SOLUTIONS
VOCABULARY

Solution

Solvent

Solute

Polar Molecule

Concentration

Dilute

Solubility

Saturated solution

Unsaturated solution

Mixtures, Solubility, and Acid/Base Solutions

Properties of Solutions

Key Concepts

- Why do some substances dissolve in water and others do not?
- How do concentration and solubility differ?
- How can the solubility of a solute be changed?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. Solutions can be solids, liquids, or gases.	
	4. A teaspoon of soup is less concentrated than a cup of the same soup.	

Mark the Text

Building Vocabulary As you read, underline any words or phrases that you do not understand. When you finish reading, discuss these words and phrases with another student or your teacher.

Read to Learn

Parts of Solutions

Recall that a solution is a homogeneous mixture. In a solution, substances are evenly mixed on the atomic level. How do substances mix on the atomic level? Dissolving is the process of mixing one substance into another to form a solution.

A solution is made up of a solvent and solutes. Generally, *the* **solvent** *is the substance that exists in the greatest quantity in a solution. All other substances in a solution are* **solutes** (SAHL yewts).

Recall that air is a solution of 78 percent nitrogen, 21 percent oxygen, and 1 percent other substances. Which substance is the solvent? In air, nitrogen exists in the greatest quantity. Therefore, nitrogen is the solvent. The oxygen and other substances are solutes. As you read about solutes and solvents in this lesson, reread the definitions on this page if you forget what the words mean.

Reading Check

1. Contrast How do a solute and a solvent differ?

_____

_____

_____

_____

Types of Solutions

You might think of a solution as a liquid. But solutions can exist in all three states of matter—solid, liquid, or gas.

The solvent exists in the greatest quantity. Therefore, the state of the solvent determines the state of the solution. Read the table on the next page. It contrasts solid, liquid, and gaseous solutions.

Types of Solutions		
State of Solution	**Solvent Is:**	**Solute Can Be:**
Solid	solid	**gas or solid (called alloys)** A saxophone is a solid solution of solid copper and solid zinc.
Liquid	liquid	**solid, liquid, and/or gas** Soda is a liquid solution of liquid water, gaseous carbon dioxide, and solid sugar and other flavorings.
Gas	gas	**gas** A gaseous mixture of gaseous argon and gaseous mercury produces the light you see in many brightly colored signs.

Water as a Solvent

Water exists naturally in all three states—solid, liquid, and gas. In nature, water almost always exists as a solution. Why does nearly all water on Earth contain dissolved solutes? The answer has to do with the structure of the water molecule.

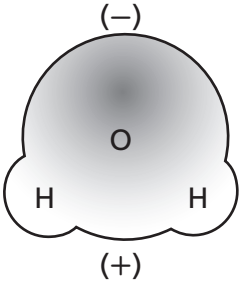
The Polarity of Water

A water molecule, such as the one illustrated in the figure below, is a covalent compound. Recall that atoms are held together with covalent bonds when sharing electrons. In a water molecule, one oxygen atom shares electrons with two hydrogen atoms.

These electrons are not shared equally. The electrons in the oxygen-hydrogen bonds are closer to the oxygen atom than they are to the hydrogen atoms. This unequal sharing of electrons gives the end with the oxygen atom a slightly negative charge and the end with the hydrogen atoms a slightly positive charge.

Polarity of a Water Molecule

The electrons spend more time near the oxygen atom. This makes the end with the oxygen atom slightly negative (–).



The end with the hydrogen atoms is slightly positive (+).

Because of the unequal sharing of electrons, a water molecule is said to be polar. *A* **polar molecule** *is a molecule with a slightly negative end and a slightly positive end*. Nonpolar molecules have an even distribution of charge. Solutes and solvents can be polar or nonpolar.

Interpreting Tables

2. Name When the solvent is a solid and the solute is a gas, what will the state of the solution be?

Visual Check

3. Analyze Shared electrons in a water molecule are closer to the oxygen atom than to the hydrogen atoms. Why does this create a slightly negative charge on the oxygen end of the molecule?

Reading Check

4. Identify What makes a molecule polar?

Key Concept Check

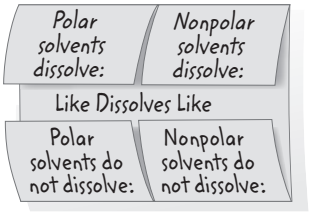
5. Explain Why do some substances dissolve in water and others do not?

Visual Check

6. Compare How is an alcohol molecule similar to a water molecule?

FOLDABLES®

Make a four-tab shutterfold to collect information about which solvents dissolve which solutes.



Visual Check

7. Name the solvent in the figure.

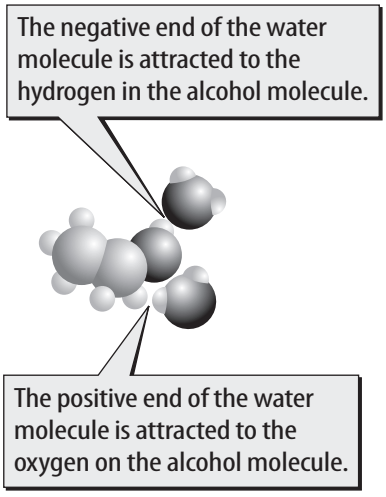
Like Dissolves Like

Water is often called the universal solvent because it dissolves many substances. But water can't dissolve everything. Why does water dissolve some substances but not others? Water is a polar solvent. Polar solvents dissolve polar solutes easily. Nonpolar solvents dissolve nonpolar solutes easily. In other words: "Like dissolves like." Because water is a polar solvent, it dissolves most polar and ionic solutes.

Polar Solvents and Polar Molecules

Because water molecules are polar, water dissolves groups of other polar molecules. The figure to the right shows rubbing alcohol in solution with water. Notice that molecules of rubbing alcohol also are polar. When alcohol and water mix, the positive ends of the water molecules attract the negative ends of the alcohol molecules. Similarly, the negative ends of the water molecules attract the positive ends of the alcohol molecules. In this way, alcohol molecules dissolve in the solvent.

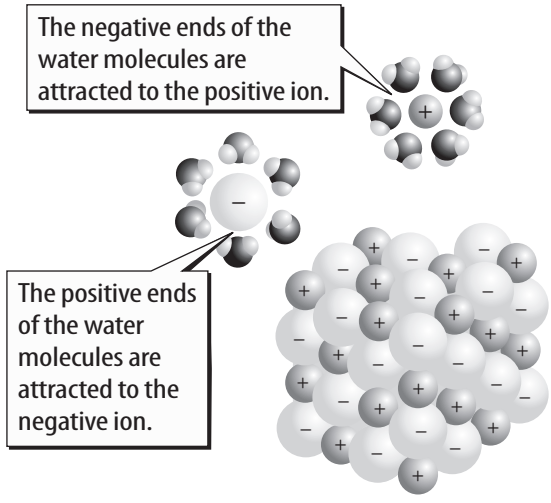
Polar Molecules in Solution



Polar Solvents and Ionic Compounds

Many ionic compounds are also soluble in water. Recall that ionic compounds are made of alternating positive and negative ions. Sodium chloride (NaCl) is an ionic compound. It is made of sodium ions (Na^+) and chloride ions (Cl^-). When sodium chloride dissolves, these ions are pulled apart. Look at the figure to the right. The negative ends of the water molecules attract the positive sodium ions. The positive ends of the water molecules attract the negative chloride ions.

Ionic Compound in Solution



Concentration—How much is dissolved?

Have you ever tasted a soup and wished it had more salt in it? Your taste buds were evaluating the concentration of salt in the soup. **Concentration** *is the amount of a particular solute in a given amount of solution*. In the soup, salt is a solute. Saltier soup has a higher concentration of salt. Soup with less salt has a lower concentration of salt. Suppose two cups each contain an equal volume of soup. You stir a teaspoon of salt into one cup of soup. You stir a half-teaspoon of salt into the other cup of soup. The soup in the first cup has a higher concentration of the solute salt than the soup in the second cup.

Concentrated and Dilute Solutions

One way to describe the soup in the first cup is to say that it is saltier. The salt is more concentrated. The less-salty soup is more dilute. The terms *concentrated* and *dilute* are one way to describe how much solute is dissolved in a solution. However, these terms don't state the exact amount of solute dissolved. One person might think that a solution is concentrated. Another person might think that the same solution is dilute. Soup that tastes too salty to you might be perfect for someone else.

Describing Concentration Using Quantity

A more precise way to describe concentration is to state the quantity of solute in a given quantity of solution. When a solution is made of a solid dissolved in a liquid, such as salt in water, concentration is the mass of solute in a given volume of solution. Mass usually is stated in grams, and volume usually is stated in liters. For example, concentration can be stated as grams of solute per 1 L of solution. However, concentration can be stated using any units of mass or volume.

Calculating Concentration—Mass per Volume

You can calculate concentration using this equation:

$$\text{Concentration } (C) = \frac{\text{mass of solute } (m)}{\text{volume of solution } (V)}$$

To calculate concentration, you must know the mass of solute and the volume of solution that contains this mass. Then divide the mass of solute by the volume of solution.

Math Skills

Suppose you want to calculate the concentration of salt in a 0.4 L can of soup. The label says it contains 1.6 g of salt. What is its concentration in g/L? In other words, how much salt would 1 L of soup have?

a. This is what you know:

mass: 1.6 g volume: 0.4 L

b. You need to find:

concentration: *C*

c. Use this formula:

$$C = \frac{m}{V}$$

d. Substitute and divide:

$$C = \frac{1.6}{0.4} = 4$$

e. Determine the units:

$$\text{units of concentration} = \frac{\text{units of mass}}{\text{units of volume}} = \frac{\text{g}}{\text{L}} = g/L$$

Answer: The concentration is 4 g/L. As you might expect, 0.4 L of soup contains less salt (1.6 g) than 1 L of soup (4 g). However, the concentration of both amounts of soup is the same: 4 g/L.

8. Solve for Concentration

1. What is the concentration of 5 g of sugar in 0.2 L of solution?

2. How many grams of salt are in 5 L of a solution with a concentration of 3 g/L?

Concentration—Percent by Volume

Not all solutions are a solid dissolved in a liquid. A solution can contain only liquids or gases. The concentration of the solution is then stated as the volume of solute in a given volume of solution. In this case, the units of volume must be the same—usually mL or L. Because the units match, you can state the concentration as a percentage.

To calculate percent by volume, first divide the volume of solute by the total volume of solution. Then multiply the quotient by 100. For example, if a container of orange drink contains 3 mL of acetic acid in a 1,000-mL container, the concentration is 0.3 percent.

$$3 \text{ mL} \div 1{,}000 = 0.003 \times 100 = 0.3\%$$

Reading Check

9. State What is the concentration of a solution?

Solubility—How much can dissolve?

What happens if you put a lot of sugar into a glass of iced tea? Not all of the sugar dissolves. You stir and stir, but some sugar still remains at the bottom of the glass. That is because there is a limit to how much solute (sugar) can dissolve in a solvent (water). **Solubility** (sahl yuh BIH luh tee) *is the maximum amount of solute that can dissolve in a given amount of solvent at a given temperature and pressure*. If a substance has a high solubility, more of it can dissolve in a given solvent.

Key Concept Check

10. Contrast How do concentration and solubility differ?

Saturated and Unsaturated Solutions

If you add water to a dry sponge, the sponge absorbs the water. If you keep adding water, the sponge becomes saturated. It can't hold any more water. This is analogous (uh NA luh gus), or similar, to what happens when you try to stir a lot of sugar into iced tea. Some sugar dissolves, but the excess sugar does not dissolve. The solution has become saturated.

A **saturated solution** *is a solution that contains the maximum amount of solute the solution can hold at a given temperature and pressure. An* **unsaturated solution** *is a solution that can still dissolve more solute at a given temperature and pressure*.

ACADEMIC VOCABULARY

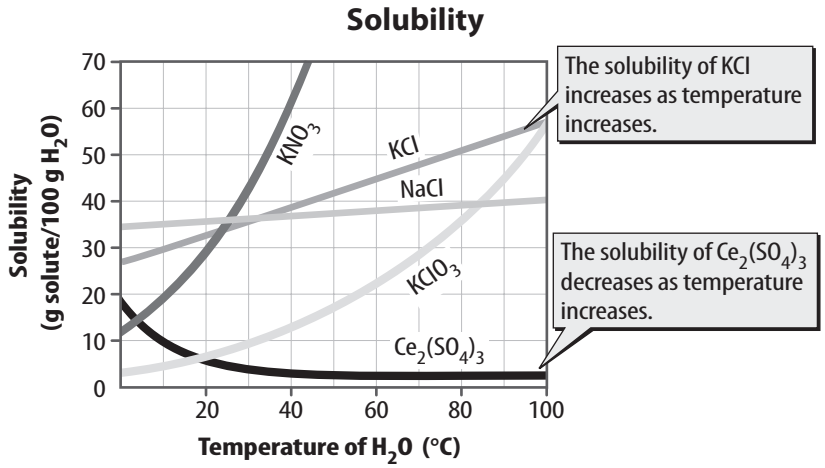
analogous
(adjective) showing a likeness in some ways between things that are otherwise different

Factors that Affect How Much Can Dissolve

Can you change a solvent so that a larger or smaller amount of a particular solute can dissolve in it? Yes. Recall the definition of solubility—the maximum amount of solute that can dissolve in a given amount of solvent at a given temperature and pressure. Changing either the temperature or the pressure of the solvent changes how much solute can dissolve in a solvent.

Effect of Temperature Have you noticed that more sugar dissolves in hot tea than in iced tea? The solubility of sugar in water increases as the temperature of the water increases. This is true for many solid solutes, as shown in the figure below. But notice that some solids are less soluble in warmer liquids than in cooler ones. The difference depends on the chemical structure of the solid.

How does temperature affect the solubility of a gas in a liquid? Soda, or soft drinks, contains carbon dioxide gas dissolved in liquid water. The bubbles in soda are undissolved carbon dioxide. More carbon dioxide bubbles out when you open a warm can of soda than when you open a cold can. This is because the solubility of a gas in a liquid decreases when the temperature of the solution increases.



Effect of Pressure What keeps carbon dioxide dissolved in an unopened can of soda? In a can, the carbon dioxide in the space above the liquid soda is under pressure. This causes the gas to move to an area of lower pressure—the solvent. The gas moves into the solvent and forms a solution. When you open the can, this pressure is released, and the carbon dioxide gas leaves the solution. Pressure does not affect the solubility of a solid solute in a liquid.

How Fast a Solute Dissolves

If solute and solvent particles come into contact more often, the solute dissolves faster. You can increase the contact between solvent and solute particles by stirring the solution. Or, you can crush the solute into smaller particles. Heating a solution will also increase this contact. Each of these methods will make a solute dissolve faster. However, stirring the solution or crushing the solute will not make more solute dissolve.

Reading Check

11. Summarize How does the temperature of water affect the solubility of sugar?

Visual Check

12. Interpret How many grams of KNO_3 will dissolve in 100 g of water at 10°C?

Key Concept Check

13. Generalize How can the solubility of a solute be changed?