8.1 Types of Solutions

Section Preview/ Specific Expectations

In this section, you will

- **explain** solution formation, referring to polar and non-polar solvents
- **identify examples** of solid, liquid, and gas solutions from everyday life
- **communicate** your understanding of the following terms: *solution*, *solvent, solutes, variable composition, aqueous solution, miscible, immiscible, alloys, solubility, saturated solution, unsaturated solution*

As stated in the chapter opener, a **solution** is a homogeneous mixture. It is uniform throughout. If you analyze any two samples of a solution, you will find that they contain the same substances in the same relative amounts. The simplest solutions contain two substances. Most common solutions contain many substances.

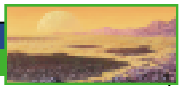
A **solvent** is any substance that has other substances dissolved in it. In a solution, the substance that is present in the largest amount (whether by volume, mass, or number of moles) is usually referred to as the solvent. The other substances that are present in the solution are called the **solutes**.

Pure substances (such as pure water, H_2O) have fixed composition. You cannot change the ratio of hydrogen, H, to oxygen, O, in water without producing an entirely new substance. Solutions, on the other hand, have **variable composition**. This means that different ratios of solvent to solute are possible. For example, you can make a weak or a strong solution of sugar and water, depending on how much sugar you add. Figure 8.1 shows a strong solution of tea and water on the left, and a weak solution of tea and water on the right. The ratio of solvent to solute in the strong solution is different from the ratio of solvent to solute in the weak solution.

Figure 8.1 **How can a solution have variable composition yet be uniform throughout?**

When a solute dissolves in a solvent, no chemical reaction occurs. Therefore, the solute and solvent can be separated using physical properties, such as boiling point or melting point. For example, water and ethanol have different boiling points. Using this property, a solution of water and ethanol can be separated by the process of distillation. Refer back to Chapter 1, section 1.2. What physical properties, besides boiling point, can be used to separate the components of solutions and other mixtures?

COURSE CHALLENGE



How can you find out what solutes are dissolved in a sample of water? What physical properties might be useful? You will need answers to these questions when you do your Chemistry Course Challenge.

Figure 8.2 **Can you identify the components of some of these solutions?**

A solution can be a gas, a liquid, or a solid. Figure 8.2 shows some examples of solutions. Various combinations of solute and solvent states are possible. For example, a gas can be dissolved in a liquid, or a solid can be dissolved in another solid. Solid, liquid, and gaseous solutions are all around you. Steel is a solid solution of carbon in iron. Juice is a liquid solution of sugar and flavouring dissolved in water. Air is an example of a gaseous solution. The four main components of dry air are nitrogen (78%), oxygen (21%), argon (0.9%), and carbon dioxide (0.03%). Table 8.1 lists some other common solutions.

Table 8.1 Types of Solutions

Original state of solute	Solvent	Examples
gas	gas	air; natural gas; oxygen-acetylene mixture used in welding
gas	liquid	carbonated drinks; water in rivers and lakes containing oxygen
gas	solid	hydrogen in platinum
liquid	gas	water vapour in air; gasoline-air mixture
liquid	liquid	alcohol in water; antifreeze in water
liquid	solid	amalgams, such as mercury in silver
solid	gas	mothballs in air
solid	liquid	sugar in water; table salt in water; amalgams
solid	solid	alloys, such as the copper-nickel alloy used to make coins

mind STRETCH

Take another look at the four components of dry air. Which component would you call the solvent? Which components are the solutes?

Electronic Learning Partner

Your Chemistry 11 Electronic Learning Partner can help you learn more about the properties of water.

You are probably most familiar with liquid solutions, especially aqueous solutions. An **aqueous solution** is a solution in which water is the solvent. Because aqueous solutions are so important, you will focus on them in the next two sections of this chapter and again in Chapter 9.

Some liquids, such as water and ethanol, dissolve readily in each other in any proportion. That is, any amount of water dissolves in any amount of ethanol. Similarly, any amount of ethanol dissolves in any amount of water. Liquids such as these are said to be **miscible** with each other. Miscible liquids can be combined in any proportions. Thus, either ethanol or water can be considered to be the solvent. Liquids that do not readily dissolve in each other, such as oil and water, are said to be **immiscible**.

As you know from Chapter 4, solid solutions of metals are called **alloys**. Adding even small quantities of another element to a metal changes the properties of the metal. Technological advances throughout history have been linked closely to the discovery of new alloys. For example, bronze is an alloy of copper and tin. Bronze contains only about 10% tin, but it is much stronger than copper and more resistant to corrosion. Also, bronze can be melted in an ordinary fire so that castings can be made, as shown in Figure 8.3.

CHEM FACT

An alloy that is made of a metal dissolved in mercury is called an *amalgam*. A traditional dental amalgam, used to fill cavities in teeth, contains 50% mercury. Due to concern over the use of mercury, which is toxic, dentists now use other materials, such as ceramic materials, to fill dental cavities.

Solubility and Saturation

The ability of a solvent to dissolve a solute depends on the forces of attraction between the particles. There is always some attraction between solvent and solute particles, so some solute always dissolves. The **solubility** of a solute is the amount of solute that dissolves in a given quantity of solvent, at a certain temperature. For example, the solubility of sodium chloride in water at 20˚C is 36 g per 100 mL of water.

A **saturated solution** is formed when no more solute will dissolve in a solution, and excess solute is present. For example, 100 mL of a saturated solution of table salt (sodium chloride, NaCl) in water at 20˚C contains 36 g of sodium chloride. The solution is saturated with respect to sodium chloride. If more sodium chloride is added to the solution, it will not dissolve. The solution may still be able to dissolve other solutes, however.

An **unsaturated solution** is a solution that is not yet saturated. Therefore, it can dissolve more solute. For example, a solution that contains 20 g of sodium chloride dissolved in 100 mL of water at 20˚C is unsaturated. This solution has the potential to dissolve another 16 g of salt, as Figure 8.4 demonstrates.

Figure 8.3 The introduction of the alloy bronze around 3000 BCE led to the production of better-quality tools and weapons.

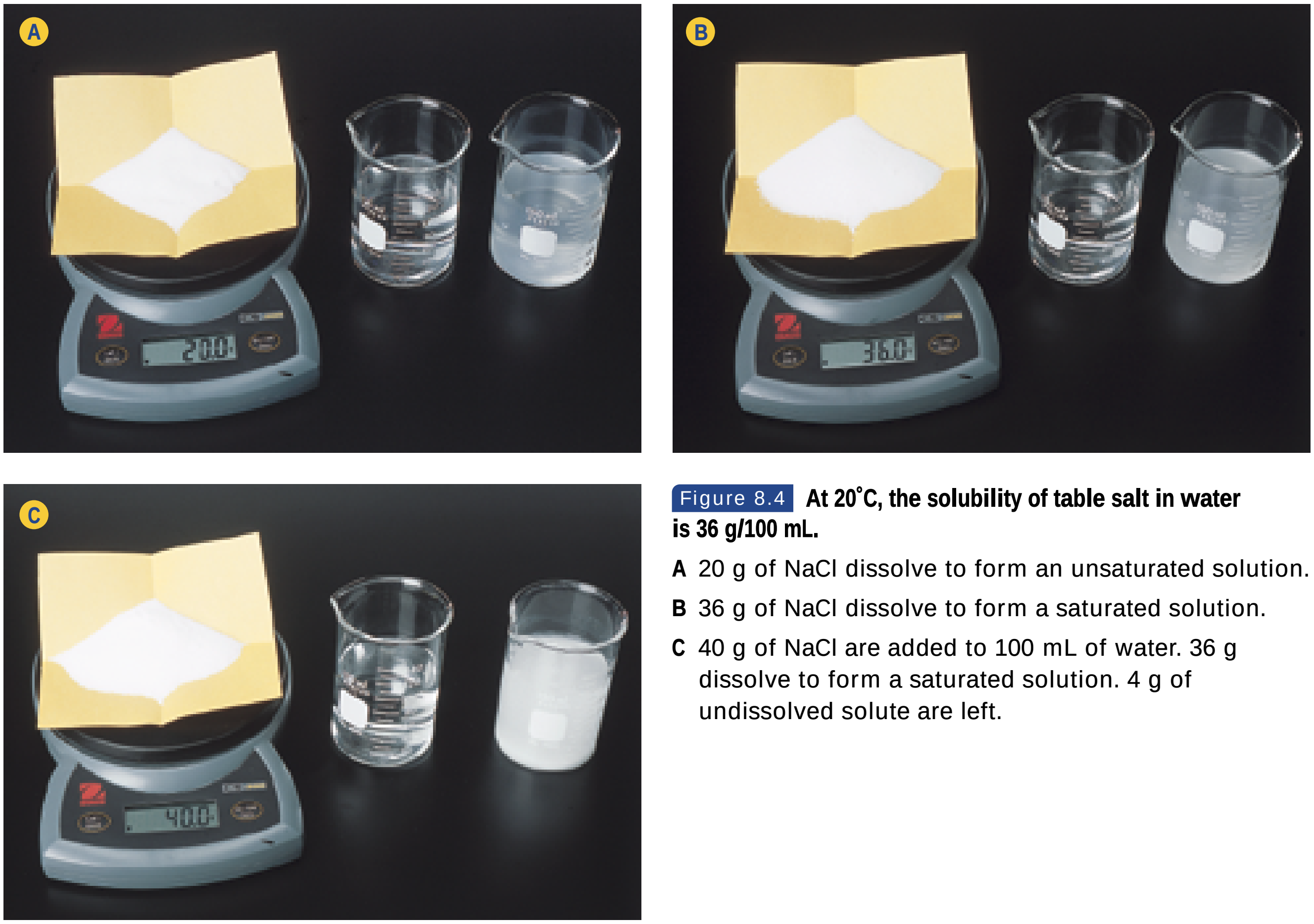


Figure 8.4 **At 20°C, the solubility of table salt in water is 36 g/100 mL.**

A 20 g of NaCl dissolve to form an unsaturated solution.

B 36 g of NaCl dissolve to form a saturated solution.

C 40 g of NaCl are added to 100 mL of water. 36 g dissolve to form a saturated solution. 4 g of undissolved solute are left.

Suppose that a solute is described as *soluble* in a particular solvent. This generally means that its solubility is greater than 1 g per 100 mL of solvent. If a solute is described as *insoluble*, its solubility is less than 0.1 g per 100 mL of solvent. Substances with solubility between these limits are called *sparingly soluble*, or *slightly soluble*. Solubility is a relative term, however. Even substances such as oil and water dissolve in each other to some extent, although in very tiny amounts.

The general terms that are used to describe solubility for solids and liquids do not apply to gases in the same way. For example, oxygen is described as soluble in water. Oxygen from the air dissolves in the water of lakes and rivers. The solubility of oxygen in fresh water at 20°C is only 9 mg/L, or 0.0009 g/100 mL. This small amount of oxygen is enough to ensure the survival of aquatic plants and animals. A solid solute with the same solubility, however, would be described as insoluble in water.

mind STRETCH

Imagine that you are given a filtered solution of sodium chloride. How can you decide whether the solution is saturated or unsaturated?

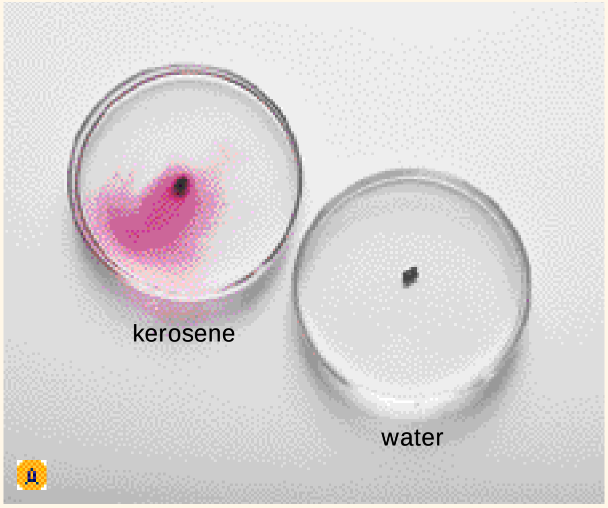
Identifying Suitable Solvents

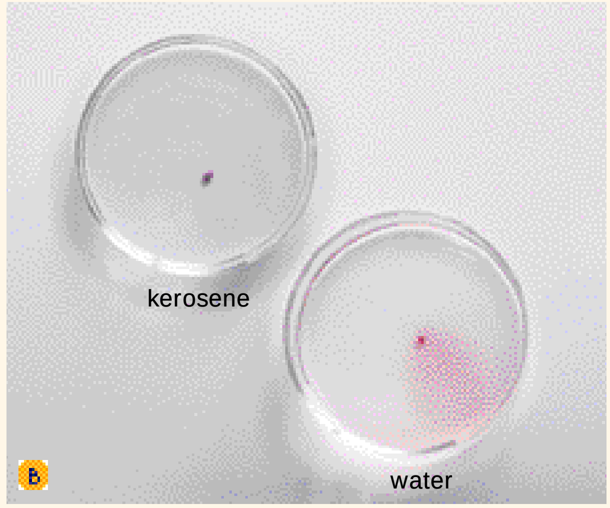
Water is a good solvent for many compounds, but it is a poor solvent for others. If you have grease on your hands after adjusting a bicycle chain, you cannot use water to dissolve the grease and clean your hands. You need to use a detergent, such as soap, to help dissolve the grease in the water. You can also use another solvent to dissolve the grease. How can you find a suitable solvent? How can you predict whether a solvent will dissolve a particular solute? Try the Thought Lab on the next page to find out for yourself.

Electronic Learning Partner

Go to your Chemistry 11 Electronic Learning Partner to find out more about the properties of two solvents: water and benzene.

ThoughtLab Matching Solutes and Solvents





Although there is a solvent for every solute, not all mixtures produce a solution. Table salt dissolves in water but not in kerosene. Oil dissolves in kerosene but not in water. What properties must a solvent and a solute share in order to produce a solution?

In an investigation, the bottom of a Petri dish was covered with water, as shown in photo A. An equal amount of kerosene was added to a second Petri dish. When a crystal of iodine was added to the water, it did not dissolve. When a second crystal of iodine was added to the kerosene, however, it did dissolve.

Procedure

Classify each compound as ionic (containing ions), polar (containing polar molecules), or non-polar (containing non-polar molecules).

(a) iodine,

(b) cobalt(II) chloride,

(c) sucrose, (Hint: Sucrose contains 8 O–H bonds.)

In photo B, the same experiment was repeated with crystals of cobalt(II) chloride. This time, the crystal dissolved in the water but not in the kerosene.

Analysis

1. Water is a polar molecule. Therefore, it acts as a polar solvent.
   (a) Think about the compounds you classified in the Procedure. Which compounds are soluble in water?
   (b) Assume that the interaction between solutes and solvents that you examine here applies to a wide variety of substances. Make a general statement about the type of solute that dissolves in polar solvents.
2. Kerosene is non-polar. It acts as a non-polar solvent.
   (a) Which of the compounds you classified in the Procedure is soluble in kerosene?
   (b) Make a general statement about the type of solute that dissolves in non-polar solvents.

Section Wrap-up

In this section, you learned the meanings of several important terms, such as *solvent*, *solute*, *saturated solution*, *unsaturated solution*, *aqueous solution*, and *solubility*. You need to know these terms in order to understand the material in the rest of the chapter. In section 8.2, you will examine the factors that affect the rate at which a solute dissolves in a solvent. You will also learn about factors that affect solubility.

Section Review

1 K/U Name the two basic components of a solution.

2 K/U Give examples of each type of solution.

(a) solid solution

(b) liquid solution

(c) gaseous solution (at room temperature)

3 K/U Explain the term “homogeneous mixture.”

4 C How do the properties of a homogeneous mixture differ from the properties of a heterogeneous mixture, or mechanical mixture? Use diagrams to explain.

5 K/U Give examples of each type of mixture.

(a) homogeneous mixture

(b) mechanical mixture (heterogeneous mixture)

6 K/U Distinguish between the following terms: soluble, miscible, and immiscible.

7 K/U Distinguish between an alloy and an amalgam. Give one example of each.

8 K/U What type of solute dissolves in a polar solvent, such as water? Give an example.

9 I Potassium bromate, , is sometimes added to bread dough to make it easier to work with. Suppose that you are given an aqueous solution of potassium bromate. How can you determine if the solution is saturated or unsaturated?

10 K/U Two different clear, colourless liquids were gently heated in an evaporating dish. Liquid A left no residue, while liquid B left a white residue. Which liquid was a solution, and which was a pure substance? Explain your answer.

11 I You are given three liquids. One is a pure substance, and the second is a solution of two miscible liquids. The third is a solution composed of a solid solute dissolved in a liquid solvent. Describe the procedure you would follow to distinguish between the three solutions.

12 MC In 1989, the oil tanker Exxon Valdez struck a reef in Prince William Sound, Alaska. The accident released 40 million litres of crude oil. The oil eventually covered 26 000 of water.

(a) Explain why very little of the spilt oil dissolved in the water.

(b) The density of crude oil varies. Assuming a value of 0.86 g/mL, estimate the average thickness of the oil slick that resulted from the Exxon Valdez disaster.

(c) How do you think most of the oil from a tanker accident is dispersed over time? Why would this have been a slow process in Prince William Sound?

13 MC Food colouring is often added to foods such as candies, ice cream, and icing. Are food colouring dyes more likely to be polar or non-polar molecules? Explain your answer.