> *"It is clear that under these circumstances the classical theory can not be retained. All experimental material indicates that its fundamental starting point should be abandoned, and that, in particular, an equilibrium calculated on the basis of the mass action law does not correspond to the actual phenomena."*
>
> *P. Debye and E. Hückel*

Solutions

To a chemist, a solution is nothing more than a homogeneous mixture. The defining phrase is comprised of two words, each of which has a very specific meaning in chemistry: Homogeneous, meaning that the sample has a uniform appearance and composition throughout, plus mixture, a sample that consists of two or more substances. If both of these definitions are met, a sample is a solution.

Solutions are frequently, both in the chemistry laboratory and in everyday life. In the laboratory, solutions are an excellent medium for promotion of chemical reactions and growing crystals. The particles are much closer together than in a gas, and they have more freedom of movement than in a solid. Outside of the laboratory, the process of life itself depends on solutions. The air we breathe and the oceans, lakes, and streams that cover most of our planet are examples of solutions.

Solution Terminology

Solutions are not limited to ionic and molecular solids being dissolved in water as in the workshop *"Ions in Solution"*.

Terms, which relate to solutions, need to be expanded. In general, the component of the solution that is present in the greatest amount is called the *solvent*. The substance with the smaller amount in the solution is called the *solute*. These terms are not precise, however, and their usage varies among different specialties in chemistry. For example in water solutions, water is almost always referred to as the solvent no matter its relative amount. Also when a solid or a gas is dissolved in a liquid, the liquid is generally called the solvent.

It is often important to know the maximum amount of a solute that will dissolve in a given solvent at a specified temperature. This measure is known as the *solubility* of that solute. Reference sources often report solubilities in grams of solute per 100 grams of solvent. When a solution contains a solute amount less than the solubility limit, it is said to be *unsaturated*; if it is at the solubility limit, it is *saturated*. Under certain special conditions, a solution can contain more solute than it normal solubility limit, and in this case, it is called *supersaturated*.

The terms concentrated and dilute are often used to describe solutions. It is important to keep in mind that these terms are valid only in a relative sense. A *concentrated* solution has a relatively large amount of solute per given amount of solvent when compared with a *dilute* solution. The comparison is only valid for systems of the same solute and solvent.

When discussing solutions of liquids in liquids, the term *miscible* is used to describe two liquids that will dissolve in one another in all possible combinations. When liquids will not dissolve in one another, they are said to be *immiscible.* A chemist would say that oil and water are immiscible, whereas alcohol and water are miscible.

Solution Concentration Units

A number of different units are used to express the quantity of solute dissolved in a given amount of solvent. Molarity was introduced in the workshop *"Ions in Solution".*

$$\text{molarity} = \text{M} = \frac{\text{moles solute}}{\text{liters solution}}$$

Some other common units include percentage by mass, percentage by volume, (which relates to alcoholic proof), parts per million, parts per billion, and molality. The definition of each provides the basis for calculations with that unit.

$$\%\ \text{by mass} = \frac{\text{mass solute}}{\text{mass solution}} \times 100$$

$$\%\ \text{by volume} = \frac{\text{volume solute}}{\text{volume solution}} \times 100$$

[Proof = % by volume x 2]

$$\text{parts per million} = \text{ppm} = \frac{\text{mass solute}}{\text{mass solution}} \times 10^6$$

$$\text{parts per billion} = \text{ppb} = \frac{\text{mass solute}}{\text{mass solution}} \times 10^9$$

$$\text{molality} = \text{m} = \frac{\text{moles solute}}{\text{kilograms solvent}}$$

The choice of concentration unit is largely a matter of application and convenience; other units beyond these may be encountered. There are some technical factors that must be considered. Percentage by mass, parts per million, parts per billion, and molality are applicable at any temperature. However, molarity and percent by volume must specify a temperature, since the volume varies with temperature.