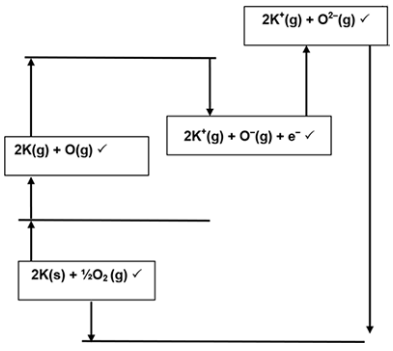
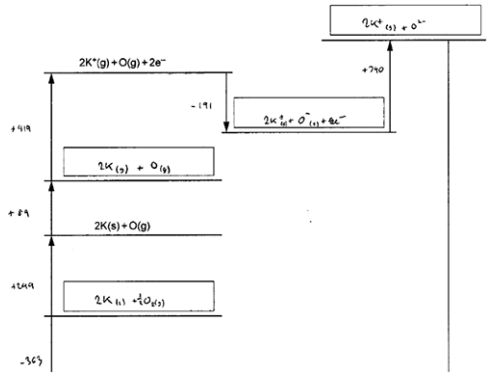
Mark scheme – Lattice Enthalpy

Question			Answer/Indicative content	Marks	Guidance
1		i	$Mg^{2+}(g) + 2Br(g) + 2e^- \checkmark$ $Mg(s) + Br_2(l) \checkmark$	2 (AO 1.2× 2)	State symbols required. **CARE**: Liquid state symbol for Br_2 **Examiner's Comments** Many candidates got the second ionisation energy equation. Very few candidates got the correct state symbol on the lower line for Br_2, with solid being the common response.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –346.5 award 2 marks** ---------- 2Δ*H* hyd = – 525 – 186 – (2 x 112) – 148 – 736 – 1450 + (2 x -325) + 1926 **OR** – 525 – 186 – 224 – 148 – 736 – 1450 + 650 + 1926 **OR** = – 693 ✓ Δ*H* hyd = –346.5 (kJ mol^{-1}) ✓	2 (AO 2.2×2)	**ALLOW** -347 (kJ mol^{-1}) for **2 marks**. **ALLOW** for 1 mark **ONE** error with sign **OR** use of 2: –693 (not divided by 2 at the end) 346.5 (wrong sign on answer) **Common errors for 1 mark** –2272.5 (–1926 instead of 1926) -1386 (**2 x** -693 instead of -693) –996.5 (–650 instead of 650) –509 (**2 ×** 325 not used) –290.5 (**2 ×** 112 not used) –198.5 (148 instead of –148) –160.5 (186 instead of –186) –122.5 (224 instead of –224) 178.5 (525 instead of –525) 389.5 (736 instead of –736) 1103.5 (1450 instead of –1450) **For other answers**, check for a **single** transcription error or calculation error which could merit 1 mark **DO NOT ALLOW** any answer which involves two errors e.g. –453 (**2** × 325 not used **AND 2 x** 112 not used)
		iii	**Equation:** $Mg^{2+}(g) + 2Br^-(g) \rightarrow MgBr_2(s) \checkmark$ **CHECK THE ANSWER ON ANSWER LINE** **If answer = –2433 award 2 marks** ---------- Lattice enthalpy = $\Delta_{hy}H(Mg^{2+}) + 2 \times \Delta_{hy}H(Br^-) - \Delta_{sol}H(MgBr_2)$ **OR** -1926 + (2 x -346.5) – (-186)	3 (AO 1.2) (AO 2.2 x 2)	State symbols required **For other answers**, check for a **single** transcription error or calculation error which could merit 1 mark **DO NOT ALLOW** any answer which involves two errors

			OR $\Delta_f H(MgBr_2) - 2\Delta_{at}H(Br) - \Delta_{at}H(Mg)$ – 1st IE(Mg) – 2nd IE(Mg) – $2\Delta_{ea}H(Br)$ **OR** -525 – (2 x 112) – 148 – 736 – 1450 – (2 x -325) ✓ **Lattice enthalpy** = –2433 kJ mol^{-1} ✓		**ALLOW ECF** from incorrect answer to (ii) **Examiner's Comments** This Born Haber cycle combined the traditional cycle with the enthalpy solution/hydration cycle. Many candidates were successful in calculating the values from the information given and showed full working to complete the calculation. The commonest errors were not doubling the atomisation and electron affinity values (112 and 325) and not dividing the enthalpy of hydration by two. Some candidates did not show working or just listed numbers. Candidates should remember to provide written indications of what it is they are working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation. Some candidates did not produce an equation for (iii) and wrote the lattice enthalpy sum in its place.
			Total	**7**	
2	a	i		4 (AO 1.2 ×4)	Mark each marking point independently Correct species **AND** state symbols required for each mark For e^-, **ALLOW** e For e^- **only**, **IGNORE** any state symbols added **Examiner's Comments** Some candidates wrote illegible state symbols where (g) and (s) were impossible to tell apart. Also, many candidates choose to write state symbols as a very small sub-script e.g. $2K_{(s)} + ½O_{2(g)}$. The convention is to use lower case letters of normal size e.g. 2K(s) + ½O_2(g) **Exemplar 1** 

					In this exemplar it was impossible to tell if K had (s) or (g) as a state symbol. Consequently, no marks could be given.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –2277 (kJ mol^{-1}) award 2 marks** –363 – (2 × +89 +249 + 2 × 419 – 141 + 790) ✓ –363 – 1914 = –2277 ✓ (kJ mol^{-1})	2 (AO 2.2 ×2)	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **See list below for marking of answers from common errors** **ALLOW** for 1 mark **ONE** mistake with sign **OR** use of 2 ×: +2277 (wrong sign) –601 (2 × –419 instead of 2 × +419) –697 (–790 instead of +790) –1551 (+363 instead of –363) –1858 (2 × +419 not used for K) –1921 (2 × –89 instead of 2 × +89) –2152.5 or –2153 (+249 ÷ 2) –2188 (2 × +89 not used for K) –2280 (rounded to 3SF) –2559 (+141 instead of –141) **For other answers**, check for a **single** transcription error or calculator error which could merit 1 mark **<u>Examiner's Comments</u>** Most candidates scored both marks. Candidates tended to forget the mole ratio of K meant its values should be multiplied by 2 in two places during this calculation.
	b	i	*For sodium* **atomic** radius smaller **OR** fewer shells ✓ nuclear **attraction** increases **OR** (outer) electron(s) experience more **attraction** ✓	2 (AO 1.1 ×2)	**ALLOW** 'Na/sodium is smaller' **IGNORE** smaller radius / fewer shells / less shielding if applied to ions but **DO NOT ALLOW** responses which refer to ions losing electrons **DO NOT ALLOW** molecules **ALLOW** energy levels for shells **IGNORE** fewer orbitals **OR** fewer sub–shells **ALLOW less** (electron) shielding **OR** electron repulsion between shells **IGNORE** just 'shielding' **ALLOW** more/stronger/bigger nuclear attraction etc **IGNORE** 'pull' for attraction **IGNORE** electrons more tightly held **IGNORE** 'nuclear charge' for 'nuclear attraction'

					IGNORE more energy (in question) **ALLOW** reverse argument for potassium throughout **Examiner's Comments** Candidates coped well with this question which was based on the AS part of the specification. Some candidates gave vague and unnecessarily long responses to this question.
		ii	***Comparison of size of cations*** For sodium ions ionic radius of sodium / Na^+ is small**er** ✓ ***Comparison of attraction of cation and anion*** Na^+ has stronger attraction to O^{2-} ✓	2 (AO 1.2 ×2)	comparison of **IONS** is essential **ALLOW** Na^+ has a larger charge density **IGNORE** 'Na has smaller atomic radius' but **DO NOT ALLOW** contradictory sentences eg 'Na+ ions have smaller atomic radius' **IGNORE** pull for attraction **ALLOW** 'sodium ion' and 'oxygen ion' **IGNORE** just 'oxygen' or just 'O' for oxygen ion **ALLOW** stronger attraction between oppositely charged ions **Examiner's Comments** Many candidates did not achieve full marks, often through ambiguous statements. A typical example is shown in the exemplar below. **Exemplar 4** It takes less energy to form the bonds in sodium oxide as opposed to potassium oxide due to its smaller ionic size making it easier for the oxygen to bond. [2] The exemplar here uses the vague term 'due its smaller ionic size'. It is unclear which of the ions the candidate is referring to (or if they're assuming that the metal oxide entity is an ion) and so they could not be given marks.. Also, it is oxygen ions that 'bond' – the reference to oxygen bonding in the response is not specific enough.
			Total	**10**	

3		i	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Calculates **CORRECT** enthalpy change with correct – signs for $\Delta_{sol}H$ ($CuSO^4(s)$) for **reaction 5.2** **AND** Δ_rH, for **reaction 5.1.** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Calculates a value of $\Delta_{sol}H$ ($CuSO_4(s)$) for **reaction 5.2** from the: Energy change **AND** Amount in mol of $CuSO_4$. *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Processes experimental data to obtain the: Energy change from *mc*ΔT **OR** Amount in mol of $CuSO_4$. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** – No response or no response worthy of credit	6 AO3.1x 4 AO3.2x 2	*Indicative scientific points may include:* **1. Processing experimental data** **Energy change from *mc*ΔT** • Energy in J **OR** kJ *Using 50.70 g, 50.0 g* = **50.70** × 4.18 × 13.5 = **2861** (J) **OR** 2.861 (kJ) *3SF or more (2.861001 unrounded)* **OR 50.0** × 4.18 × 13.5 = **2821.5** (J) **OR** 2.8215 (kJ) **Amount in mol of $CuSO_4$** • $n(CuSO_4) = \frac{7.98}{159.6} = 0.0500$ (mol) --- **2. ± value of $\Delta_{sol}H(CuSO_4(s))$ for reaction 5.2** From m = 50.70 g = $\pm\frac{2.861}{0.0500}$ = **±57.22** (kJ mol^{-1}) *(–57.22002 unrounded)* From m = 50.0 g = $\pm\frac{2.8215}{0.0500}$ = **±56.43** (kJ mol^{-1}) --- **3. CORRECT enthalpy changes for reactions 5.2 and 5.1 with signs (using 50.70 g ONLY)** **Reaction 5.2** = **–57.22** (kJ mol^{-1}) *3SF or more with correct – sign* **Reaction 5.1** $\Delta_rH = \Delta_{sol}H(CuSO_4(s)) - \Delta_{sol}H(CuSO_4•5H_2O(s))$ = –57.22 – 8.43 = –65.65 (kJ mol^{-1}) *3SF or more with correct – sign* **NOTE:** *A clear and logically structured response would include an energy cycle* **ALLOW** omission of trailing zeroes **ALLOW** minor slips

Examiner's Comments

This question was assessed by level of response (LoR). Candidates were required to process raw experimental results to determine one enthalpy change, and then to determine a second enthalpy change by constructing and using an energy cycle. Levels were determined by the accuracy of the candidates' processing, calculations and use of the energy cycle. This question discriminated extremely well.

Level 3 candidates used the mass of solution as 50.7 g with $mc\Delta T$ to obtain an energy change of 2861 J. They then divided this value by the moles of $CuSO_4$ that reacted (0.05 mol) to obtain the enthalpy change of –57.22 kJ mol^{-1}. Finally, they constructed an energy cycle which they then used to obtain the second enthalpy change of –65.65 kJ mol^{-1}.

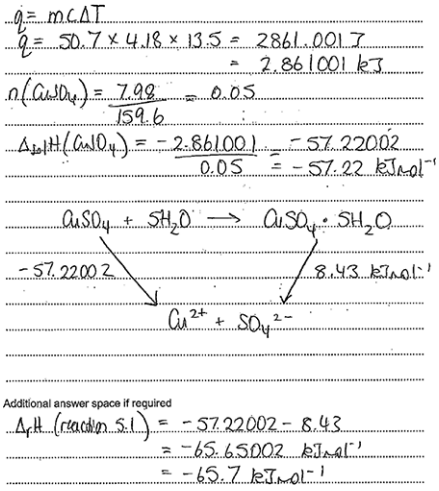
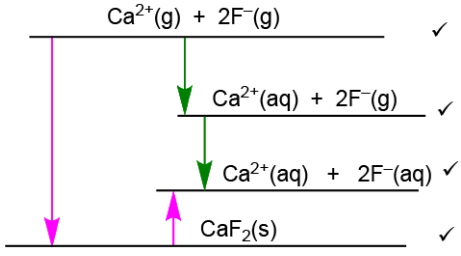
Level 2 candidates determined the first enthalpy change but may have used the approximate mass of 50 g for the mass of solution from the experimental method. Their energy cycle was often incorrect or absent, with the second enthalpy change calculated incorrectly.

Level 1 candidates often calculated the initial energy change using $mc\Delta T$ but made little further correct progress.
A significant number of lower ability candidates used the solid mass of copper sulfate in their calculation.

Overall, mathematical skills were displayed well but some basic errors were made, particularly with subtractions. This may have been the result of mis-keying values into a calculator and believing the answer displayed. An example was the mass of the solution (74.13 – 23.43) being seen as 49.7 rather than 50.7.

A significant number of candidates added or subtracted the mass of copper sulfate from 50.7 or 50 for their value of m in $mc\Delta T$, using for example 57.98 and 42.72. This limited the level that they could reach.

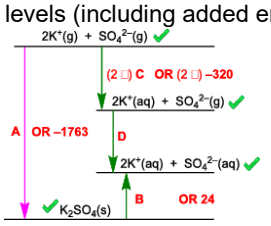
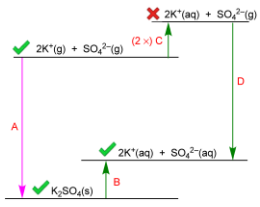
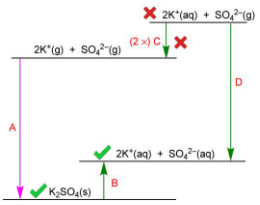
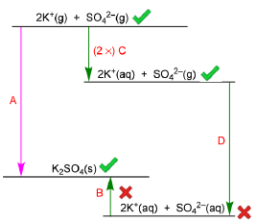
Exemplar 4 is an excellent response from a Level 3 candidate. All stages can be clearly followed, the initial energy change using $mc\Delta T$, the first enthalpy change using the

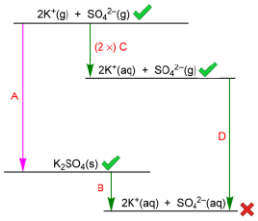
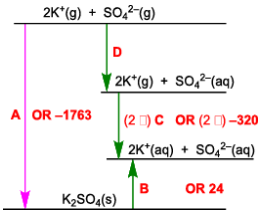
					energy change with the moles of copper sulfate, and the second enthalpy change including a clear energy cycle. Numbers are clearly shown and unrounded until the final values. This is an excellent response. **Exemplar 4** 
		ii	Temperature change = $0.2 \times \frac{100}{20}$ **=1(.0)°C** ✓	1 AO 2.8	**IGNORE** direction of temperature change Working **NOT** required **Examiner's Comments** Just over half the candidates obtained the correct temperature change of 1°C. A common error was a temperature change of 0.5°C, the result of not considering that two temperature readings are made when calculating a temperature change.
			Total	**7**	
4		i	(enthalpy change when)✓ 1 mole of gaseous ions react✓ **OR** 1 mole of hydrated/aqueous ions are formed ✓ gaseous ions dissolve in **water** **OR** gaseous ions form aqueous/hydrated ions ✓	**2**	**IGNORE** 'energy released' OR 'energy required' **Examiner's Comments** Most candidates were able to state that one mole of gaseous ions was dissolved into water. Common errors seen included candidates referring to the dissolving of one mole of substance (i.e. the enthalpy change of solution); the use of the generic term 'solvent' rather than water; and dissolving of gaseous ions into one mole of water.
		ii	 	**4**	Correct species **AND** state symbols required for each mark. (mark independently) On 2nd line, **ALLOW** $Ca^{2+}(g) + 2F^{-}(aq)$ (i.e. F^- hydrated before Ca^{2+})

					On 3rd line, **ALLOW** $CaF_2(aq)$ **DO NOT ALLOW** when first seen but **ALLOW ECF** for ' 2' missing and for use of the following ions F^- F2✓ $Ca^{+/3+}$ **Examiner's Comments** Most candidates were able to score some marks on this question with more able candidates scoring all 4 marks. Common errors included the omission of state symbols and the use of only one F−(g) ion (often despite a correct formula of CaF2 being seen on the bottom line). For some reason, many candidates write their lower case 's' in an identical way to their lower case 'g'. This means the examiner cannot distinguish between these state symbols on such scripts. Centres may wish to stress this point to prevent candidates losing marks unnecessarily.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = −504 (kJ mol^{-1}) award 2 marks** **IF answer = −1008 (kJ mol^{-1}) award 1 mark** --- $2 \times \Delta_{hyd}H(F^-)$ = [−2630 + 13] − (−1609) **OR** −2617 + 1609 **OR** −1008(kJ mol^{-1}) ✓ $\Delta_{hyd}H(F^-) = \frac{-1008}{2} = -504$ ✓ (kJ mol^{-1})	**2**	**IF** alternative answer, check to see if there is any **ECF** credit possible using working below. '−' sign is needed. **COMMON ERRORS** for 1 mark: (+)2694: *signs all reversed* −2113: *sign wrong for −1609* −2126: *sign wrong for 2630* −517: *sign wrong for 13* +504: *sign wrong* **IF ALL 3 relevant values from the information at the start of Q16a(iii) have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF** **Examiner's Comments** Most candidates were able to do this relatively straightforward calculation by rearranging the values of the enthalpy changes associated with the energy cycle diagram. However, a significant number forgot to divide –1008 by 2 to score full marks.

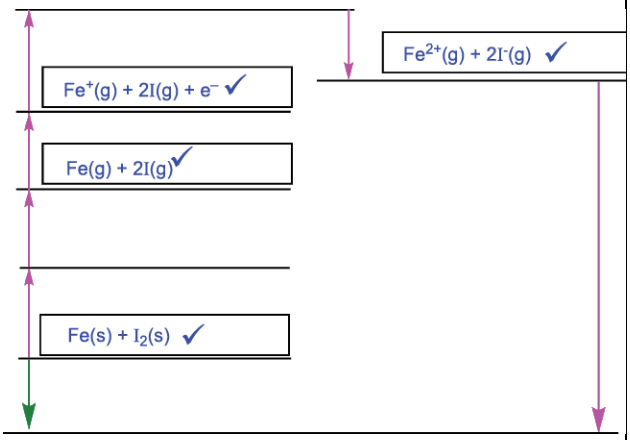
		iv	**Correct comparison of Δ_{hyd} linked to sizes** $\Delta_{hyd}H(F^-)$ more negative/exothermic (than $\Delta_{hyd}H(Cl^-)$) **AND** F^- has smaller size (than Cl^-) ✓ ***Comparison of attraction between ions and water*** F^- OR smaller sized ion linked to greater attraction **to H_2O** ✓	**2**	**ORA** **IGNORE** 'atomic' before radius when comparing size of ions **IGNORE** charge density **IGNORE** electronegativity **IGNORE** nuclear attraction **DO NOT ALLOW** 'forms stronger hydrogen bonds with water' OR 'forms stronger van der Waals' forces with water' **ALLOW** 'forms bonds' for attraction' **DO NOT ALLOW** F^- greater attraction to H_2O if given as larger ion Assume 'F' / 'Fluorine' means 'ions' but **DO NOT ALLOW** 'F molecules' **<u>Examiner's Comments</u>** When comparing enthalpy changes candidates need to be aware that descriptions such as 'bigger' or 'smaller' are meaningless as there are often negative signs involved. The correct description required here was that the enthalpy change of hydration of F^- ions would be more negative than that of Cl^- ions. Although some candidates wrote in terms of charge density, it was those candidates who related the smaller size of the F^- ion to the difference in enthalpy change of hydration who received credit and went on to say that this was as a consequence of greater attraction to water molecules.
			Total	**10**	
5		i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_{sol}H$ = −43.3 (kJ mol^{-1}) award 4 marks** ***Energy released in J OR kJ*** =113.42 × 4.18 × 10.5 = 4978 (J) **OR** 4.978 (kJ) ✓ ***Correctly calculates $n(H_2SO_4)$*** $\frac{11.28}{98.1}$ = 0.115 (mol) ✓ **ΔH value in J OR kJ** *Answer **MUST** divide energy by $n(H_2SO_4)$*	4	***FULL ANNOTATIONS MUST BE USED*** **Calculator:** 4978.0038 **DO NOT ALLOW** less than 3 SF **IGNORE** units **ALLOW** *correctly calculated number in J **OR** kJ* **Calculator** 0.1149847095

			(–) $\frac{4978}{0.115}$ **OR** (−)43286 (J) **OR** (–) $\frac{4978}{0.115}$ **OR** (−)43.3 (kJ) ✓ *(Sign ignored and/or more than 3 SF)* Correct $\Delta_{sol}H$ in kJ **AND** − sign **AND** 3 SF = −43.3 (kJ mol^{-1}) ✓		**ALLOW ECF** from $n(H_2SO_4)$ **AND/OR** Energy **Calculator from 4978 and 0.115 = 43286.95652 From unrounded values, = 43292.74581** **IGNORE** absence of − sign and **3 SF** requirement Final mark requires − sign, kJ **AND** 3 SF **NOTE:** Use of 100 for m → 4389 J **ECF** available for → −38.2 kJ mol^{-1} (3 marks)
		ii	$\frac{0.5}{10.5} \times 100 \times 2 = 9.5\%$ ✓ *One decimal place required*	1	
		iii	**Predictions** ΔT is less **AND** $\Delta_{sol}H$ is the same ✓ **Reason for ΔT less** (same) energy/heat spread over larger volume (of water) ✓ ΔT = 7°C ✓ **Reason for $\Delta_{sol}H$ same** Same energy released per mole of H_2SO_4 ✓	4	**ALLOW** heat spread over more water **ALLOW** 6−8 °C **Note**: m is ~ 1/3 larger. $q = mc\Delta T$ and so ΔT will be ~ 1/3 smaller **ALLOW** $\Delta_{sol}H$ is for dissolving 1 mol
			Total	**9**	
6	a		(enthalpy change for) 1 mole of gaseous ions **OR** 1 mole of hydrated ions / aqueous ions ✓ gaseous ions forming aqueous / hydrated ions ✓	2	**one mole** can be stated just once **EITHER** with gaseous ions **OR** with aqueous ions, e.g. • 1 mole of gaseous ions **forms** hydrated ions / aqueous ions • Gaseous ions **form 1 mole of** hydrated ions / aqueous ions **ALLOW** 1 mol for 1 mole **IGNORE** 'energy released' **OR** 'energy required'

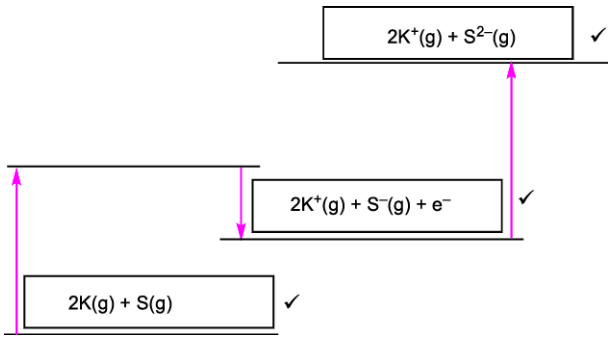
					For 2nd mark **IGNORE** gaseous ions are hydrated **IGNORE** gaseous ions dissolve in water ***Particles formed not stated*** **ALLOW** 1 mark for: 1 mole of gaseous **IONS** forms aqueous / hydrated **atoms / particles / molecules** **Examiner's Comments** This question assessed enthalpy changes in aqueous solutions. Most candidates were awarded both marks for a clear definition stating that 1 mole of gaseous ions formed 1 mole of aqueous ions. Some candidates instead gave a definition for enthalpy change of solution.
	b	i	**4 marks** for species **AND** state symbols on all 4 energy levels (including added energy level)  **1 mark** for **B**, **C AND D** labels **OR** enthalpy values **AND** arrow directions correct ✓ **ALLOW** $K_2SO_4(aq)$ for $2K^+(aq) + SO_4^{2-}(aq)$ **ALLOW** arrows not touching lines. **Direction** is important: • **FROM** $2K^+(g) + SO_4^{2-}(g)$ line • **FROM** $K_2SO_4(s)$ line Extra energy line placed **ABOVE** top line 3 out of 4 marks awarded for energy lines and species. Top arrow is shown **FROM** $2K^+(g) + SO_4^{2-}(g)$ and arrow directions correct. Letter labels correct so last mark is awarded. **4/5 marks**  Extra energy line placed **BELOW** bottom line 3 out of 4 marks awarded for energy lines and species.	5	**IF** extra energy level is **above** top line **OR below** bottom line, **DO NOT ALLOW** mark for species on this line. Same as left-hand response **BUT** top arrow shown **TO** $2K^+(g) + SO_4^{2-}(g)$ so last mark not awarded **3/5 marks**  Same as left-hand response **BUT** bottom arrow shown **TO** $K_2SO_4(s)$ so last mark not awarded **3/5 marks**  **ALLOW C** and **D** with associated labels, the other way round:

			Top arrow is shown **FROM** $K_2SO_4(s)$ and arrow directions correct. Letter labels correct so last mark is awarded. **4/5 marks**  '2 ×' is **NOT** required – *part of calculation mark*		 State symbols are **essential** **IF** no extra energy level is shown with **C** and **D** combined forming $2K^+(aq) + SO_4^{2-}(aq)$, • No mark for the extra energy level with species • No mark for labels as **C** and **D** are combined Therefore 3 max for species on energy levels provided **Examiner's Comments** This question assessed enthalpy changes in aqueous solutions. Many candidates successfully completed the energy cycle to obtain all marks. Correct species and state symbols are essential in such cycles and marks could not be awarded for species such as $K^-(g)$ or $SO_4^-(g)$. Poorly-prepared candidates often scored no marks at all, having shown random species on the energy levels. Candidates are advised to ensure that the state symbols (s) and (g) are clearly distinguished.
		ii	ΔH(hydration) SO_4^{2-} = **−1099** (kJ mol^{-1}) ✓	1	**ONLY** correct answer **Examiner's Comments** This question assessed enthalpy changes in aqueous solutions. Although many candidates correctly calculated the lattice enthalpy, errors were common. A common error was use of −320 (instead of 2 × −320) giving −1419. Answer = −1099 kJ mol^{-1}
	c	i	**Aqueous** particles are more disordered than **solid** (particles) **OR** **Solid** particles are more ordered than **aqueous** (particles) ✓	1	For particles, **ALLOW** ions **DO NOT ALLOW** molecules / atoms **ALLOW** 'When the state changes from solid to aqueous, disorder increases'

					For more disordered, **ALLOW** less ordered / more freedom / more ways of arranging energy / more random For aqueous particles, **ALLOW particles in solution** **IGNORE** dissolved **Examiner's Comments** This question assessed enthalpy changes in aqueous solutions. In this part, candidates needed to recognise that solid particles are forming aqueous particles with an increase in disorder. Many candidates incorrectly used 'liquid' instead of aqueous and others started from gaseous particles, perhaps confusing enthalpy change of solution with hydration.
		ii	***Calculation (2 marks)*** *ΔG* = 24 − (298 × 0.225) **OR** 24 − 67.05 *(in kJ)* **OR** 24000 − (298 × 225) **OR** 24000 − 67050 *(in J)* ✓ **Calculation of *ΔG* (IGNORE UNITS)** *ΔG* = −43 (kJ mol^{-1}) **OR** −43000 (J mol $^{-1}$) ✓ *Subsumes 1st calculation mark* **Reason for solubility** Calculated value of ΔG that is **negative** **AND** Statement that: Δ*G* is negative **OR** Δ*G* < 0 **OR** −43 < 0 **OR** Δ*H* − *T*Δ*S* < 0 **OR** *T*Δ*S* > Δ*H* ✓	3	**Contact TL if solely entropy approach rather than Δ*G*** **ALLOW** −43.1 OR −43.05 (*calculator value*) **ALLOW 1 calculation mark (IGNORE units) for** −67.(026) **OR** −67026 ***ECF** from 225 instead of 0.225* 18.(375) **OR** +18.375 ***ECF** from 25* instead of 298 **ALLOW other ECF** from **ONE** error in 1st step of calc, e.g. incorrect value for Δ*H* such as −1099 from 3bii → −1166.05 **TAKE CARE** that same units used for Δ*H* and Δ*S* **NO reason mark from a +ve value of Δ*G*** **Examiner's Comments** This question assessed enthalpy changes in aqueous solutions. The majority of candidates recognised that the Gibbs' equation was required. Usually the correct enthalpy change of +24 kJ mol^{-1} was used to obtain a negative value for Δ*G*. The majority then went on to link the negative value to feasibility for the dissolving process. A

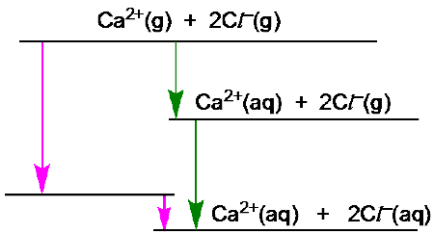
					significant number of candidates used the wrong enthalpy change (or no enthalpy change at all) or mixed units of J and kJ. Answer: $\Delta G = -43$ kJ mol^{-1}
			Total	**12**	
7		i	 **Mark each marking point independently**	4	Correct species **AND** state symbols required for each marks **ALLOW** e for e$^-$ **TAKE CARE**: In top left box, e$^-$ may be in centre of response and more difficult to see than at end. There is only **ONE** correct response for each line *From the gaps in the cycle, there is **NO** possibility of any **ECF*** **Examiner's Comments** Many candidates completed the Born-Haber cycle to obtain three out of the four available marks. Strangely, very few candidates showed the correct species in the bottom box for the elements under standard conditions. Almost invariable, iodine was shown incorrectly, usually as I$_2$(g) or 2I(g). The other three boxes were usually correct although sometimes state symbols had been omitted or electrons had been included together with the gaseous ions in the top right box. Candidates are advised to check carefully between stages in the cycle to ensure that all species charges and state symbols are included and accounted for.
		ii	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd mark: one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark **DO NOT ALLOW** any marks for a definition for enthalpy change of **formation BUT** note the two concessions in guidance	2	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed / made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE**: Fe^{2+}(g) + 2I$^-$(g) → FeI$_2$(s) (Part of cycle) **ALLOW** 1 mark for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓

					ALLOW 1 mark for ΔH_f definition with 'gaseous': the **formation** of **one mole** of a(n ionic) compound from its **gaseous** elements (under standard conditions) ✓ **Examiner's Comments** The majority of candidates had learnt the definition for lattice enthalpy and scored two marks. When fewer marks were awarded, the more common reasons were for responses in terms of a mole of gaseous ions, or omission of the mole altogether. Occasionally, some weaker candidates confused the definition with that for the enthalpy change of formation and so referred to forming a mole of the ionic compound from its constituent elements. Such responses gained no credit.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = −2473 (kJ mol^{-1}) award 2 marks** …… (−113) = 416 + (2 × +107) + 759 + 1561 + (2 × −295) + $\Delta H_{LE}(FeI_2)$ **OR** $\Delta H_{LE}(FeI_2)$ = −113 − (416 + (2 × +107) + 759 + 1561 + (2 × −295)) **OR** −113 − 2360 ✓ = − 2473 ✓ (kJ mol^{-1})	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors** …… **ALLOW** for 1 mark: +2473 wrong sign −2661 107 and −295 used instead of **2 ×** 107 and **2 ×** −295 −2366 +107 used instead of **2 ×** 107 −2768 −295 used instead of **2 ×** −295 −3653 wrong sign for 295 −2247 wrong sign for 113 −1641 wrong sign for 416 −2045 wrong sign for 2 **×** 107 −955 wrong sign for 750 +649 wrong sign for 1561 −3653 wrong sign for **2 ×** −295 Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only e.g. one transcription error: e.g. +461 instead of +416 **Examiner's Comments** Most candidates correctly calculated the lattice enthalpy using a correct sequence of enthalpy values. The commonest mistake was the omission of '2' for either the atomisation or ionisation of iodine, leading to answers of

					−2366 or −2661 kJ mol^{-1}, or use of incorrect signs. There were more transcription errors seen than in previous session, most notably, −113 shown as −133. Candidates are advised to check carefully that any balancing numbers are linked to the correct enthalpy changes in the cycle and to double check values for possible transcription errors. Answer = −2473 kJ mol^{-1}
			Total	**8**	
8	a	i	 ✓ ✓ ✓	3	Mark each marking point independently Correct species **AND** state symbols required for each mark For S^{2-}, **DO NOT ALLOW** S^{-2} For e^-, **ALLOW** e For e^- **only, IGNORE** any state symbols added **ALLOW** k and s *It can be very difficult distinguishing K from k; S from s* **Examiner's Comments** Many candidates successfully completed the Born-Haber cycle to obtain all three marks. The species including any ionic charges and state symbols were almost always correct but sometimes one or more state symbols had been omitted. The commonest error was in the number of electrons in the middle stage; some showed two electrons and the electron was more often omitted entirely. Candidates are advised to check carefully between stages in the cycle to ensure that all species charges and state symbols are accounted for and included.
		ii	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓ ✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd mark: one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark	2	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed / made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE:** $2K^+(g) + S^{2-}(g) \rightarrow K_2S(s)$ (question asks for words)

			Note: A definition for enthalpy change of **formation** will receive **no** marks		**ALLOW** 1 mark (special case) for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓ **Examiner's Comments** The majority of candidates had learnt the definition for lattice enthalpy and scored two marks. When fewer marks were awarded, the more common reasons were for responses in terms of a mole of gaseous ions, or omission of the mole altogether. Occasionally some weaker candidates confused the definition with that for the enthalpy change of formation and so referred to forming a mole of the ionic compound from its constituent elements. Such responses gained no credit.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = −2116 (kJ mol^{-1}) award 2 marks** −381 − (2 × +89 + 279 + 2 × +419 −200 + 640) ✓ −381 − 1735 = − 2116 ✓ (kJ mol^{-1})	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors** **ALLOW** for 1 mark **ONE** mistake with sign **OR** use of 2: −2027 (**2** × 89 not used for K) −1697 (**2** × 419 not used for K) −2516 (+200 rather than −200 for S 1st electron affinity) (+)2116 (wrong sign) −1354 (+381 instead of −381) (+)1354 (+1735 instead of −1735) −836 (−640 instead of +640) −1558 (−279 instead of +279) −1760 (−2 × 89 instead of +2 x 89) −439 (−2 × 419 instead of +2 x 419) −2120 (rounded to 3SF) **For other answers**, check for a **single** transcription error or calculator error which could merit 1 mark **DO NOT ALLOW** any other answers, e.g. −1608 (2 errors: **2** × 89 and **2 ×** 419 not used for K) −846 (3 errors:) **Examiner's Comments** Most candidates correctly calculated the lattice enthalpy using a correct sequence of enthalpy values. The commonest mistakes were

					omission of '2' for either the atomisation or ionisation of potassium or use of incorrect signs. Candidates are advised to check carefully that any balancing numbers are linked to the correct enthalpy changes in the cycle. Answer = −s2116 kJ mol^{-1}
	b		Lowest melting point **KI** **RbC*l*** Highest melting point **NaBr** Correct order ✓ **Mark 2nd and 3rd marking points independently** **Attraction and ionic size linked:** Greater attraction from smaller ions / closer ions / larger charge density ✓ *Comparison needed* **Energy AND attraction / breaking bonds linked:** More **energy / heat** to overcome attraction (between ions) **OR** More **energy / heat** to break (ionic) bonds ✓	3	***FULL ANNOTATIONS MUST BE USED*** **ORA** throughout Response must clearly refer to **ions** for explanation marks **2nd and 3rd marking point must be comparative** **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **DO NOT ALLOW** responses using nuclear size or attraction **DO NOT ALLOW** responses linked with **loss** of electrons **IGNORE** larger **electron** density **ALLOW** smaller **sum** of radii gives a greater ionic attraction **IGNORE** NaBr has greater ionic attraction **IGNORE** NaBr has smallest ionic radius (*not focussing on size of **each** ion*) **ASSUME** bonds broken are ionic unless otherwise stated **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **Note**: Comparison for energy **only** *(i.e. link between more energy and breaking bonds / overcoming attraction)* **Examiner's Comments** This descriptive part caused more problems. Candidates were expected to apply their knowledge and understanding of lattice enthalpies to supplied data. The predicted order of melting points based on the sum of the ionic radii gave the easiest mark, although some showed the order the opposite way round. The explanation proved to be much harder. Candidates were expected to relate

					ionic size with attraction and then to the energy required to overcome the attractive force. Precision in language is always essential here and many candidate spoilt their response by use of incorrect particles. It was very common to see terms such as 'atomic radius, molecules, van der Waals' forces and ionic radius of NaBr. Some candidates simply compared the radii, the skill required for the first marking point.
			Total	**10**	
9	a		**solution**: (enthalpy change for) 1 mole of a compound / substance / solid / solute dissolving **in water**	1	**IGNORE** 'energy released' **OR** 'energy required' For dissolving, **ALLOW** forms aqueous / hydrated ions **DO NOT ALLOW** dissolving elements **IGNORE** ionic **OR** covalent **DO NOT ALLOW** response that implies **formation** of **1 mole** of aqueous ions
	b	i		3	Correct species **AND** state symbols required for each mark. (mark independently) On middle line, **ALLOW** $Ca^{2+}(g) + 2Cl^-(aq)$ (i.e. Cl^- hydrated before Ca^{2+}) On bottom line, **ALLOW** $CaCl_2(aq)$
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF** answer = −142 (kJ mol^{-1}) award 2 marks …… $\Delta_{sol}H$ ($CaCl_2$) = [−1616 + (2 × −359)] − (−2192) **OR** −2334 + 2192 = −142 (kJ mol^{-1})	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using the working shown. **IF ALL 3 relevant values from the information at the start of Q3 have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF**
		iii	***Comparison of size*** $Ca^{2+} > Mg^{2+}$ ***Comparison of charge*** $Na^+ < Mg^{2+} < Al^{3+}$ ***Comparison of attraction between ions*** size **AND** charge linked to greater attraction **to H_2O** ✓	3	**IGNORE** comparison of size: $Na^+ > Mg^{2+} > Al^{3+}$
	c	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF** answer = −132 (kJ mol^{-1}) award 4 marks …… Correctly calculates energy released in J **OR** kJ	4	**FULL ANNOTATIONS MUST BE USED** …… **ALLOW** calculator value of 6611.1507 down to 3SF value of 6610

			= 50.21 × 4.18 × 31.5 = 6611 (J) **OR** 6.611 (kJ) Correctly calculates $n(CaCl_2)$ $= \frac{5.56}{111.1}$ = 0.05(00) mol Correctly calculates ΔH value in J **OR** kJ In J: $= (-)\frac{6611}{0.0500}$ **OR** (−)132,220 (J) **OR** In kJ: $= (-)\frac{6.611}{0.0500}$ **OR** (−)132.22 (kJ) (*Sign ignored and / or more than 3 SF*) Correct $\Delta_{sol}H$ in kJ **AND** sign **AND** 3SF = −132 (kJ mol^{-1})		**DO NOT ALLOW** fewer than 3 SF **IGNORE** units for this mark, i.e. just **ALLOW** correctly calculated number in either J or kJ **ALLOW ECF** from $n(CaCl_2)$ **AND / OR** Energy released **IGNORE** absence of − sign and 3 SF requirement Final mark requires − sign, kJ **AND** 3 SF
		ii	Temperature change is double / × 2 / 63 °C **AND** $\Delta_{sol}H$ is the same Twice the energy produced in the same volume **AND** **ratio** of energy produced to mass or number of moles is the same **OR** $\frac{q}{n}$ is the same	2	**ALLOW** temperature reached would be 85 °C
			Total	**15**	
10	a		Lattice enthalpy of $MgCl_2$ is more exothermic than $CaCl_2$ … (1) because magnesium ion / Mg^{2+} is smaller (than calcium ions / Ca^{2+}) **OR** Mg^{2+} has a greater charge density … (1) … therefore the attraction between Mg^{2+} and Cl^- is greater (than between Ca^{2+} and Cl^-) (1)	3	**ora** throughout **allow** 'charge density' here **only** **allow** magnesium / Mg is smaller **do not allow** Mg^{2+}has a smaller **atomic** radius **do not allow** chlorine ions **do not allow** Mg has greater attraction **allow** 'attracts with more force' for greater attraction but **do not allow** 'greater force' (could be repulsion)
	b	i	**F** **B** **G** **E** **D** **FIVE** correct (3)	3	**allow** 1450 736 G 76 −642

			FOUR correct (2) **THREE** correct (1)		**if** only one or two correct, award 0 marks.
		ii	−642 − (+76 + (2 × 150) + 736 + 1450 + (2 × −349)) (1) −642 − 1864 = −2506 (1) (kJ mol^{-1})	2	**allow** for 1 mark: −2705 (2 × 150 and 2 × 349 not used for C*l*) −2356 (2 × 150 not used for C*l*) −2855 (2 × 349 not used for C*l*) +2506 (wrong sign) **do not allow** any other answers
			Total	**8**	