Skills to Develop

- To understand the general characteristics of ionic solids

**Ionic Solids** are solids composed of oppositely charged ions. They consist of positively charged **cations** and negatively charged **anions**. When Ionic Solids are dissolved in water the cations and the anions **separate**, they become free to move about in the water allowing the solution to conduct electrical current.

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**Introduction**

You learned previously that an ionic solid consists of positively and negatively charged ions held together by electrostatic forces. Ionic solids can be composed of simple ions as seen in NaCl (sodium chloride) or can be composed of polyatomic ions as seen in ammonium nitrate NH₄NO₃ with NH₄⁺ and NO₃⁻ ions. Ionic compounds are held together by the attractive electrostatic interactions between cations and anions. In an ionic compound, the cations and anions are arranged in space to form an extended three-dimensional array that maximizes the number of attractive electrostatic interactions and minimizes the number of repulsive electrostatic interactions (Figure 1). As shown in Equation 2.7.1, the electrostatic energy of the interaction between two charged particles is proportional to the product of the charges on the particles and inversely proportional to the distance between them:

\[
\text{electrostatic energy} \propto \frac{Q_1 Q_2}{r} \tag{2.7.1}
\]

where \(Q_1\) and \(Q_2\) are the electrical charges on particles 1 and 2, and \(r\) is the distance between them. When \(Q_1\) and \(Q_2\) are both positive, corresponding to the charges on cations, the cations repel each other and the electrostatic energy is positive. When \(Q_1\) and \(Q_2\) are both negative, corresponding to the charges on anions, the anions repel each other and the electrostatic energy is again positive. The electrostatic energy is negative only when the charges have opposite signs; that is, positively charged species are attracted to negatively charged species and vice versa.

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*Figure 1: The ionic compound NaCl forms when electrons from sodium atoms are transferred to chlorine atoms. The resulting Na⁺ and Cl⁻ ions form a three-dimensional solid that is held together by attractive electrostatic interactions.*
Lattice Energy

The lattice energy (i.e., the energy required to separate 1 mol of a crystalline ionic solid into its component ions in the gas phase) is directly proportional to the product of the ionic charges and inversely proportional to the sum of the radii of the ions. For example, NaF and CaO both crystallize in the face-centered cubic (fcc) sodium chloride structure, and the sizes of their component ions are about the same: Na\(^+\) (102 pm) versus Ca\(^{2+}\) (100 pm), and F\(^-\) (133 pm) versus O\(^{2-}\) (140 pm). Because of the higher charge on the ions in CaO, however, the lattice energy of CaO is almost four times greater than that of NaF (3401 kJ/mol versus 923 kJ/mol). The forces that hold Ca and O together in CaO are much stronger than those that hold Na and F together in NaF, so the heat of fusion of CaO is almost twice that of NaF (59 kJ/mol versus 33.4 kJ/mol), and the melting point of CaO is 2927°C versus 996°C for NaF. In both cases, however, the values are large; that is, simple ionic compounds have high melting points and are relatively hard (and brittle) solids.

Note

Due to most ionic compounds lattice energies being high, ions do not easily detach themselves from their crystal structure into a gaseous state.

Ionic solids typically do not go from a solid state to gas state at ordinary temperatures. They can although be melted by applying thermal energy enough to interrupt the crystalline lattice. Therefore, the higher the lattice energy is of an ionic compound, the higher the melting point is. Energy that is needed to break apart an ionic crystal when it is dissolved comes from the interaction of ions in the crystal (solid) with the molecules of the solvent. The lattice energy of an ionic solid is what an ionic solid depends on to dissolve in a solvent. Therefore, the lower the lattice energy, the higher the quantity an ionic solid that can be dissolved in any quantity of solvent.

References


Contributors

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