Tailored Tutors

LATTICE ENTHALPY (5.2.1)

1. Which equation matches the enthalpy change of atomisation of iodine?

A $I_2(g) \rightarrow 2I(g)$
B $\frac{1}{2}I(g) \rightarrow I(g)$
C $I_2(s) \rightarrow 2I(g)$
D $\frac{1}{2}I_2(s) \rightarrow I(g)$

Your answer ☐

[1]

2. The lattice enthalpy of calcium chloride can be calculated using **three** of the enthalpy changes below.

Which enthalpy change is **not** required?

A enthalpy change of solution of calcium chloride
B enthalpy change of hydration of Cl^- ions
C enthalpy change of formation of calcium chloride
D enthalpy change of hydration of Ca^{2+} ions

Your answer ☐

[1]

3(a). Lattice enthalpies give an indication of the strength of ionic bonding.

How would the lattice enthalpies of magnesium chloride and calcium chloride differ?

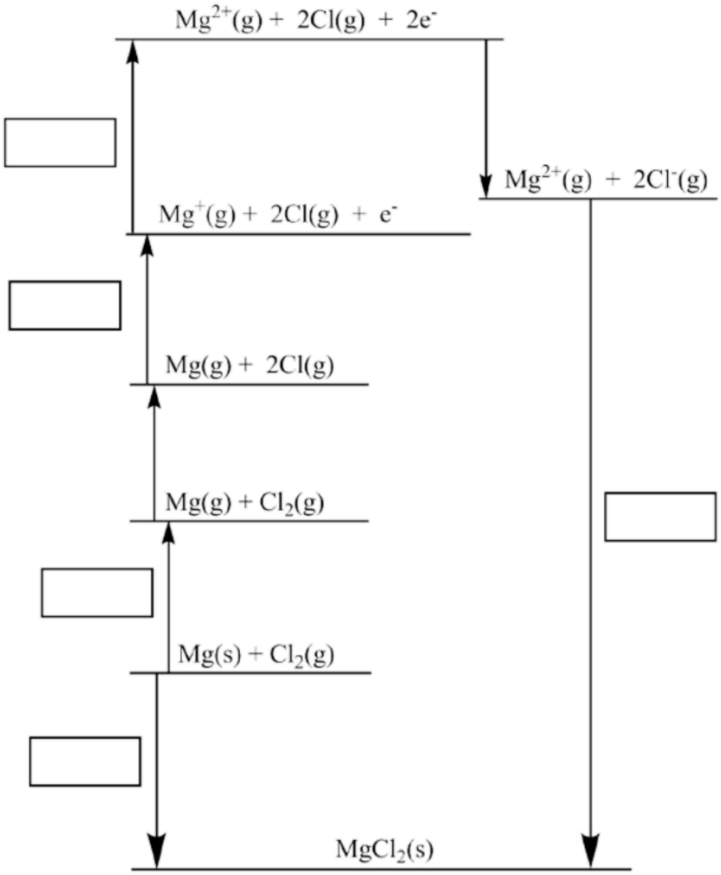
Explain your answer.

---[3]

(b). The table below shows the enthalpy changes that are needed to determine the lattice enthalpy of magnesium chloride, $MgCl_2$.

Letter	Enthalpy change	Energy / kJ mol^{-1}
A	1st electron affinity of chlorine	–349
B	1st ionisation energy of magnesium	+736
C	atomisation of chlorine	+150
D	formation of magnesium chloride	–642
E	atomisation of magnesium	+76
F	2nd ionisation energy of magnesium	+1450
G	lattice enthalpy of magnesium chloride	

(i) On the cycle below, write the correct letter in each box.



[3]

(ii) Use the Born–Haber cycle to calculate the lattice enthalpy of magnesium chloride.

lattice enthalpy = _____ kJ mol^{-1} [2]

4. Iron(II) iodide, FeI_2, is formed when iron metal reacts with iodine.

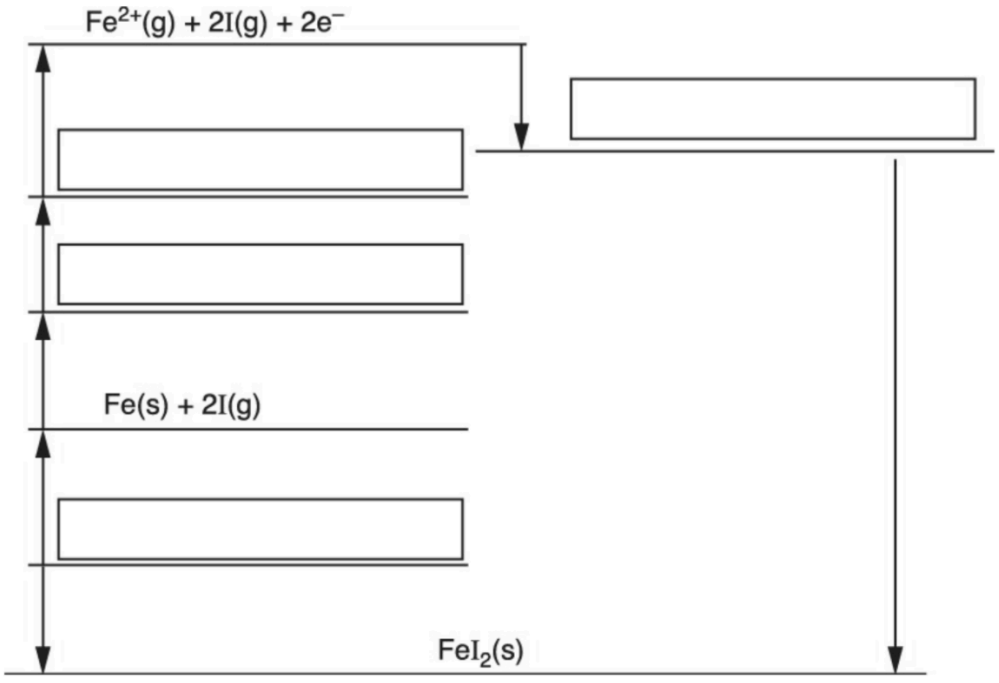
The table below shows enthalpy changes involving iron, iodine and iron(II) iodide.

	Enthalpy change / kJ mol^{-1}
Formation of iron(II) iodide	−113
1st electron affinity of iodine	−295
1st ionisation energy of iron	+759
2nd ionisation energy of iron	+1561
Atomisation of iodine	+107
Atomisation of iron	+416

(i) The incomplete Born–Haber cycle below can be used to determine the lattice enthalpy of iron(II) iodide.

In the boxes, write the species present at each stage in the cycle.

Include state symbols for the species.



[4]

(ii) Define the term *lattice enthalpy*.

---[2]

(iii) Calculate the lattice enthalpy of iron(II) iodide.

lattice enthalpy = _____ kJ mol^{-1} [2]

5. Which enthalpy change(s) is/are endothermic?

1 The bond enthalpy of the C–H bond

2 The second electron affinity of oxygen

3 The standard enthalpy change of formation of magnesium

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ [1]

6(a). Enthalpy changes of solution can be determined both indirectly from other enthalpy changes, and directly from the results of experiments.

The table below shows the enthalpy changes that can be used to determine the enthalpy change of solution of calcium chloride, $CaCl_2$, indirectly.

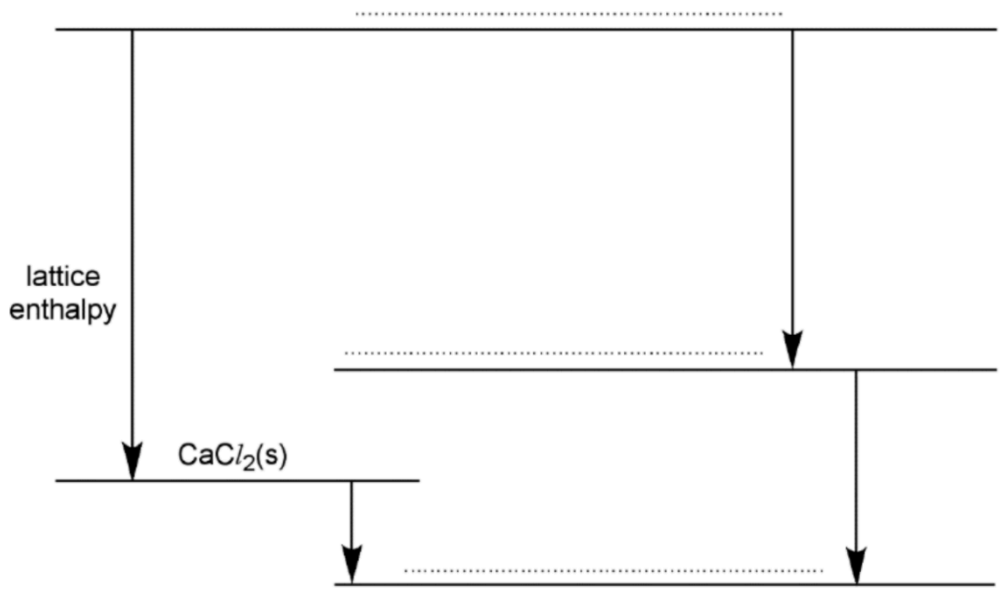
Enthalpy change	Energy / kJ mol^{-1}
Hydration of calcium ions	–1616
Hydration of chloride ions	–359
Lattice enthalpy of calcium chloride	–2192

Explain what is meant by the term *enthalpy change of solution*.

---[1]

(b). The diagram below shows an incomplete energy cycle that can be used to determine the enthalpy change of solution, $\Delta_{sol}H$, of $CaCl_2$.

(i) On the **three** dotted lines, add the species present, including state symbols.



[3]

(ii) Calculate the enthalpy change of solution of $CaCl_2$.

$\Delta_{sol}H$ = _____ kJ mol^{-1} **[2]**

(iii) The table shows enthalpy changes of hydration.

Ion	Enthalpy change of hydration / kJ mol^{-1}
aluminium ion	–4741
calcium ion	–1616
magnesium ion	–1963
sodium ion	–424

Explain the differences between these enthalpy changes of hydration.

---**[3]**

(c). **Student 1** carries out an experiment to determine the enthalpy change of solution, $\Delta_{sol}H$, of $CaCl_2$ directly.

The student follows the method outlined below.

- Weigh an empty polystyrene cup and weigh the bottle containing $CaCl_2$.
- Add about 50 cm^3 of water to the cup and measure the temperature of the water.
- Add the $CaCl_2$ to the cup, stir the mixture, and record the maximum temperature.
- Weigh the polystyrene cup + final solution, and weigh the empty bottle.

Results

Mass of bottle + $CaCl_2$	28.38 g
Mass of empty bottle	22.82 g

Mass of polystyrene cup + final solution	85.67 g
Mass of polystyrene cup	35.46 g
Initial temperature of water	22.0 °C
Final temperature of solution	53.5 °C

(i) Calculate $\Delta_{sol}H$, in kJ mol^{-1}, for calcium chloride.

Give your answer to an **appropriate** number of significant figures.

Assume that the density and specific heat capacity, *c*, of the solution have the same values as water.

$\Delta_{sol}H$ = _____ kJ mol^{-1} **[4]**

(ii) **Student 2** carries out the same experiment but uses twice the mass of $CaCl_2$. All other quantities are very similar to **Student 1**'s experiment.

Predict any differences between the temperature change and the calculated value of $\Delta_{sol}H$ from the experiments of the two students. Explain your reasoning.

---[2]

7(a). This question is about four enthalpy changes, **A**–**D**, that can be linked to the dissolving of potassium sulfate, K_2SO_4, in water.

	Name of enthalpy change	Enthalpy change / kJ mol^{-1}
A	lattice enthalpy of potassium sulfate	–1763
B	enthalpy change of solution of potassium sulfate	+24
C	enthalpy change of hydration of potassium ions	–320
D	enthalpy change of hydration of sulfate ions	

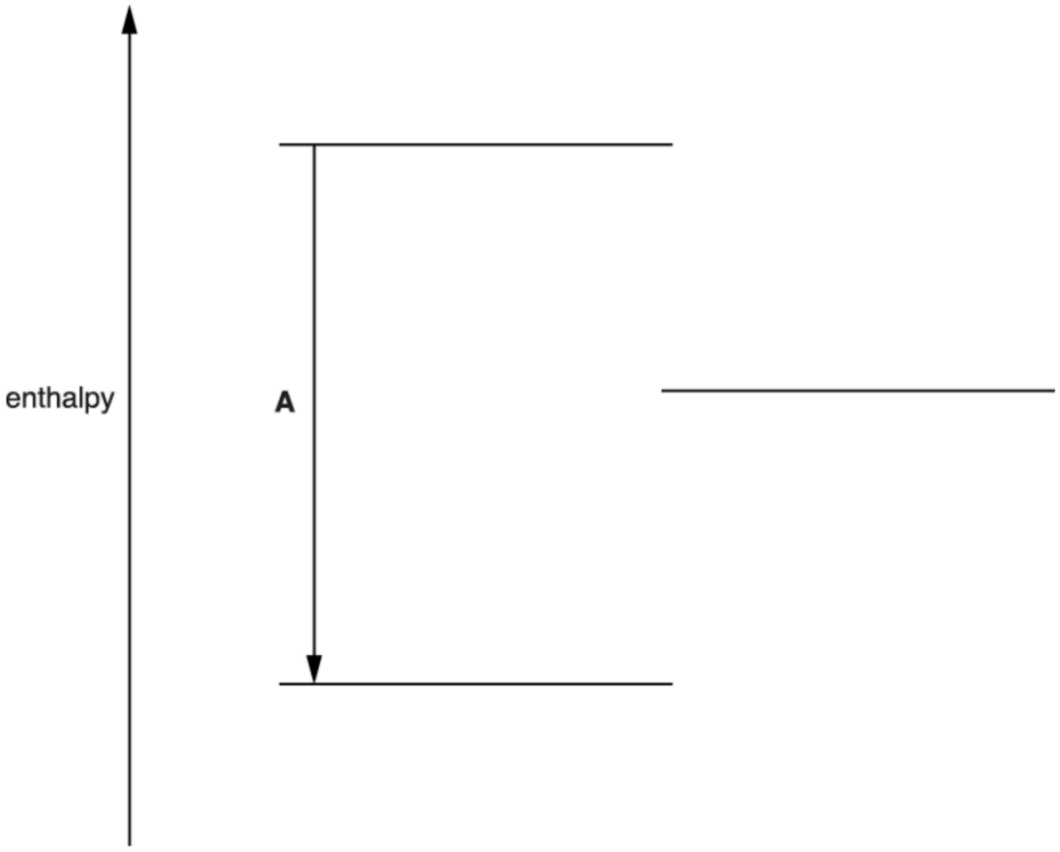
Table 3.1

Define the term *enthalpy change of hydration.*

---[2]

(b). The diagram below is an incomplete energy cycle linking the four enthalpy changes in **Table 3.1**. One of the four energy levels is missing.

Include state symbols for all species.



(i) Complete the energy cycle as follows.

- Add the missing energy level to the diagram. Add the species on all **four** energy levels.
- Add arrows to show the direction of the three missing enthalpy changes. Label these enthalpy changes using the letters **B–D** from **Table 3.1**.

[5]

(ii) Calculate the enthalpy change of hydration of sulfate ions.

ΔH = _____ kJ mol^{-1} **[1]**

(c). The entropy change of solution of K_2SO_4 is +225 J K^{-1} mol^{-1}.

(i) Suggest, in terms of the states of the particles involved, why this entropy change is positive.

---[1]

(ii) Explain, using a calculation, why K_2SO_4 dissolves in water at 25 °C, despite the enthalpy change of solution being endothermic.

---[3]

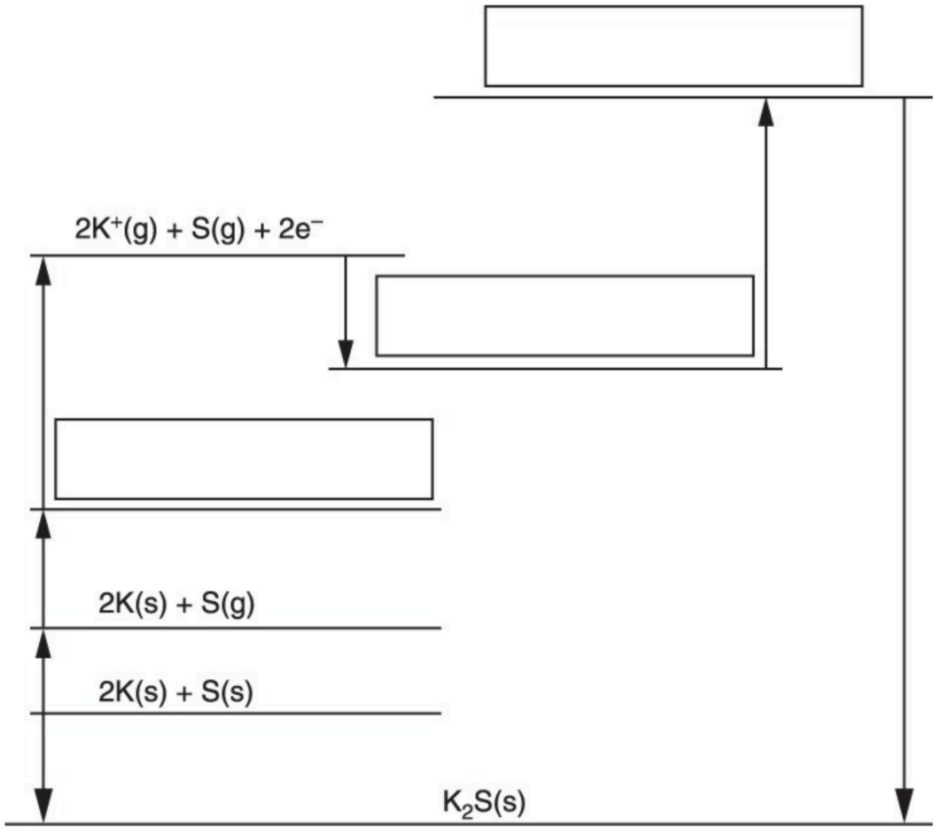
8. Born—Haber cycles can be used to calculate enthalpy changes indirectly.

The table below shows enthalpy changes for a Born—Haber cycle involving potassium sulfide, K_2S.

	Enthalpy change / kJ mol^{-1}
Formation of potassium sulfide, K_2S	−381
1st electron affinity of sulfur	−200
2nd electron affinity of sulfur	+640
Atomisation of sulfur	+279
1st ionisation energy of potassium	+419
Atomisation of potassium	+89

(i) The incomplete Born—Haber cycle below can be used to determine the lattice enthalpy of potassium sulfide.

In the boxes, write the species present at each stage in the cycle.
Include state symbols for the species.



[3]

(ii) Define, in words, the term *lattice enthalpy*.

---[2]

(iii) Using the Born—Haber cycle, calculate the lattice enthalpy of potassium sulfide.

lattice enthalpy = _____ kJ mol^{-1} [2]

9. This question is about enthalpy changes.

Table 16.1 shows enthalpy changes that can be used to determine the enthalpy change of hydration of fluoride ions, F^-.

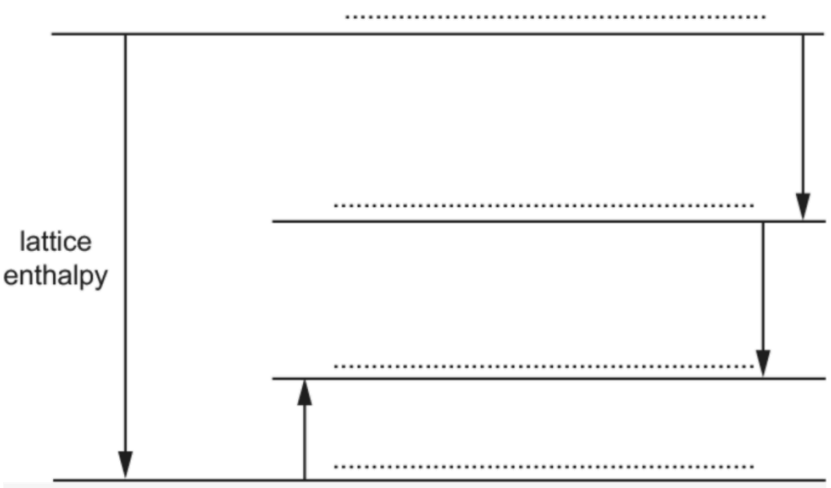
Enthalpy change	Energy / kJ mol^{-1}
Hydration of Ca^{2+}	−1609
Solution of CaF_2	+13
Lattice enthalpy of CaF_2	−2630

Table 16.1

(i) Explain what is meant by the term *enthalpy change of hydration*.

---[2]

(ii) The enthalpy change of hydration of F^- can be determined using the enthalpy changes in **Table 16.1** and the incomplete energy cycle below.
On the dotted lines, add the species present, including state symbols.



[4]

(iii) Calculate the enthalpy change of hydration of fluoride ions, F^-.

enthalpy change of hydration = ... kJ mol^{-1} [2]

(iv) Predict how the enthalpy changes of hydration of F^- and Cl^- would differ.

Explain your answer.

---[2]

10. A student carries out an experiment to find the enthalpy change of solution, $\Delta_{sol}H$, of sulfuric acid using the following method.

1. A plastic cup is weighed.

2. Approximately 100 cm^3 of distilled water is added to the cup.

3. The temperature of the water in the plastic cup is measured.

4. A bottle containing concentrated sulfuric acid is weighed.

5. The sulfuric acid is poured into the plastic cup. The solution formed is stirred with the thermometer.

6. The maximum temperature reached by the solution is recorded.

7. The plastic cup containing the solution is weighed.

8. The empty bottle is weighed.

The student's results are shown in the table below:

Mass readings

Mass of bottle + H_2SO_4/g	25.66
Mass of empty bottle/g	14.38

Mass of plastic cup/g	8.74
Mass of plastic cup + solution formed/g	122.16

Temperature readings

Maximum temperature reached by solution/°C	32.0
Initial temperature of distilled water/°C	21.5

(i) Use the student's results to calculate the enthalpy change of solution of sulfuric acid, in kJ mol^{-1}.

Assume that the specific heat capacity, *c*, of the solution is the same as for water.

Give your answer to an **appropriate** number of significant figures.

enthalpy change of solution, $\Delta_{sol}H$, = _____ kJ mol^{-1} **[4]**

(ii) The student's thermometer has a maximum error of ±0.5 °C.

Calculate the percentage uncertainty in the student's temperature change.

Give your answer to **one** decimal place.

percentage uncertainty = _____ % **[1]**

(iii) The student carries out a second experiment using 150 cm^3 of distilled water instead of 100 cm^3 of distilled water. The mass of concentrated sulfuric acid is the same as in the first experiment.

Predict and explain the effect, if any, of the larger volume of water on the following:

- The temperature change, ΔT
- The calculated value of $\Delta_{sol}H$ for H_2SO_4.

---

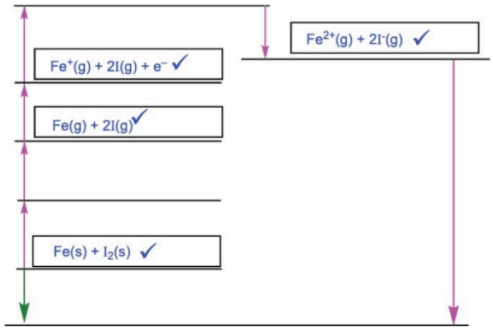
[4]

END OF QUESTION PAPER

LATTICE ENTHALPY (5.2.1)

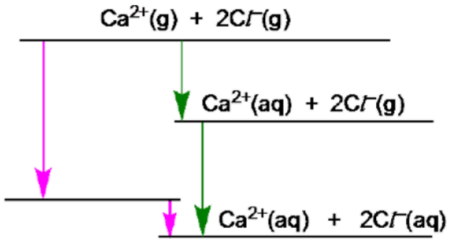
Question			Answer/Indicative content	Marks	Guidance
1			D	1	
			Total	1	
2			C	1	
			Total	1	
3	a		Lattice enthalpy of $MgCl_2$ is more exothermic than $CaCl_2$ … (1) because magnesium ion / Mg^{2+} is smaller (than calcium ions / Ca^{2+}) **OR** Mg^{2+} has a greater charge density … (1) … therefore 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) **FOUR** correct (2) **THREE** correct (1)	3	**allow** 1450 736 G 76 –642 **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 Cl) –2356 (2 × 150 not used for Cl) –2855 (2 × 349 not used for Cl) +2506 (wrong sign) **do not allow** any other answers
			Total	8	

LATTICE ENTHALPY (5.2.1)

Question			Answer/Indicative content	Marks	Guidance
4		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.

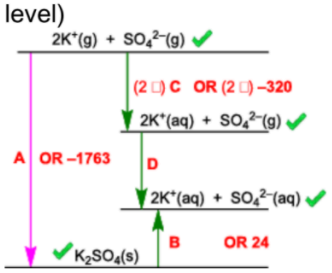
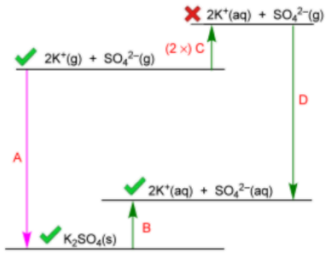
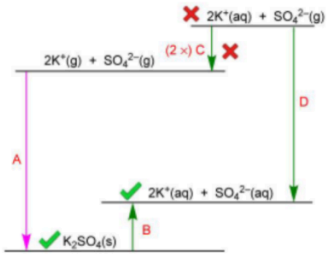
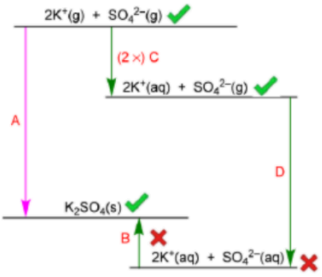
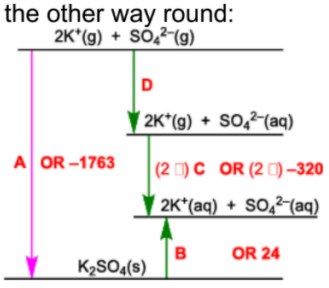
Question			Answer/Indicative content	Marks	Guidance
		ii	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd 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**: $Fe^{2+}(g) + 2I^{-}(g) \rightarrow FeI_2(s)$ (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.

Question			Answer/Indicative content	Marks	Guidance
		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	

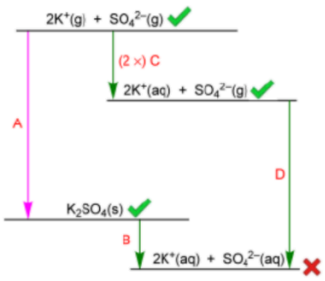
Question			Answer/Indicative content	Marks	Guidance
5			B	1 (AO 1.1)	Examiner's Comments D was the common distractor given as the answer by many candidates, suggesting confusion with the first electron affinity and second electron affinity of oxygen.
			Total	1	
6	a		**solution**: (enthalpy change for) 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 --- $\Delta_{sol}H(CaCl_2) = [-1616 + (2 \times -359)] - (-2192)$ **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 = 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)*	**4**	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW** calculator value of 6611.1507 down to 3SF value of 6610 **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
			Correct $\Delta_{sol}H$ in kJ **AND** sign **AND** 3SF = –132 (kJ mol^{-1}) ✓		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

Question			Answer/Indicative content	Marks	Guidance
7	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**

Question			Answer/Indicative content	Marks	Guidance
	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: 

LATTICE ENTHALPY (5.2.1)

Question			Answer/Indicative content	Marks	Guidance
			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}

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	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.

Question			Answer/Indicative content	Marks	Guidance
		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: ΔG is negative **OR** ΔG < 0 **OR** –43 < 0 **OR** ΔH – TΔS < 0 **OR** TΔS > ΔH ✓	3	**Contact TL if solely entropy approach rather than ΔG** **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 ΔH such as –1099 from 3bii → –1166.05 **TAKE CARE** that same units used for ΔH and ΔS **NO reason mark from a +ve value of ΔG** **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 ΔG. 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: ΔG = –43 kJ mol^{-1}
			Total	**12**	

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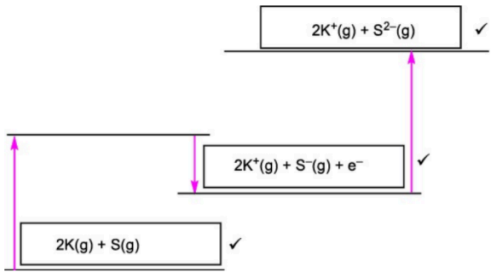
8		i		3	Mark each marking point independently Correct species **AND** state symbols required for each mark For S^{2-}, **DO NOT ALLOW** S^{-2} For e^-, **ALLOW** e For e^- **only, IGNORE** any state symbols added **ALLOW** k and s *It can be very difficult distinguishing K from k; S from s* **Examiner's 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.

Question			Answer/Indicative content	Marks	Guidance
		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 Note: A definition for enthalpy change of **formation** will receive **no** marks	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) **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.

Question			Answer/Indicative content	Marks	Guidance
		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}
			Total	7	

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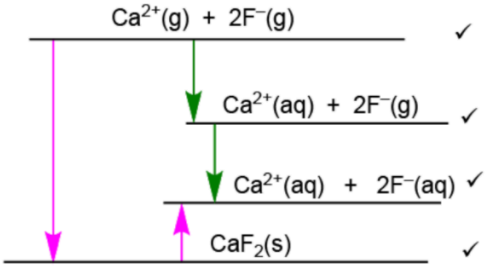
Question			Answer/Indicative content	Marks	Guidance
9		i	(enthalpy change when)✓ 1 mole of gaseous ions react✓ **OR** 1 mole of hydrated/aqueous ions are formed ✓ gaseous ions dissolve in **water** **OR** gaseous ions form aqueous/hydrated ions ✓	2	**IGNORE** 'energy released' OR 'energy required' Examiner's 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.

Question			Answer/Indicative content	Marks	Guidance
		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.

Question			Answer/Indicative content	Marks	Guidance
		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' Examiner's Comments 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	

Question			Answer/Indicative content	Marks	Guidance
10		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 $n(H_2SO_4)$* (–) $\frac{4978}{0.115}$ **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}) ✓	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 **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 $m \rightarrow$ 4389 J **ECF** available for → –38.2 kJ mol^{-1} (3 marks)
		ii	$\frac{0.5}{10.5}$ × 100 × 2 = 9.5% ✓ *One decimal place required*	1	

Question			Answer/Indicative content	Marks	Guidance
		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	