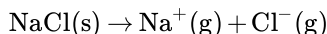


2.7: Lattice Energy and the Born-Haber Cycle

An important enthalpy change is the Lattice Energy, which is the energy required to take one mole of a crystalline solid to ions in the gas phase. For NaCl(s) , the lattice energy is defined as the enthalpy of the reaction

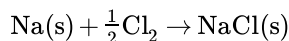


with ΔH called the lattice energy (ΔH_{Lat}).

The Born-Haber Cycle

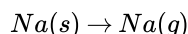
A very handy construct in thermodynamics is that of the thermodynamic cycle. This can be represented graphically to help to visualize how all of the pieces of the cycle add together. A very good example of this is the **Born-Haber cycle**, describing the formation of an ionic solid.

Two pathways can be envisioned for the formation. Added together, the two pathways form a cycle. In one pathway, the ionic solid is formed directly from elements in their standard states.

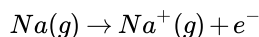


with $\Delta H_f(\text{NaCl})$.

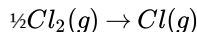
The other pathway involves a series of steps that take the elements from neutral species in their standard states to ions in the gas phase.



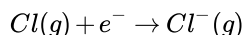
with $\Delta H_{\text{sub}}(\text{Na})$



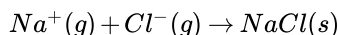
with $1^{\text{st}} \text{IP}(\text{Na})$



with $\frac{1}{2}D(\text{Cl}-\text{Cl})$



with $1^{\text{st}} \text{EA}(\text{Cl})$



with $\Delta H_{\text{Lat}}(\text{NaCl})$

It should be clear that when added (after proper manipulation if needed), the second set of reactions yield the first reaction. Because of this, the total enthalpy changes must all add.

$$\Delta H_{\text{sub}}(\text{Na}) + 1^{\text{st}} \text{IP}(\text{Na}) + \frac{1}{2}D(\text{Cl}-\text{Cl}) + 1^{\text{st}} \text{EA}(\text{Cl}) + \Delta H_{\text{Lat}}(\text{NaCl}) = \Delta H_f(\text{NaCl})$$

This can be depicted graphically, the advantage being that arrows can be used to indicate endothermic or exothermic changes. An example of the Born-Haber Cycle for NaCl is shown below.

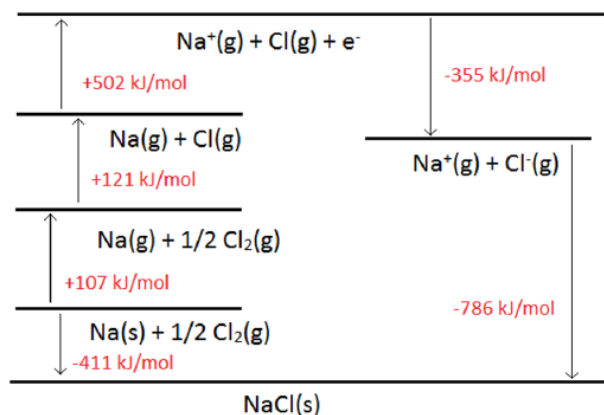
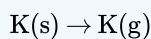


Figure 3.6.1: the Born-Haber Cycle for NaCl.

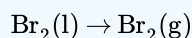
In many applications, all but one leg of the cycle is known, and the job is to determine the magnitude of the missing leg.

✓ Exercise 2.7.1: Potassium Bromide

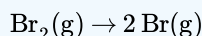
Find ΔH_f for KBr given the following data.



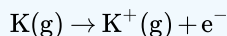
with $\Delta H_{\text{sub}} = 89 \text{ kJ/mol}$



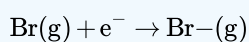
with $\Delta H_{\text{vap}} = 31 \text{ kJ/mol}$



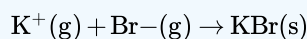
with $D(\text{Br} - \text{Br}) = 193 \text{ kJ/mol}$



with $1^{\text{st}} \text{IP}(\text{K}) = 419 \text{ kJ/mol}$



with $1^{\text{st}} \text{EA}(\text{Br}) = 194 \text{ kJ/mol}$



with $\Delta H_{\text{Lat}} = 672 \text{ kJ/mol}$

Answer

$$\Delta H_f = -246 \text{ kJ/mol}$$

Note: This cycle required the extra leg of the vaporization of Br₂. Many cycles involve ions with greater than unit charge and may require extra ionization steps as well!

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