Chemical Energetics

A-Level Chemistry ▪ Topic 23

A-Level Chemistry

What we will cover

1. Lattice energy & Born–Haber
2. Enthalpies of solution
3. Entropy ΔS
4. Gibbs free energy ΔG

an ionic lattice

1 Lattice energy

Lattice energy and Born–Haber

Lattice energy 晶格能 is the enthalpy change when 1 mol of an ionic solid forms from gaseous ions. It is always exothermic. A **Born–Haber cycle** 玻恩-哈伯循环 applies

Hess's law around the formation of the solid: atomisation → ionisation → electron affinity → lattice energy, closing with ΔH_f.

> More negative (stronger) for a higher ionic charge and a smaller ionic radius.

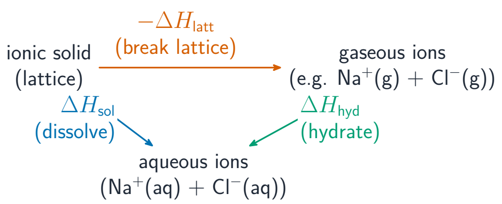
Lattice energy: worked example

NaCl from the cycle

$\Delta H_{\text{latt}} = \Delta H_f - (\Delta H_{\text{at}} + \text{IE} + \text{EA}) = -411 - (107 + 122 + 496 - 349) = -787\,\text{kJ mol}^{-1}$

> Lattice energy is more negative (stronger) for a higher ionic charge and a smaller ionic radius – both strengthen the attraction.

Enthalpies of solution and hydration



$\Delta H_{\text{sol}} = -\Delta H_{\text{latt}} + \Delta H_{\text{hyd}}$

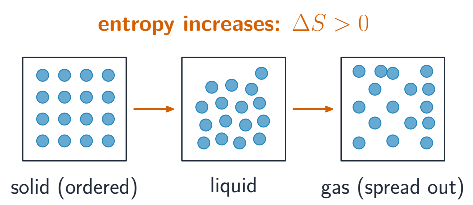
To dissolve, pull the lattice apart, then **hydrate** 水合 the ions:

$$\Delta H_{\text{sol}} = -\Delta H_{\text{latt}} + \Delta H_{\text{hyd}}$$

Hydration 水合焓变 is more exothermic for higher charge & smaller radius.

2 Entropy and free energy

Entropy ΔS



Entropy 熵 measures the number of arrangements ("disorder").

- solid → liquid → gas, dissolving: $\Delta S > 0$
- more gas molecules: $\Delta S > 0$

$\Delta S^\ominus = \sum S^\ominus_{\text{products}} - \sum S^\ominus_{\text{reactants}}$.

Gibbs free energy ΔG

	ΔS **positive**	ΔS **negative**
ΔH **neg.**	feasible at **all** temperatures	feasible only at **low** temperature
ΔH **pos.**	feasible only at **high** temperature	**never** feasible

$\Delta G = \Delta H - T\Delta S$; **feasible when** $\Delta G \leq 0$

Gibbs free energy 吉布斯自由能:

$$\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$$

> A reaction is **feasible** 可行 when $\Delta G \leq 0$. Whether it is can depend on temperature.

ΔG: worked example

$\Delta H = +120\,\mathrm{kJ\,mol^{-1}}$, $\Delta S = +0.200\,\mathrm{kJ\,K^{-1}mol^{-1}}$

at 298 K: $\Delta G = 120 - 298 \times 0.200 = +60\,\mathrm{kJ\,mol^{-1}}$ (not yet feasible)

Set $\Delta G = 0$: $T = \dfrac{\Delta H}{\Delta S} = \dfrac{120}{0.200} = 600\,\mathrm{K}$ – feasible above 600 K.

3 Recap

Topic 23 – key takeaways

1. **Born–Haber**
   Hess cycle to find lattice energy
2. **Lattice**
   stronger for high charge, small radius
3. **Entropy**
   $\Delta S > 0$ for more disorder/gas
4. **Gibbs**
   feasible when $\Delta G = \Delta H - T\Delta S \leq 0$

Check yourself

1. Is lattice energy positive or negative?
2. What makes a lattice energy stronger?
3. Sign of ΔS when a gas forms?
4. A reaction is feasible when ΔG is what?

Answers **1.** negative **2.** higher charge & smaller radius **3.** positive **4.** negative (or zero)