# Solutions and Concentration

You will find that many of the activities suggested throughout this book make use of solutions. It was mentioned earlier that solutions are mixtures. They consist of a **solvent** (a liquid, such as water) and one or more **solutes** (substances that are dissolved in the solvent.) The dissolving of a solute in a solvent is a physical change. However, chemical reactions often occur between substances that are in solution. These chemical changes can depend on the amount of substances—that is, their concentrations—in the solution.
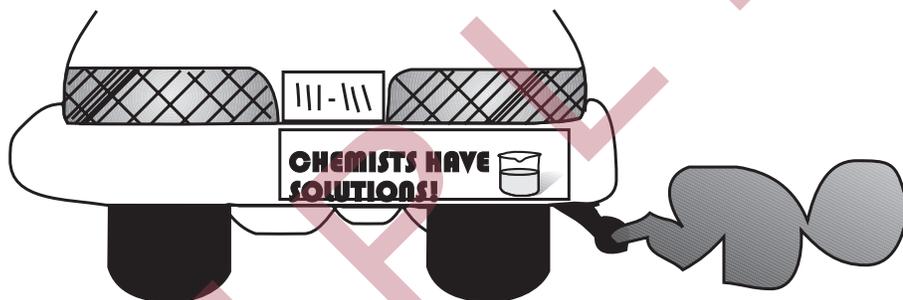
You will often hear a solution referred to as **dilute** or **concentrated**. A dilute solution is one that contains a relatively small amount of the solute in a given volume of solvent. Tap water is an example of a dilute solution; it contains very small quantities of dissolved minerals. A concentrated solution contains a relatively large amount of the solute in the same volume of solvent. Most commercial acids are concentrated solutions. For example, commercial hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) are concentrated solutions.

Application

Stomach acid is a dilute solution of hydrochloric acid. The acid aids in digesting the protein in foods. Anyone with an ulcer can attest to the problems that this dilute acid solution can cause!

Examples of dilute and concentrated solutions are depicted in Figure 3.6. A dilute solution (a) contains a smaller amount of solute than does a concentrated solution (b). Moreover, a dilute solution contains more solvent than an equal volume of concentrated solution does.
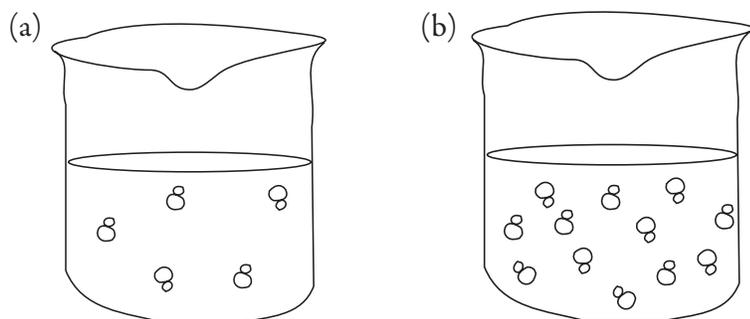
(a)   (b)

Figure 3.6. (a) Dilute solution and (b) concentrated solution

Try This

Often when a solute is dissolved in a solvent, heat is either consumed or produced, as demonstrated by the following two activities.

1. Instant cold packs are used in first aid to treat injuries. They consist of a divided plastic bag containing a solid separated from blue-dyed water to allow you to see if the partition has broken. The solid is usually ammonium nitrate. Cold packs work by using a physical process (not a chemical reaction) based on a solid dissolving in water. When the partition is broken, the solid and water mix. As the solid dissolves it absorbs energy from the surroundings, and you notice a cooling effect.

Make an instant cold pack by placing 30 g (1/8 cup) of ammonium nitrate in a zipper-type plastic bag or plastic cup. Add 100 mL (1/2 cup) water at room temperature and stir the contents. Use a thermometer to measure the drop in temperature. The temperature will be lowered by about 15 °C.

2. Mountain hikers and campers often carry hot packs during the winter months. Hot packs work in a manner similar to cold packs, except that the salt that dissolves in the water releases energy. That is, heat is evolved.

Make an instant hot pack by placing 40 g (1/4 cup) calcium chloride in 100 mL (1/2 cup) of water at room temperature in a plastic bag or cup. Use a thermometer to measure the rise in temperature.

For many solutions, there is a limit to the amount of solute that can be dissolved in the solvent. A solution in which no more solute will dissolve is called a **saturated** solution. When you add a lot of sugar to your ice tea, not all the sugar will dissolve, and your solution (of sugar in tea) is saturated. Under certain conditions, you can get an excess amount of solute to dissolve; that is, you can get more than the amount that is expected to dissolve in a saturated solution. A solution that contains an excess of dissolved solute is called **supersaturated**. Actually, a supersaturated solution is unstable and some solute will crystallize if the solution is disturbed. For example, adding a small crystal of the solute can start the crystallization. You may have noticed this phenomenon in a jar of honey. After the honey jar has been sitting for a long time, you might see solid sugar crystallizing.

The terms "dilute," "concentrated," and "saturated" can be useful when talking about how much solute is in a solution, but they do not tell us *exactly* how much solute is present. Chemists often need to express concentrations in more precise terms. Three precise ways of expressing concentrations are described below.

Weight Percent

Weight percent is often used to express the concentration of a solid substance dissolved in a liquid. The *weight percent* is equal to the weight of the substance (solute) divided by the total weight of the solution and multiplied by 100 to get a percentage.

$$\text{weight percent} \ = \ \frac{\text{weight of solute}}{\text{total weight of solution}} \ \times \ 100$$

For example, a 1% sodium chloride solution in water contains 1 gram of sodium chloride (NaCl) in a total of 100 grams of solution. The amount of water is 99 grams, the difference between the total weight (100 grams) and the weight of the solute (1 gram).

Volume Percent

Volume percent is often used to express the concentration of a liquid solute in a liquid solvent. The volume percent is equal to the volume of the solvent divided by the total volume of the solution and multiplied

by 100 to get a percentage.

$$\text{volume percent} = \frac{\text{volume of solute}}{\text{total volume of solution}} \times 100$$

Common rubbing alcohol is a 70% solution of rubbing alcohol (isopropyl alcohol) in water; that is, it contains 70 mL of isopropyl alcohol in 100 mL of total solution.

Application

The alcohol content of alcoholic beverages (vodka, gin, wines, whiskeys) is given in proof. The concentration of alcohol expressed in "proof" is double the volume percent. For example, a wine that is 12% alcohol by volume is 24 proof. Don't be fooled by this unit of proof. It does not mean you are getting more alcohol for your money!

FwC Activity

When preparing solutions, you might notice that the volume of the final solution is often less than the sum of the volumes of the original components; that is, the volumes are not additive! This phenomenon is explored in "Nonadditive Volumes" in Fun with Chemistry, Volume 2, p. 181.

Parts Per Million

Many environmental samples contain trace amounts of solute impurities and the concentration of these impurities are reported in *parts per million (ppm)*. Parts per million means the number of milligrams of substance dissolved in 1 liter of water. One ppm is the same as a penny in 1 million cents. The EPA recommended limit of lead in tap water is 0.015 ppm.