

How Substances Dissolve

KEY IDEAS

As you read this section, keep these questions in mind:

- Why is water called the universal solvent?
- How do substances dissolve?

Why Do Substances Dissolve in Certain Solvents?

Water is often called a universal solvent because many substances dissolve in it. However, no one substance can dissolve every solute. A general rule in chemistry is that “like dissolves like.” This rule means that a solvent will dissolve substances that have similar molecular structures. ✓

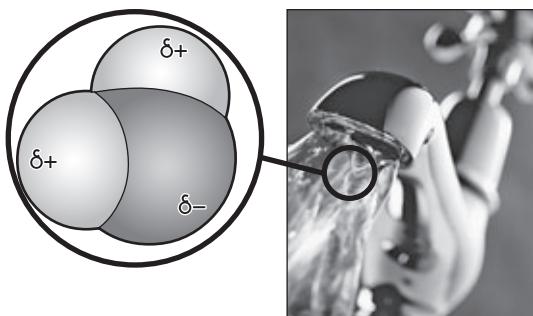
A solvent must be able to attract solute particles and pull them away from one another. Thus, solvent particles must attract solute particles more strongly than the solute particles attract one another.

POLAR MOLECULES

Recall that atoms bonded together do not all share electrons equally. For example, a water molecule is made up of two hydrogen atoms bonded to one oxygen atom. The oxygen atom attracts electrons more strongly than the hydrogen atoms do. Thus, the electrons spend more time near the oxygen atom. This gives each hydrogen atom a partial positive charge (δ^+) and the oxygen atom a partial negative charge (δ^-). ✓

Molecules that have partially charged positive and negative areas are **polar**. Because water molecules are polar, water can dissolve many other polar substances. Water can also dissolve ionic compounds such as table salt.

Water is a polar molecule because the oxygen atom strongly attracts electrons. Because the electrons spend more time near the oxygen atom, the oxygen atom has a partial negative charge.



READING TOOLBOX

Summarize Read each page of the section silently to yourself. With a partner, take turns summarizing each page.

READING CHECK

1. Identify Why is water called a universal solvent?

because
many substances dissolve
in it

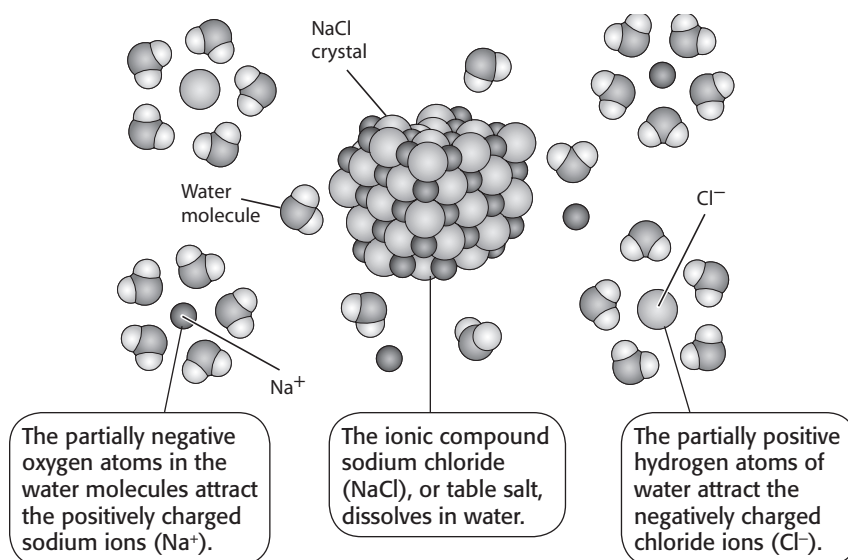
READING CHECK

2. Explain Why does a water molecule have partial charges?

The oxygen atom attracts
electrons more strongly
than the hydrogen atoms
do. Thus, the electrons
spend more time near the
oxygen atom

SECTION 2 How Substances Dissolve *continued***WATER AND IONIC COMPOUNDS**

Recall that charged particles attract particles with an opposite charge. Because a water molecule has areas of partial positive charge and partial negative charge, it can attract charged particles. The two partially positive hydrogen atoms attract negative particles. The one partially negative oxygen atom attracts positive particles.

**LOOKING CLOSER**

3. Describe On the diagram, circle the **solute** particles that have already dissolved. Describe the arrangement of the particles.

solute = particles that are surrounded by water

The attractions between ions in crystals of table salt are strong. However, the attraction between a water molecule and Na⁺ ions and Cl⁻ ions is even stronger. NaCl dissolves in water because attractions between its ions and water molecules are stronger than attractions between the ions. The water molecules pull the ions away from the crystal and surround them.

Water dissolves many other ionic compounds in the same way that it dissolves NaCl. However, some ionic compounds, including silver chloride (AgCl), do not dissolve in water. Why do some ionic compounds dissolve in water and some do not? In compounds such as AgCl, attractions between ions in the crystal are stronger than those between the ions and water molecules. Thus, the water molecules cannot pull the ions apart. ✓

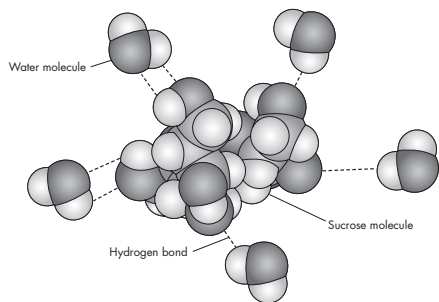
READING CHECK

4. Explain Why can water dissolve NaCl but not AgCl?

attractions between ions in the crystal are stronger than those between the ions and water molecules.

WATER AND POLAR MOLECULAR COMPOUNDS

The partially positive hydrogen atoms in a water molecule are attracted to the partially negative oxygen atoms of other water molecules. These attractions are known as **hydrogen bonds**.

SECTION 2 How Substances Dissolve *continued*

Hydrogen bonds between water molecules and sucrose molecules help pull sucrose molecules toward water molecules and away from one another. However, individual sucrose molecules do not break apart.

Many molecular compounds, including ethanol, vitamin C, and table sugar, are polar. Like water, these compounds contain hydrogen atoms bonded to oxygen atoms. Thus, hydrogen bonds can form between the partially charged atoms of water molecules and other polar molecules.

NONPOLAR COMPOUNDS

The electrons of a **nonpolar** molecule are distributed evenly over the whole molecule. Thus, a nonpolar molecule has no partial charges. Most nonpolar compounds do not dissolve in polar compounds. In other words, they are *insoluble* in polar compounds. For example, olive oil is a mixture of nonpolar compounds. Olive oil does not dissolve in water. Most nonpolar substances dissolve only in nonpolar solvents.

What Is the Role of Energy in Dissolving a Solute?

Attractions between particles of a solute and solvent help keep solute particles apart. However, for a solute to dissolve, energy is needed to break the attractions between particles of solute. Where does this energy come from?

Recall that particles of matter, such as atoms and molecules, move constantly. When you add sugar to a glass of water, water molecules collide with sugar molecules. When they collide, the water molecules transfer energy to the sugar molecules. This energy helps break the hydrogen bonds between sugar molecules. Thus, a solute such as sugar, dissolves due to the following:

- attractions between particles in the solute and solvent; and
- a transfer of energy that breaks attractions between solute particles.

LOOKING CLOSER

5. Explain When a molecular compound dissolves, do the molecules break apart? Explain your answer.

Hydrogen bonds between water molecules and the molecules, however, individual molecules do not break apart.

Critical Thinking

6. Infer Could NaCl dissolve in olive oil? Explain your answer.

No, NaCl is ionic (meaning it is polar) and will not dissolve in a nonpolar substance (oil)

READING CHECK

7. Explain Why is energy needed to dissolve a solute?

energy is needed to break the attractions between particles of solute

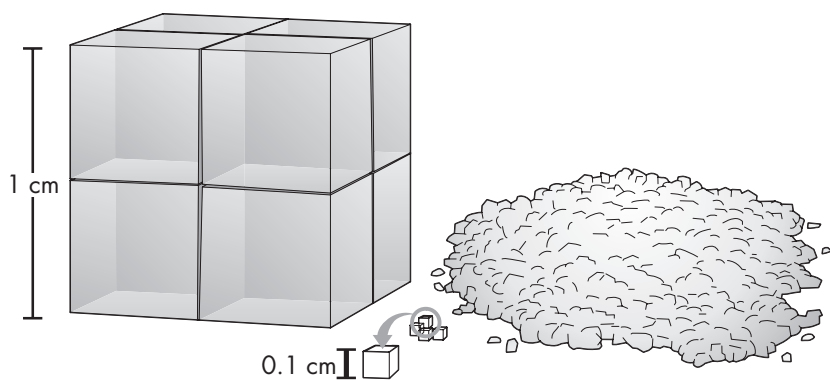
SECTION 2 How Substances Dissolve *continued*

What Can Cause a Solute to Dissolve More Quickly?

A solute dissolves because its particles interact with the particles of a solvent. Anything that allows more solvent to touch more solute will cause a solute to dissolve more quickly.

INCREASE IN SURFACE AREA

Small pieces of a substance dissolve faster than large pieces. For a given amount of a substance, many smaller pieces will have more *surface area* than a single larger piece. Greater surface area allows more solute to touch the solvent. As a result, there are more collisions between solute particles and solvent particles.



If you break a solute into smaller pieces, you will increase the total amount of surface area. Because more of the solute touches the solvent at one time, more collisions happen between solute and solvent particles.

TEMPERATURE INCREASE

If you heat a sample of matter, its particles move more quickly. This causes the solute to dissolve more quickly in two ways. First, faster moving particles collide more frequently. Second, at higher temperatures, collisions among particles transfer more energy.



Larger amounts of energy help break bonds between solute particles more easily.

LOOKING CLOSER

8. Explain How does an increase in surface area help a solute dissolve more quickly?

Greater surface area allows more solute to touch the solvent. As a result, there are more collisions between solute particles and solvent particles

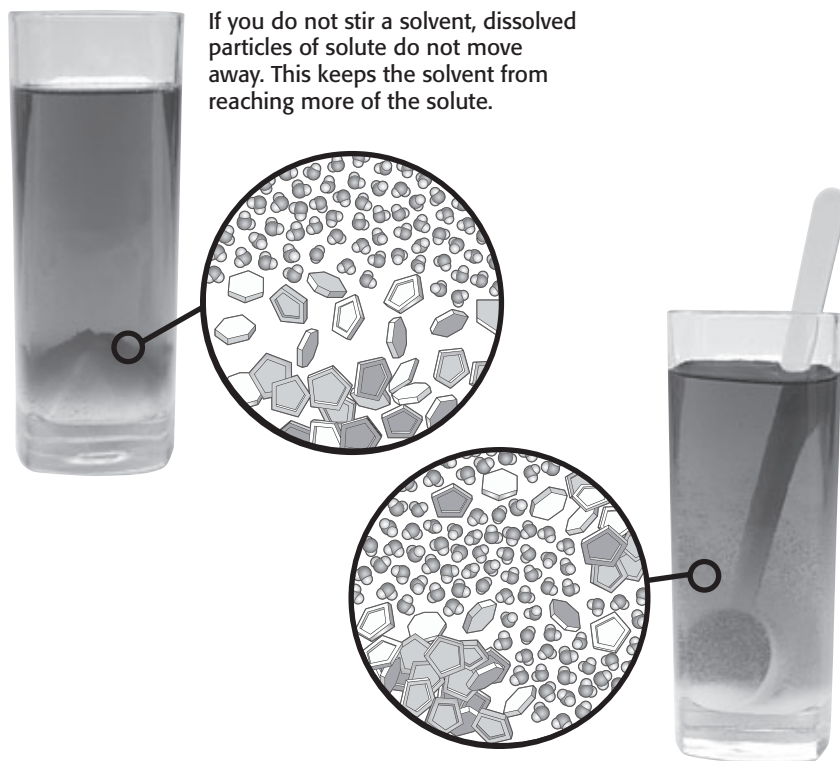
LOOKING CLOSER

9. Explain How does an increase in temperature help a solute dissolve?

If you heat a sample of matter, its particles move more quickly. Faster moving particles collide more frequently higher and collisions among particles transfer more energy

SECTION 2 How Substances Dissolve *continued***STIR OR SHAKE**

If you pour some sugar into a glass of water and let it sit, the sugar will dissolve slowly. However, if you stir or shake the water, the sugar will dissolve more quickly.



Stirring or shaking moves the dissolved solute particles away from the rest of the solute. Then, more solvent can reach the solute that has not dissolved.

LOOKING CLOSER

10. Explain How does stirring a solution allow more contact between solvent and solute particles?

Stirring or shaking moves the dissolved solute particles away from the rest of the solute. Then, more solvent can reach the solute that has not dissolved

How Can a Solute Affect a Solution's Physical Properties?

A solute can change the physical properties of the pure solvent. For example, the boiling point of pure water is $100\text{ }^{\circ}\text{C}$ and the freezing point is $0\text{ }^{\circ}\text{C}$. If you dissolve 12 g of sodium chloride in 100 mL of water, the boiling point of the solution increases from $100\text{ }^{\circ}\text{C}$ to $102\text{ }^{\circ}\text{C}$. The freezing point decreases from $0\text{ }^{\circ}\text{C}$ to $-8\text{ }^{\circ}\text{C}$.

The effect of a solute on freezing and melting point of a solvent can be useful. For example, a car's radiator contains a solution of water and ethylene glycol. This solution acts as antifreeze because the freezing point is $-30\text{ }^{\circ}\text{C}$. It also helps prevent boiling in hot weather because the boiling point is $109\text{ }^{\circ}\text{C}$.

Talk About It

Research Copy the ingredients from the labels of several household products that are solutions. For each, try to identify the solvent from the list of ingredients. What does the solvent tell you about how the product is used? Make a poster that describes your findings and present it to the class.

Section 2 Review

SECTION VOCABULARY

hydrogen bond the intermolecular force occurring when a hydrogen atom that is bonded to a highly electronegative atom of one molecule is attracted to two unshared electrons of another molecule

nonpolar describes a molecule in which centers of positive and negative charge are not separated

polar describes a molecule in which the positive and negative charges are separated

1. Explain Why can water dissolve many ionic compounds?

because water is a polar molecule and is able to either break apart ionic compounds or form hydrogen bonds with polar covalent compounds

2. Describe Describe and explain three methods you could use to make a spoonful of salt dissolve quickly in a glass of water.

stir the salt

heat the water

use smaller salt grains

3. Predict Use the rule of “like dissolves like” to predict whether the polar compound glycerol is soluble in water.

since both are polar, glycerol will be soluble

4. Identify Relationships How does the attraction between particles affect the ability of a solvent to dissolve a substance?

if the solvent is highly attracted to itself, it is harder to get a substance to dissolve

5. Apply Concepts You combine water, sugar, and drink mix to make a fruit-flavored drink. You decide to freeze the mixture to make ice cubes. Into the freezer you place one ice cube tray filled with the drink and one ice cube tray filled with plain water. Two hours later you find that the water has frozen but the drink has not. Explain this result.

for water to freeze, it must form hydrogen bonds with other water molecules. The drink mix and sugar prevent hydrogen bonds from forming and the water does not freeze as fast