9.4: The Effect of Temperature on Solubility

Learning Objectives

- Describe how temperature affects solubility of different types of solute.

The solubility of the majority of solid substances increases as the temperature increases. However, the effect is difficult to predict and varies widely from one solute to another. The temperature dependence of solubility can be visualized with the help of a **solubility curve**, a graph of the solubility vs. temperature (Figure $9.4.1$ below).

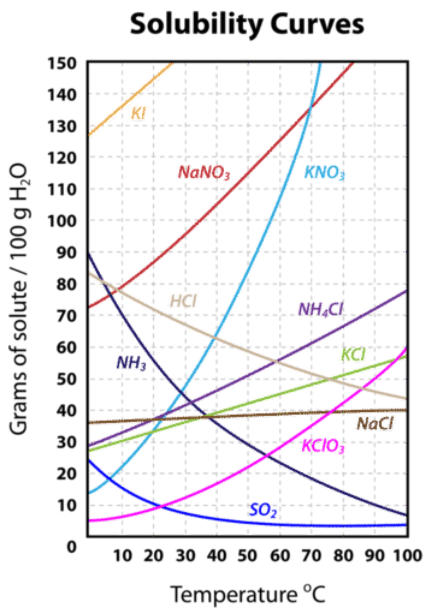

Figure $9.4.1$: A solubility curve is a graph of the solubility of a substance as a function of temperature.

Notice how the temperature dependence of $NaCl$ is fairly flat, meaning that an increase in temperature has relatively little effect on the solubility of $NaCl$. The curve for KNO_3, on the other hand, is very steep, and so an increase in temperature dramatically increases the solubility of KNO_3.

Several substances—HCl, NH_3, and SO_2—have solubility that decreases as temperature increases. They are all gases at standard pressure. When a solvent with a gas dissolved in it is heated, the kinetic energy of both the solvent and solute increase. As the kinetic energy of the gaseous solute increases, its molecules have a greater tendency to escape the attraction of the solvent molecules and return to the gas phase. Therefore, the solubility of a gas decreases as the temperature increases.

Solubility curves can be used to determine if a given solution is *saturated* or *unsaturated*. Suppose that 80 g of KNO_3 is added to 100 g of water at $30^\circ C$. According to the solubility curve in Figure $9.4.1$, approximately 48 g of KNO_3 will dissolve at $30^\circ C$. This means that the solution will be saturated since 48 g is less than 80 g. We can also determine that there will be $80 - 48 = 32$ g of undissolved KNO_3 remaining at the bottom of the container. In a second scenario, suppose that this saturated solution is heated to $60^\circ C$. According to the curve, the solubility of KNO_3 at $60^\circ C$ is about 107 g. The solution, in this case, is unsaturated since it contains only the original 80 g of dissolved solute. Suppose in a third case, that the solution is cooled all the way down to $0^\circ C$. The solubility at $0^\circ C$ is about 14 g, meaning that $80 - 14 = 66$ g of the KNO_3 will recrystallize.

Supersaturated Solutions

Some solutes, such as sodium acetate, do not recrystallize easily. Suppose an exactly saturated solution of sodium acetate is prepared at $50^\circ C$. As it cools back to room temperature, no crystals appear in the solution, even though the solubility of sodium acetate is lower at room temperature. A **supersaturated solution** is a solution that contains more than the maximum amount of solute that is capable of being dissolved at a given temperature. The recrystallization of the excess dissolved solute in a supersaturated solution can be initiated by the addition of a tiny crystal of solute, called a seed crystal. The seed crystal provides a nucleation site on which the excess dissolved crystals can begin to grow. Recrystallization from a supersaturated solution is typically very fast.

> **Chemistry in Everyday Life: Handwarmers**
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> Recrystallization of excess solute from a supersaturated solution usually gives off energy as heat. Commercial heat packs, such as the one in Figure 9.4.2, containing supersaturated sodium acetate ($NaC_2H_3O_2$) take advantage of this phenomenon. You can probably find them at your local drugstore.
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> Figure 9.4.2: This hand warmer produces heat when the sodium acetate in a supersaturated solution precipitates. Precipitation of the solute is initiated by a mechanical shockwave generated when the flexible metal disk within the solution is "clicked." (credit: modification of work by "Velela"/Wikimedia Commons)