

Exercise walk-through

4.2.2

Born–Haber and solution cycles

Pearson Edexcel · International A-Level · Chemistry

Find the temperature boundary

Your turn

$\Delta H = +36.0 \text{ kJ mol}^{-1}$; $\Delta S(\text{system}) = +120 \text{ J mol}^{-1} \text{ K}^{-1}$. Which condition gives positive total entropy?

- A. T below 300 K
- B. T above 300 K
- C. Every temperature
- D. No temperature

Buffer after neutralisation

Your turn

0.0100 mol HA receives 0.00400 mol OH^- . Which HA:A⁻ ratio enters the buffer expression?

- A. 10:4
- B. 6:4
- C. 4:6
- D. 10:6

Independent structural identification

Your turn

$\text{C}_3\text{H}_6\text{O}$ has two carbon-13 signals, gives iodoform and no Tollens' silver. Which structure fits?

- A. Propanal
- B. Propanone
- C. Propan-1-ol
- D. Ethanoic acid

Exercises 2.1·2.3

2.1 Define lattice formation enthalpy, including the required states and amount. [3]

2.2 For a salt, lattice formation = -850 and total hydration = -820 kJ mol^{-1} . Calculate solution enthalpy. [2]

2.3 Explain why the second electron affinity of oxygen is endothermic although the first is exothermic. [2]

3 Exam-style questions

Exercises 2.1·2.3

2.1 Define lattice formation enthalpy, including the required states and amount. [3]

2.1 Enthalpy change when one mole of ionic solid forms from its gaseous ions under stated standard conditions.

2.2 For a salt, lattice formation = -850 and total hydration = -820 kJ mol^{-1} . Calculate solution enthalpy. [2]

2.2 $\Delta H_{sol} = +850 - 820 = +30 \text{ kJ mol}^{-1}$.

2.3 Explain why the second electron affinity of oxygen is endothermic although the first is exothermic. [2]

3 Exam-style questions

2.3 An electron approaches an already negative O^- ion; energy is needed to overcome electron-ion repulsion.

Exercises 3.1·3.2

3.1 For $\text{MgCl}_2(\text{s})$, use $\Delta H_f = -642$; Mg atomisation $+148$; each Cl atomisation $+121$; $\text{IE}_1 +738$; $\text{IE}_2 +1451$; each Cl electron affinity -349 , all in kJ mol^{-1} . Calculate lattice formation enthalpy. [4]

3.2 A Born–Haber lattice value is substantially more negative than a purely ionic-model estimate. Explain a possible bonding interpretation. Why can a negative solution enthalpy alone not establish solubility? [3]

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3.1 $-642 = 148 + 2(121) + 738 + 1451 + 2(-349) + \Delta H_{latt}$. Other steps sum to 1881, giving $\Delta H_{latt} = -2523 \text{ kJ mol}^{-1}$.

3.2 A Born–Haber lattice value is substantially more negative than a purely ionic-model estimate. Explain a possible bonding interpretation. Why can a negative solution enthalpy alone not establish solubility? [3]

3.2 Extra stabilisation can support covalent character, from cation polarisation of anion electron density. Dissolution also involves entropy, so enthalpy alone does not determine the total entropy change.

Exercise 3.3

3.3 Two illustrative sulfate salts A and B have lattice dissociation enthalpies $+2500$ and $+2450 \text{ kJ mol}^{-1}$, and total hydration enthalpies -2510 and $-2420 \text{ kJ mol}^{-1}$. Both have solution entropy $+40.0 \text{ J mol}^{-1} \text{ K}^{-1}$. Calculate each solution enthalpy and total entropy at 298 K . Use the data to explain which dissolution is favoured and why hydration alone is not the calculation.

[6]

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3.3 For A, $\Delta H_{\text{sol}} = 2500 - 2510 = -10 \text{ kJ mol}^{-1}$; for B, $2450 - 2420 = +30 \text{ kJ mol}^{-1}$. A: $\Delta S_{\text{total}} = 40 - (-10000/298) = +73.6 \text{ J mol}^{-1} \text{ K}^{-1}$. B: $40 - 30000/298 = -60.7 \text{ J mol}^{-1} \text{ K}^{-1}$. A has favourable positive total entropy; hydration and lattice terms compete and entropy must also be included. These are illustrative data, not measured values assigned to named salts.

Exercise 3.4

3.4 Construct a complete Born–Haber cycle for $\text{CaF}_2(\text{s})$, using these supplied illustrative enthalpies in kJ mol^{-1} : formation -1220 ; Ca atomisation $+178$; atomisation of one mole of F atoms $+79$; Ca $\text{IE}_1 +590$ and $\text{IE}_2 +1145$; first electron affinity of F -328 . Label every intermediate species/state, electron count and arrow; include the appropriate factors. Use your cycle to calculate lattice formation enthalpy. [7]

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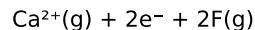
3.4 A complete construction is shown below. Ca atomisation contributes $+178$ and two fluorine atomisations $+158$ with correct gaseous-atom states. Both calcium ionisations contribute $+590 +1145$, with $\text{Ca}^+/\text{Ca}^{2+}$ and one/two electrons correctly shown. Two electron affinities contribute -656 and produce two gaseous F^- ions. The formation arrow goes from $\text{Ca}(\text{s}) + \text{F}_2(\text{g})$ to $\text{CaF}_2(\text{s})$, -1220 ; lattice formation goes from $\text{Ca}^{2+}(\text{g}) + 2\text{F}^-(\text{g})$ to the solid. Hess route: $-1220 = 178 + 2(79) + 590 + 1145 + 2(-328) + \Delta H_{\text{latt}}$, hence $\Delta H_{\text{latt}} = -2635 \text{ kJ mol}^{-1}$. Accept an equivalent complete cycle with directions and signs consistent.

CaF₂: supplied illustrative enthalpies / kJ mol^{-1}

Full solution 3.4 (1/2)

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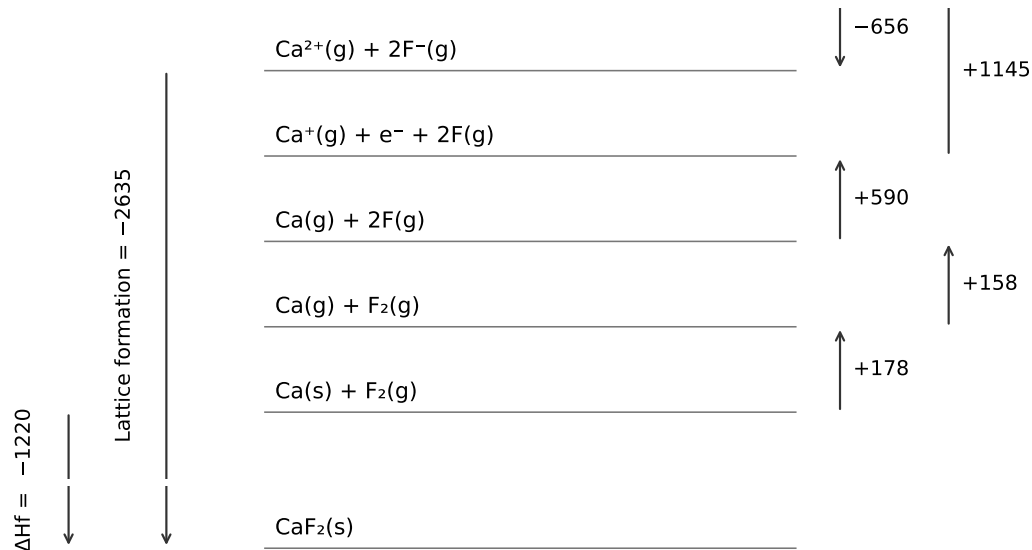
CaF_2 : supplied illustrative enthalpies / kJ mol^{-1}



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Full solution 3.4 (2/2)



Vertical spacing is schematic; arrows define each reaction and its sign.

Exercise 3.5

3.5 Define hydration enthalpy for chloride ions and solution enthalpy for MgCl_2 using equations, amounts and states. Construct a cycle for MgCl_2 dissolution from supplied illustrative values: lattice formation -2523 , hydration of Mg^{2+} -1920 and hydration of each Cl^- -381 kJ mol^{-1} . Calculate the solution enthalpy. [7]

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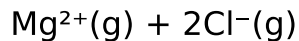
3.5 Hydration: $\text{Cl}^-(\text{g}) \rightarrow \text{Cl}^-(\text{aq})$, for one mole of gaseous chloride ions under stated standard conditions. Solution: $\text{MgCl}_2(\text{s}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq})$, for one mole of solid in sufficient water that further dilution causes no enthalpy change, under stated standard conditions. The cycle separates the lattice to $\text{Mg}^{2+}(\text{g}) + 2\text{Cl}^-(\text{g})$, $+2523$, then hydrates one Mg^{2+} and two Cl^- ions. Total hydration $= -1920 + 2(-381) = -2682 \text{ kJ mol}^{-1}$. The solution arrow and indirect route have matching initial/final species and signs, giving $\Delta H_{\text{sol}} = 2523 - 2682 = -159 \text{ kJ mol}^{-1}$.

MgCl_2 solution cycle: supplied illustrative data / kJ mol^{-1}

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MgCl₂ solution cycle: supplied illustrative data / kJ mol⁻¹



Full solution 3.5 (2/2)

