Question Number	Acceptable Answers	Reject	Mark
1(a)(i)	Ammonia / barium chloride is toxic OR Ammonia / barium chloride is poisonous OR Barium hydroxide is corrosive / caustic OR Ammonia (solution) is corrosive OR Ammonium chloride is harmful / **eye**-irritant ALLOW Barium hydroxide is toxic / poisonous **IGNORE** Use of fume cupboard / gloves, etc	References to just 'barium' Ammonium chloride "is toxic"	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	$\Sigma S^{\ominus}_{(products)}$ = ((2 x 192) + (10 x 70) + 124 =) (+)1208 (J mol^{-1} K^{-1}) **(1)** $\Sigma S^{\ominus}_{(reactants)}$ = ((2 x 95) + 427 =) (+)617 (J mol^{-1} K^{-1}) **(1)** $\Delta S^{\ominus}_{system}$ = (1208 – 617 =) +591 J mol^{-1} K^{-1} Allow units in any order **(1)** Correct answer without working scores 3		**(3)**

Question Number	Acceptable Answers	Reject	Mark
***1(a)(iii**	(Positive value as expected because) 3 moles → 13 moles / more moles of products (than reactants) Allow 'molecules' for moles If numbers (of compounds) are stated, then these must be 3 and 13 **COMMENT:** Ignore any type of particle(s) mentioned **(1)** (Two) solids → a gas / a liquid (+ 1 solid) OR "No gaseous reactants, but gaseous products (formed)" **(1)**	**(0) Overall if** $\Delta S^{\ominus}_{system}$ **negative or entropy decrease**	**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(b)	$\Delta S^{\ominus}_{surroundings} = (-\Delta H \div T) = -\frac{162\,000 \text{ J mol}^{-1}}{298 \text{ K}}$ **(1)** $= -543.6241611/-544 \text{ J mol}^{-1} \text{ K}^{-1}$ Allow −0.544 **kJ** $\text{mol}^{-1} \text{ K}^{-1}$ **(1)** Correct answer without working scores 2 IGNORE sf except 1 sf	−543 543	**(2)**

Question Number	Acceptable Answers	Reject	Mark
1(c)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{system} + \Delta S^{\ominus}_{surroundings}$ $\Delta S^{\ominus}_{total}$ = ans (a)(ii) + ans (b) $= +591 - 544 = +47 \text{ J mol}^{-1} \text{ K}^{-1}$ TE on answers from (a)(ii) and (b)		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(d)	**M1:** $\Delta S^{\ominus}_{\text{surroundings}}$ becomes less negative / more positive smaller in MAGNITUDE (because you are dividing $-\Delta H$ by a larger T) IGNORE **Just** "smaller" / **just** "decreases" / **just** "bigger" / **just** "greater" **(1)** **M2:** $\Delta S^{\ominus}_{\text{system}}$ / ΔH are not (significantly) affected by a change in temperature **(1)** **M3:** (So) $\Delta S^{\ominus}_{\text{total}}$ increases ALLOW a TE for M3 $\Delta S^{\ominus}_{\text{total}}$ decreases, **only if** incorrect M1 (i.e. $\Delta S^{\ominus}_{\text{surroundings}}$ becomes "less positive") **(1)** Mark M1, M2 and M3 in any order within candidate's answer		**(3)**

Question Number	Acceptable Answers	Reject	Mark
1(e)(i)	(K = $e^{(-44/8.31)}$=) 0.005017/ 5.017 x 10^{-3} Ignore any units Allow any sf except 1 sf		**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(e)(ii)	Barium hydroxide will not be (very) soluble / will be sparingly soluble **and** K value suggests that the equilibrium lies to the left-hand side / reactants **OR** ($1x10^{-10}$<) K <1 so reactants predominant No TE on incorrect large value in (e)(i)	Just 'K is small'	**(1)**

Question Number	Acceptable Answers	Reject	Mark
1(e)(iii)	Hydroxides get more soluble as you descend Group 2 **(1)** **M2:** ΔS^{e}_{total} gets less negative / more positive as you go from $Ca(OH)_2$ to $Ba(OH)_2$ IGNORE **Just** "smaller" / **just** "decreases" / **just** "bigger" / **just** "greater" **(1)** ALLOW Reverse argument No TE on calculated value "more negative" for $Ba(OH)_2$ Mark M1 and M2 independently		**(2)**

TOTAL FOR QUESTION = 16 MARKS

Question Number	Acceptable Answers	Reject	Mark
2 (a)(i)	+89.6 – [+32.7 + 165] **(1)** = −108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} Value, sign and **units** **(1)** Ignore SF except one Internal TE for recognisable numbers allowed, for example: $\Delta H^{\ominus}_{at}$ magnesium chloride (147.7→ -223.1) Halving $S^{\ominus}$ [Cl_2] (82.5 → -25.6) Correct answer with no working **(2)** +/no sign 108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
2 (a)(ii)	(The sign is negative because) Any two from: • (A solid and) a gas reacting to form a solid. OR (Entropy decreases because) a gas reacting to form a solid. • There are fewer ways of arranging particles in a solid than a gas or vice-versa. OR Decrease in disorder as solid more ordered than gas or vice versa • Two mol(es) of reactant forming one mole of product. (Ignore two molecules form one molecule) OR Number of mol(es)/molecules decreases OR Fewer/less mol(es) of products than reactants	Energy... '(Positive) Answer is as expected...' **(0)**	**2**

Question Number	Correct Answer	Reject	Mark
2 (b)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{surroundings} + \Delta S^{\ominus}_{system}$ OR = +2152 + (-108.1) = (+)2043.9 Value 2043.9 / 2044 **(1)** = (+)2040 (J mol^{-1} K^{-1}) 3SF This mark conditional on correct value or correct TE value from (a)(i) **(1)** Accept TE from (a)(i), for example, -223.1 → +1928.9 → +1930 -25.6 → +2126.4 → +2130 Correct answer (2040, etc) with or without working scores 2		**2**

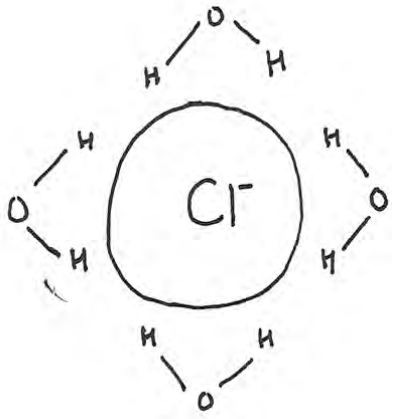
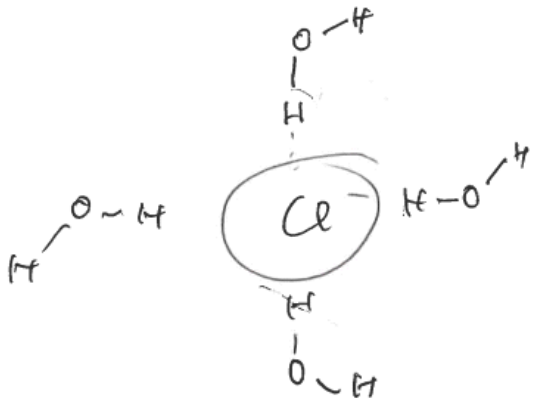
Question Number	Correct Answer1	Reject	Mark
2 (c)	$\Delta S^{\ominus}_{surroundings} = -\frac{\Delta H^{\ominus}}{298}$ $\Delta H^{\ominus} = -\Delta S^{\ominus}_{surroundings} \times 298$ OR $\Delta H^{\ominus} = -2152 \times 298$ **(1)** $= -641.296$ $= -641.3$ (kJ mol^{-1}) **(1)** ALLOW $= -641.3 \times 10^3$ **J mol^{-1}** Note 1. -640.1338 = -640.1 (if 2040/answer to part (b) used to recalculate entropy change of surroundings first.) **(2)** 2. $\Delta H^{\ominus} = +641.3$ (kJ mol^{-1}) **(1)** 3. $\Delta H^{\ominus} = -\frac{\Delta S^{\ominus}_{surroundings}}{298}$ **(0)** Ignore SF except one		**2**

Question Number	Correct Answer	Reject	Mark
2 (d)(i)	50 x 4.2 x 22.5 = 4725 (J) Ignore sign ALLOW 4.725 **kJ** Ignore SF except one		**1**

Question Number	Correct Answer	Reject	Mark
2 (d)(ii)	There are two legitimate answers to this part. If **both** methods have been used, you **must** send the item to review under mark scheme (−)4725 ÷ 0.0300 = −157.5 (kJ mol^{-1}) /−157500 **J mol^{-1}** OR (−)4725 ÷ 0.0500 = /−94.5 (kJ mol^{-1}) /−94500 **J mol^{-1}** ALLOW TE answer (d)(i) ÷ 0.0300/0.0500 Ignore SF except one Value **(1)** Sign **(1)** The mark for the negative sign is awarded for their calculation even if value is wrong, providing any **energy divided by moles or energy multiplied by 1/number of moles** calculation has been done.		**2**

Question Number	Correct Answer	Reject	Mark
2 (d)(iii)	There are two correct answers: Using 0.03 gives the answer of -381.75 kJ mol^{-1} Using 0.05 gives the answer of -350.25 kJ mol^{-1} Both these answers score full marks with or without correct working. **First mark** Appreciation of Hess's Law either in words, numbers, symbols or on the diagram For example, $\Delta H_{solution}$ + Lattice energy $= \Delta H_{hydration}\, Mg^{2+} + (2)\Delta H_{hydration}\, Cl^{-}$ **(1)** **Second mark** $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 157.5 -$ $(-1920) = -763.5$ OR $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 94.5 -$ $(-1920) = -700.5$ ALLOW Any number or group of numbers minus (-1920) **(1)** **Third mark** $\Delta H_{hydration}\, Cl^{-} = -381.75$ (kJ mol^{-1}) OR $\Delta H_{hydration}\, Cl^{-} = -350.25$ (kJ mol^{-1}) Any number, wherever it has come from,		**3**

	divided by two can score this mark, provided that the sign is consistent. **(1)** Ignore SF except one Use of lattice energy – 2326 gives −281.75/−250.25 scores **(2)** ALLOW TE from (d)(ii)		

Question Number	Correct Answer	Reject	Mark
2 (d)(iv)	 OR  • One/several water molecule(s) all correctly orientated. • $H^{\delta+}$/ hydrogen (one or two hydrogens from each water molecule) towards chloride ion • with negative charge either on chlorine or on the whole hydrated ion. ALLOW • A minus sign with a ring around it for the Cl^- • Bonds shown by lines/broken lines/dotted lines/wedges	**$Cl^-.H_2O$** $H^{\delta-}$ / H^+ / H^- $Cl^{\delta-}$ / Cl (with no charge)	**1**

Question Number	Correct Answer	Reject	Mark
2(d)(v)	Both marks may be awarded in either part. **First mark** (Temperature increases) because the reaction/process/dissolving/hydration of ions is **exothermic**. OR Strong(er) forces between the δ+ H and Cl^- OR Strong(er) forces between the δ– O and Mg^{2+} OR Strong(er) ion-dipole forces OR Formation of bonds releases energy OR Strong(er) bonds formed OR Enthalpy of hydration is greater than lattice energy **(1)** **Second mark** (Volume decreases so) shorter bonds between ion and water molecules ALLOW Water molecules more tightly arranged/pack better/occupy less space OR Water molecules more ordered/ clustered (around the ions). **(1)**	The breaking of the lattice is exothermic. Ions more tightly arranged Ions more ordered	**2**

Question Number	Acceptable Answers	Reject	Mark
3(a)(i)	+104.6 – [+41.4 +165] **(1)** = -101.8 J mol^{-1} K^{-1} Value, sign and unit **(1)** Ignore SF except one Internal TE allowed for recognisable numbers, for example: $\Delta H^{\ominus}_{at}$ calcium instead of $S^{\ominus}$ (178.2 → -238.6) OR Halving $S^{\ominus}$ [Cl_2] (82.5 → -19.3) Correct answer with no working **(2)** +/no sign 101.8 J mol^{-1} K^{-1} **(1)**		2

Question Number	Acceptable Answers	Reject	Mark
3 (a)(ii)	(The sign is negative because) Any two from: • (A solid and) a gas reacting to form a solid. OR (Entropy decreases because) a gas reacting to form a solid. • There are fewer ways of arranging particles in a solid than a gas or vice-versa. OR Decrease in disorder as solid more ordered than gas or vice versa • Two mol(es) of reactant forming one mole of product. (Ignore two molecules form one molecule) OR Number of mol(es)/molecules decreases OR Fewer/less mol(es) of products than reactants **COMMENT** If answer to (a)(i) is positive then answer should start 'Answer is not as expected because...' Then score as above (which can score full marks).	 Energy...	2

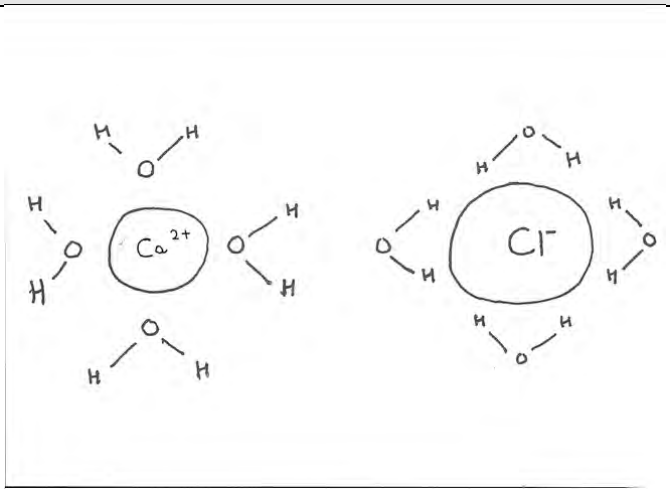
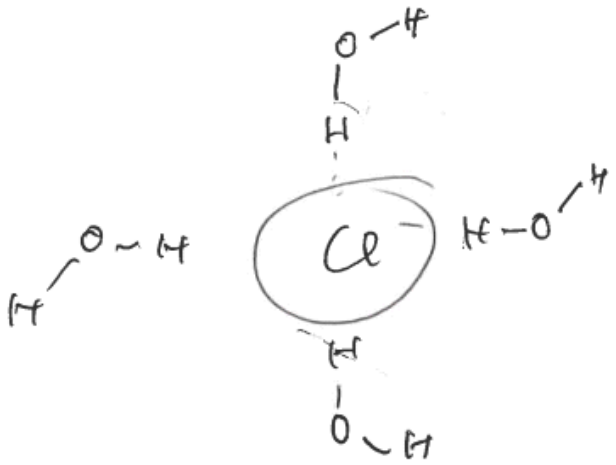
Question Number	Correct Answer	Reject	Mark
3 (b)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{surroundings} + \Delta S^{\ominus}_{system}$ OR = +2670 + (-101.8) = (+)2568.2 Value 2568.2/2568 **(1)** = (+)2570 (J mol^{-1} K^{-1}) 3SF This mark is conditional on correct value or correct TE value from (a)(i) **(1)** Accept TE from (a)(i) -238.6 → +2431.4 → +2430 -19.3 → 2650.7 → +2650 Correct answer (2570, etc) with or without working scores (2)		2

Question Number	Correct Answer1	Reject	Mark
3 (c)	$\Delta S^{\ominus}_{surroundings} = - \frac{\Delta H^{\ominus}}{298}$ $\Delta H^{\ominus} = - \Delta S^{\ominus}_{surroundings} \times 298$ OR $= -2670 \times 298$ **(1)** $= -795.660$ $= -795.7$ (kJ mol^{-1}) **(1)** ALLOW $= -795.7 \times 10^3$ **J mol^{-1}** Note 1. -796 = -796.1964 (if 2570 used to calculate entropy change of surroundings first.) 2. $\Delta H^{\ominus}$ (= + $\Delta S^{\ominus}_{surroundings}$ x 298) = +795.7 (kJ mol^{-1}) **(1)** But $\Delta H^{\ominus} = - \frac{\Delta S^{\ominus}_{surroundings}}{298}$ **(0)** Ignore SF except one		2

Question Number	Correct Answer	Reject	Mark
3 (d)(i)	50 x 4.2 x 15.0 = 3150 (J) Ignore sign ALLOW 3.15 **kJ** Ignore SF except one		1

Question Number	Correct Answer	Reject	Mark
3 (d)(ii)	3150/0.05 or 20 x 3150 = -63 (kJ mol^{-1}) /-63000 **J mol^{-1}** Allow TE answer (d)(i) / 0.05 Ignore SF except one Value **(1)** Sign **(1)** The mark for the negative sign is awarded for the calculation even if the value is wrong, providing any **energy divided by moles or energy multiplied by 1/number of moles** calculation has been done.		2

Question Number	Correct Answer	Reject	Mark
***3(d)(iii)**	The correct answer: -380.5/-381 kJ mol^{-1} Full marks with or without correct working. **First mark** Appreciation of Hess's Law either in words, numbers, symbols or on the diagram For example, $\Delta H_{solution}$ + Lattice energy $= \Delta H_{hydration}\, Ca^{2+} + (2)\Delta H_{hydration}\, Cl^{-}$ **(1)** **Second mark** $2\ \Delta H_{hydration}\, Cl^{-} = -2258 - 63 -$ $(-1560) = -761$ ALLOW Any number or group of numbers minus (-1560) **(1)** **Third mark** $\Delta H_{hydration}\, Cl^{-} = -380.5/-381$ (kJ mol^{-1}) Any number, wherever it has come from, divided by two can score this mark, provided that the sign is consistent. **(1)** Ignore SF except one Use of lattice energy – 2223 gives −363 scores **(2)** ALLOW TE from (d)(ii)		3

Question Number	Correct Answer	Reject	Mark
3 (d)(iv)	 OR 	**$Cl^-.H_2O$**	2
	• One/several water molecule(s) all correctly orientated.		
	• $H^{\delta+}$/ hydrogen (one or two hydrogens from each water molecule) towards chloride ion and O / oxygen (one oxygen from each water molecule) towards calcium ion	$H^{\delta-}$ / H^+ / H^-	
	• With negative charge either on chlorine or on the whole hydrated ion and with double positive charge either on calcium or on the whole hydrated ion.		
	ALLOW		
	• A minus sign with a ring around it for the Cl^- and a 2+ sign with a ring around it for the Ca^{2+}	$Cl^{\delta-}$ / Cl (with no charge)	
	• Bonds shown by lines/broken lines/dotted lines/wedges		

Question Number	Correct Answer	Reject	Mark
3(d)(v)	Both marks may be awarded in either part. **First mark** (Temperature increases) because the reaction/process/dissolving/hydration of ions is **exothermic**. OR Strong(er) forces between the δ+ H and Cl^- OR Strong(er) forces between the δ– O and Mg^{2+} OR Strong(er) ion-dipole forces OR Formation of bonds releases energy OR Strong(er) bonds formed OR Enthalpy of hydration is greater than lattice energy **(1)** **Second mark** (Volume decreases so) shorter bonds between ion and water molecules ALLOW Water molecules more tightly arranged/pack better/occupy less space OR Water molecules more ordered/ clustered (around the ions). **(1)**	The breaking of the lattice is exothermic. Ions more tightly arranged Ions more ordered	2

Question Number	Acceptable Answers	Reject	Mark
4(a)	Units are not required in (a) or (c) but if used should be correct. Penalise incorrect units in (a), (b) & (c) once only IGNORE case of J and K order of units **First mark:** 65.3/ 130.6 **and** 69.9 (J mol^{-1} K^{-1}) **(1)** **Second mark:** ΔS = 69.9 − (130.6 +102.5) **(1)** **Third mark:** ΔS = −163.2 = −163 (J mol^{-1} K^{-1}) **(1)** Correct answer with no working scores 3 Ignore SF except 1 SF TE at each stage If 65.3 used instead of 130.6 penalize once (answer is then ΔS = −97.9 (J mol^{-1} K^{-1})	+163 or an positive answer	**3**

Question Number	Acceptable Answers	Reject	Mark
4(b)	$\Delta S_{surroundings}$ = − ΔH / T or just numbers **(1)** = +285800/298 = +959.06 = +959 J mol^{-1} K^{-1} / +0.959 kJ mol^{-1} K^{-1} Correct value to 3SF **(1)** Correct units and positive sign **(1)** Correct answer with no working scores 3	answer with no sign	**3**

Question Number	Acceptable Answers	Reject	Mark
4(c)	$\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$ **(1)** Allow $\Delta S_{reaction}$ for ΔS_{system} ΔS_{total} = answer (a) + answer (b) $= -163.2 + 959$ $= (+)795.8 = (+)796$ (J mol^{-1} K^{-1}) If $\Delta S_{surroundings} = +959.06$ then $\Delta S_{total} = +795.9$ **(1)** Correct answer with no working scores 2 Ignore SF except 1 SF TE on values in (a) & (b) no TE on incorrect equation If answer to (a) = -97.9 (J mol^{-1} K^{-1}) ΔS_{total} = (+)861.1 (J mol^{-1} K^{-1})		**2**

Question Number	Acceptable Answers	Reject	Mark
4(d)	A mixture of hydrogen and oxygen is **thermodynamically** unstable **because** ΔS_{total} is positive OR Reaction between hydrogen and oxygen is **thermodynamically** feasible **because** ΔS_{total} is positive ALLOW ΔS for ΔS_{total} **(1)** No TE on negative ΔS_{total} from (c) The mixture is kinetically inert /stable or reaction is (very) slow **because** the activation energy is (very) high **(1)** Mixture / reaction is **kinetically** inert / stable but **thermodynamically** unstable / feasible scores 1 mark IGNORE References to spark / flame providing the (activation) energy for reaction	Reference to the stability of individual elements	**2**