Exercise walk-through

Lattice energy and Born-Haber cycles ▪ 23.1

eXercise

You must be able to

- define enthalpy of atomisation, lattice energy and first electron affinity
- explain the trends in electron affinity down Groups 16 and 17
- construct and use Born–Haber cycles to calculate an unknown step

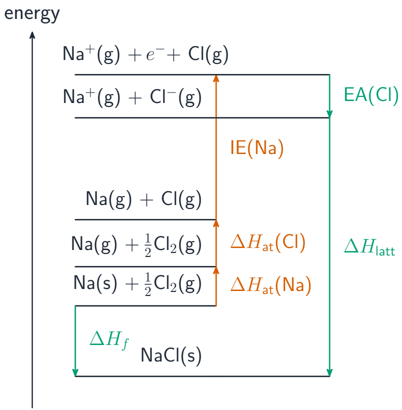
Method — The key terms

- $\Delta H_{\textbf{at}}$ — energy to make 1 mol of gaseous atoms from an element (always $+$).
- $\Delta H_{\textbf{latt}}$ — change when 1 mol of ionic solid forms from gaseous ions (always $-$).
- **first electron affinity (EA)** — change when 1 mol of gaseous atoms each gain an electron $\rightarrow$ 1 mol of 1$-$ ions (usually $-$).

EA becomes **less exothermic** down Groups 16/17 (larger atom attracts the electron less).

Method — Born–Haber cycle

For NaCl: $\Delta H_f = \Delta H_{\text{at}}(\text{Na}) + \text{IE}_1(\text{Na}) + \Delta H_{\text{at}}(\text{Cl}) + \text{EA}_1(\text{Cl}) + \Delta H_{\text{latt}}$.



Method — Born–Haber cycle

$$\begin{tikzcd}[column sep=small] \text{ionic solid (lattice)} \arrow[rr, "{-\Delta H_{\text{latt}}\ \text{(break lattice)}}"] \arrow[dr, "{\Delta H_{\text{sol}}\ \text{(dissolve)}}"'] & & \text{gaseous ions (e.g. } \mathrm{Na^+(g)} + \mathrm{Cl^-(g)}) \arrow[dl, "{\Delta H_{\text{hyd}}\ \text{(hydrate)}}"] \\ & \text{aqueous ions } (\mathrm{Na^+(aq)} + \mathrm{Cl^-(aq)}) & \end{tikzcd}$$

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

Born-Haber alongside the dissolving cycle

Practice 2.1 ▪ 2 marks

Define **lattice energy**.

Solution 2.1

Method: Born–Haber cycle

Worked steps

the enthalpy change when 1 mol of an ionic solid (lattice) forms **B1** from its gaseous ions **B1**.

Practice 2.2 ▪ 1 mark

State why the first electron affinity of chlorine is exothermic.

Solution 2.2

Method: The key terms

Worked steps

the atom gains an electron, and the attraction of the nucleus for the added electron releases energy **B1**.

Exam-style 3.1 ▪ 1 mark

The enthalpy change of atomisation is always:

A negative

B positive

C zero

D equal to the lattice energy

Solution 3.1

Method: The key terms

A negative

B positive ✓

C zero

D equal to the lattice energy

Worked steps

B. Atomisation always requires energy (bonds break), so it is positive.

Exam-style 3.2 ▪ 1 mark

Down Group 17, the first electron affinity becomes:

A more exothermic

B less exothermic

C zero

D positive

Solution 3.2

Method: The key terms

A more exothermic

B less exothermic ✓

C zero

D positive

Worked steps

B. EA becomes less exothermic down the group.

Exam-style 3.3 ▪ 3 marks

Use these data (kJ mol ^{1}) for NaCl: $\Delta H_f = -411$; $\Delta H_{\mathrm{at}}(\mathrm{Na}) = +107$; $\mathrm{IE}_1(\mathrm{Na}) = +496$; $\Delta H_{\mathrm{at}}(\mathrm{Cl}) = +122$; $\mathrm{EA}_1(\mathrm{Cl}) = -349$.

(a) Calculate the lattice energy of NaCl.

(b) State why the lattice energy is negative.

Solution 3.3

Method: Born–Haber cycle

Worked steps

(a) $\Delta H_{\text{latt}} = \Delta H_f - [\Delta H_{\text{at}}(\text{Na}) + \text{IE}_1 + \Delta H_{\text{at}}(\text{Cl}) + \text{EA}_1]$ **M1**; $= -411 - [107 + 496 + 122 - 349]$ **M1** $= -411 - 376 = -787$ kJ mol^{-1} **A1**.

(b) strong electrostatic attractions form between the oppositely charged ions (energy released) **B1**.

Exam-style 3.4 ▪ 2 marks

Explain why the lattice energy of MgO is more exothermic than that of NaCl.

Solution 3.4

Method: Born–Haber cycle

Worked steps

MgO has ions with higher charges $(2+/2-)$ and smaller radii than NaCl **M1**; so the electrostatic attraction is much stronger, making the lattice energy more exothermic **A1**.