	Marks
1(e)(ii)	ΔS is positive **AND** KCl(s) → K^+(aq) + Cl^-(aq) / ionic lattice solid forms aqueous **ions OWTTE** [1] **OR** ΔS is positive **AND** ΔG is (therefore becomes) negative / TΔS is greater than ΔH_{sol} **OWTTE** [1]	**1**
1(e)(iii)	**more soluble** **AND** ΔG is more negative at higher T / TΔS is more positive at higher T / –TΔS is more negative at higher **ecf from (e)(ii)** [sign ΔS]	**1**

37.

Question	Answer	Marks
1(a)	(energy change) when one mole of ionic solid is formed from gaseous ions	**1**
1(b)	(–2237 + 193 + 590 + 1150 + (2 × 121) – (2 × 364)) [1] = –790 [1]	**2**
1(c)	–342 **and** Br atom has larger radius	**1**
1(d)(i)	energy change when one mole dissolves in water [1] energy change when one mole of gaseous ions dissolves in water [1]	**2**
1(d)(ii)	(–2237 – 83 + 1650) / 2 [1] = –335 [1]	**2**
1(e)(i)	negative **and** reduction in number of gas molecules	**1**
1(e)(ii)	TΔS becomes more negative [1] less feasible **AND** ΔG becomes positive [1]	**2**

38.

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**

39.

Question	Answer	Marks
4(a)(i)	**M1** all five points plotted correctly **M2** best-fit straight line (ruler) with negative gradient drawn	**2**
4(a)(ii)	**M1** gradient correctly calculated **OR** gradient working seen **M2** gradient = $-\Delta S^o$ ΔS^o evaluated correctly ecf ΔS^o = (+)160 $\pm$ 10 (J K^{-1} mol^{-1})	**2**

40.

1(d)(i)	$-1473 = 180 + 503 + 965 + \Delta H^{\ominus}_f - 2469$ $\Delta H^{\ominus}_f$ of $SO_4^{2-}(g)$ = –652 kJ mol^{-1} **M1** correct five values used [1] **M2** only correct five values used [1] **M3** correct signs and evaluation [1]	**3**
1(d)(ii)	• $BaSO_4$ is more negative/bigger • as Ba^{2+} is smaller **OR** Ba^{2+} has a larger charge • stronger force of attraction between the ions One mark for two correct Two marks for all three correct	**2**

41.

1(d)(i)	$-1473 = 180 + 503 + 965 + \Delta H^{\ominus}_f - 2469$ $\Delta H^{\ominus}_f$ of $SO_4^{2-}(g)$ = –652 kJ mol^{-1} **M1** correct five values used [1] **M2** only correct five values used [1] **M3** correct signs and evaluation [1]	**3**
1(d)(ii)	• $BaSO_4$ is more negative/bigger • as Ba^{2+} is smaller **OR** Ba^{2+} has a larger charge • stronger force of attraction between the ions One mark for two correct Two marks for all three correct	**2**

42.

Question	Answer	Marks
2(a)(i)	1 mol liquid and 2 mol gas formed from 3 mol solid **OR** two solid compounds converted to a liquid and a gas	**1**
2(a)(ii)	M1: (as T increases) $T\Delta S$ becomes greater (than ΔH) **OR** (as T increases) $T\Delta S$ becomes more positive M2: (as T increases) feasibility will increase as ΔG becomes more negative	**2**
2(b)(i)	M1: = 314 + 131 – (19 + 3 $\times$ 187) use of values and correct stoichiometry M2: **= –135** (J K^{-1} mol^{-1})	**2**
2(b)(ii)	M1: $\Delta G = 0 \therefore T = \Delta H / \Delta S$ = +219.3 $\times$ 10^3 ÷ **–(b)(i)** M2: = **1624**(.4) (K)	**2**