# chapter 10 Atoms, Elements, and the Periodic Table

## section 3 Compounds and Mixtures

**PS 3.2b:** Mixtures are physical combinations of materials and can be separated by physical means. **3.3f:** There are more than 100 elements. Elements combine in a multitude of ways to produce compounds that account for all living and nonliving substances. Few elements are found in their pure form. **Also covered:** PS 3.1g, 3.3g

### Before You Read

If you mix together salt and water, what happens to the salt? What happens to the water?

_____

_____

_____

**What You'll Learn**

- what a compound is
- how different types of mixtures are similar and different

### Read to Learn

#### Substances

Scientists classify matter depending on what it is made of and how it behaves. Matter that has the same composition and properties throughout is a **substance**. Elements such as gold and aluminum are substances. Substances also can be two or more elements combined, like brass. Brass is made of copper and zinc.

##### What is a compound?

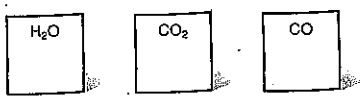
A **compound** is a substance whose smallest unit is made up of atoms of more than one element bonded together. Water is a compound. It is made up of hydrogen and oxygen. Hydrogen and oxygen are both colorless gases. But, when they are combined, they make water. Water is sometimes written as $H_2O$. H stands for hydrogen and O stands for oxygen. Many compounds have properties that are different from those of its elements. For example, water is different from the gases hydrogen and oxygen. It also is different from hydrogen peroxide ($H_2O_2$), another compound made from hydrogen and oxygen.

Study Coach

**Create a Quiz** As you read this section, write a quiz question for each paragraph. After you finish reading the section, answer your quiz questions.

FOLDABLES

**Identify** Make the following Foldables from quarter-sheets of notebook paper to help you identify the differences between $H_2O$, $C_2O$, and CO.



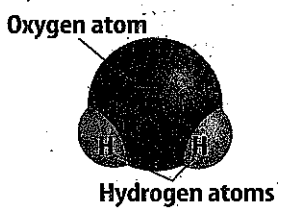
## What is a chemical formula?

Compounds have chemical formulas. A chemical formula shows the elements that make up a compound. It also shows how many atoms of each element are in the compound. For example, $H_2O$ is the chemical formula of water. The small number to the right of an element tells how many atoms are in one unit, or molecule, of that compound. When no number is written, the molecule has one atom of that element. So, a molecule of water is made up of two atoms of hydrogen and one atom of oxygen.

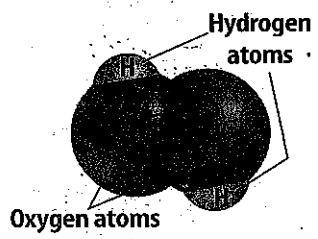
$H_2O_2$ is the chemical formula for hydrogen peroxide. It has two hydrogen atoms and two oxygen atoms. So, the elements hydrogen and oxygen form two compounds—water and hydrogen peroxide. Look at the figures below to see the differences in their structure. The properties of water are very different from the properties of hydrogen peroxide.

**Picture This**

1. **Circle** the chemical formula in each figure.




$H_2O$ Water




$H_2O_2$ Hydrogen Peroxide

**Think it Over**

2. **Identify** What is the chemical formula for carbon dioxide?

## Are compounds always the same?

A given compound always is made of the same elements and in the same proportion, or ratio. For example, one unit of water is always made of two hydrogen atoms and one oxygen atom. You can write the number of molecules of water that you have by putting a number in front of the formula. So, 6 $H_2O$ means you have six molecules of water.

## Mixtures

A mixture is made when two or more substances come together but do not combine to make a new substance. The substances can be elements, compounds, or elements and compounds. The proportions of the substances in a mixture can be changed without changing the identity of the mixture, unlike in a compound. Sand and water form a mixture. If you add more sand to the mixture, you still have a mixture of sand and water.

**Air** Another example of a mixture is air. Air is made of nitrogen, oxygen, and many other gases. There can be different amounts of these gases in the mixture. But you still have a mixture of air.

You see mixtures every day. A salad of lettuce, tomatoes, and cucumbers is a mixture. The mixture may have more tomatoes than cucumbers, but it is still a salad.

## How can mixtures be separated?

You can separate many mixtures. A mixture of solids can be separated by using different screens or filters. For example, you could separate a mixture of pebbles and sand by pouring the mixture through a screen. The screen can catch the pebbles, but let the sand go through.

You also can use a liquid to separate some mixtures of solids. If you add water to a mixture of sugar and sand, only the sugar will dissolve in the water. Then, you can pour the mixture through a filter that catches the sand. Next, you can separate the sugar from the water by heating it. As shown in the figure, even your blood is a mixture that can be separated.

## What are homogeneous and heterogeneous mixtures?

**Homogeneous Mixtures** Homogeneous means "the same throughout." So, homogeneous mixtures are those that look the same throughout. You cannot see the different parts of the mixture. Since you can't see the different parts, you might not know it is a mixture. Homogeneous mixtures can be solids, liquids, or gases. Brass, sugar water, and air are mixtures.

**Heterogeneous Mixtures** Heterogeneous means "completely different." Heterogeneous mixtures have larger parts that are different from each other. You can see the different parts of a heterogeneous mixture. Vegetable soup is a heterogeneous mixture.

FOLDABLES

**D Contrast** Make the following 2-tab Foldable to help you learn the differences between homogeneous mixtures and heterogeneous mixtures.


**Reading Check**

3. **Explain** How is a heterogeneous mixture different from a homogeneous mixture?

# After You Read

## Mini Glossary

**compound:** a substance whose smallest unit is made up of atoms of more than one element bonded together

**mixture:** made when two or more substances come together but do not combine to make a new substance

**substance:** matter that has the same composition and properties throughout

1. Review the terms and definitions in the Mini Glossary. In your own words, describe the difference between a compound and a mixture.

2. Complete the chart below to compare the substances discussed in this section.

| Substance | Definition | Examples |
|---|---|---|
| Element | | |
| Compound | | |
| Mixture | | |

End of Section

ScienceOnline Visit **glencoe.com** to access your textbook, interactive games, and projects to help you learn more about compounds and mixtures.

# chapter 11 Substances, Mixtures, and Solubility

## section 1 What is a solution?

**PS 3.1a:** Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points. **Also covered:** PS 3.1g, 3.3f

### Before You Read

Do you add sugar to your tea? How do you know that the white substance will make your drink sweeter?

_____

_____

**What You'll Learn**

- the differences between substances and mixtures
- two types of mixtures
- how solutions form
- different types of solutions

### Read to Learn

**Mark the Text**

**Underline** As you read, underline words and sentences that you think are important to remember. After you read, review what you have underlined.

#### Substances

Water, salt water, and pulpy orange juice are different liquids. Their differences can be explained by chemistry. Think about pure water. If you freeze it, melt it, or boil it, it is still water. But, if you boil salt water, the water turns to gas and leaves the salt behind. If you strain pulpy orange juice, it loses its pulp. How does chemistry explain these differences? The answer has to do with the chemical makeup of these materials.

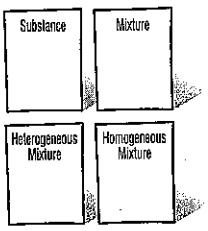
#### What are atoms, substances, and elements?

**Atoms** Recall that atoms are the basic building block of matter. Each atom has its own chemical and physical properties. These properties are determined by the number of protons the atom has.

**Substances** A substance is matter that has the same fixed makeup and properties throughout. A substance cannot be broken down into simpler parts by a physical process. For example, you can freeze, boil, stir, and filter water, but it is still water. The only way to change a substance is by a chemical process. The table on the next page shows some examples of physical processes and chemical processes.

**FOLDABLES**

**Classify** Use quarter-sheets of paper to help you organize definitions and examples of substances and mixtures.



## Picture This

1. **Explain** How do physical processes differ from chemical processes?

## Think it Over

2. **Classify** Why is water a compound and not an element?

Examples of Physical and Chemical Processes

| Physical Processes (do not change substances) | Chemical Processes (do change substances) |
|---|---|
| Boiling | Burning |
| Changing pressure | Reacting with other chemicals |
| Cooling | Reacting with light |
| Sorting | |

**Elements** An element is an example of a pure substance. An element cannot be broken down into simpler substances. The number of protons in an element cannot change unless the element changes.

### What are compounds?

Water is a compound. A compound is a substance made of two or more elements that are chemically combined. The makeup of a compound is always the same. For example, a water molecule always has two hydrogen atoms combined with one oxygen atom. All water, whether frozen, liquid, or vapor, has the same ratio of hydrogen atoms to oxygen atoms.

## Mixtures

Imagine drinking a glass of salt water. You would know right away that it is not pure water. Salt water is not a pure substance. It is a mixture of salt and water. Mixtures are made when two or more substances come together but do not chemically bond together to make a new substance. The substances can be separated by physical processes. For example, you can boil salt water to separate the salt from the water.

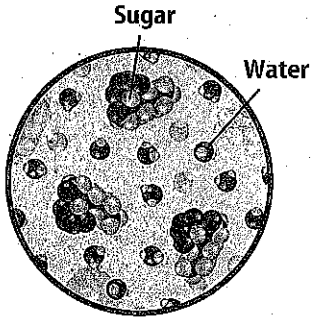
Mixtures do not contain an exact amount of each substance like a compound. Lemonade can be weak tasting or strong tasting. It depends on how much lemon juice is added to the water. It also can be sweet or sour, depending on how much sugar is added. No matter how strong, weak, sweet, or sour, it is still lemonade.

### What are heterogeneous mixtures?

Some mixtures are easy to see. A watermelon is a mixture of fruit and seeds. But, the fruit and seeds aren't mixed evenly. A **heterogeneous** (he tuh ruh JEE nee us) **mixture** is a mixture where the substances are not mixed evenly. The substances in heterogeneous mixtures are usually easy to tell apart. A bowl of cereal with milk is another example of a heterogeneous mixture.

## What are homogeneous mixtures?

When you mix sugar and water together you don't see the sugar particles floating in the water. Sugar water is a homogeneous (ho muh JEE nee us) mixture. A **homogeneous mixture** has two or more substances in which the molecules mix evenly but do not bond together. Another name for a homogeneous mixture is a **solution.** The figure shows the mixture of sugar and water molecules in a solution of sugar water.




## How Solutions Form

When you mix sugar and water together, you can't see the sugar particles in the water. The sugar doesn't actually disappear. The sugar molecules spread out until they are evenly spaced throughout the water molecules, forming a solution. This is called dissolving. The substance in a solution that dissolves, or seems to disappear, is called the **solute.** The substance that dissolves the solute in a solution is the **solvent.** In the sugar water solution, the sugar is the solute and water is the solvent.

## How can solids form from solutions?

Sometimes, a solute can come back out of a solution and form a solid. This process is called crystallization.

**Crystallization** Crystallization happens because of a physical change. For example, crystallization can happen when a solution is cooled. Crystallization also can happen when some of the solvent evaporates. A stalactite, or hanging rock, in a cave is an example of crystallization. Minerals dissolve in water as it flows through rocks. When the solution drips from the ceiling of the cave, some of the water evaporates. The minerals in the solution crystallize to form the stalactite.

### Picture This

3. **Describe** Look at the figure. How would you describe the sugar and water molecules in a solution of sugar water? Circle the answer.

   **a.** not mixed evenly
   **b.** combined
   **c.** mixed evenly
   **d.** compounded

### Think it Over

4. **Apply** Minerals dissolve in water as it flows through rocks at the top of the cave. In this solution, what is the solute and what is the solvent?

_____

_____

_____

**Precipitate Formation** When some solutions are mixed, a chemical change happens and a solid forms. A solid that forms when solutions are mixed and a chemical change happens is a **precipitate** (prih SIH puh tut). Precipitate formation is different from crystallization because a chemical change takes place. A precipitate can form in a shower. Minerals that are dissolved in water can react chemically with soap. This chemical reaction forms a precipitate called soap scum.

## Types of Solutions

Not all solutions are solid solutes dissolved in liquid solvents. Solutions can be made up of combinations of solids, liquids, and gases. See the examples in the table.

**Picture This**

5. **Interpret Data** Name two solutions that have carbon dioxide as one of the solutes.

_____

_____

_____

**Examples of Common Solutions**

| Solution | Solvent/ State | Solute/ State | State of Solution |
|---|---|---|---|
| Earth's atmosphere | nitrogen/gas | oxygen/gas<br>carbon dioxide/gas<br>argon/gas | gas |
| Carbonated beverage | water/liquid | carbon dioxide/gas | liquid |
| Brass | copper/solid | zinc/solid | solid |

## Liquid Solutions

Sugar water and salt water are examples of solutions with liquid solvents and solid solutes. The solute in a solution can be a solid, another liquid, or even a gas. The state of the solution will usually be the same as the state of the solvent. For example, sugar is a solid and water is a liquid. When sugar and water are mixed together to form a solution, the solution is a liquid, not a solid. ☑

**Reading Check**

6. **Explain** What does the state of a solution usually depend on?

_____

_____

### What are liquid-gas and liquid-liquid solutions?

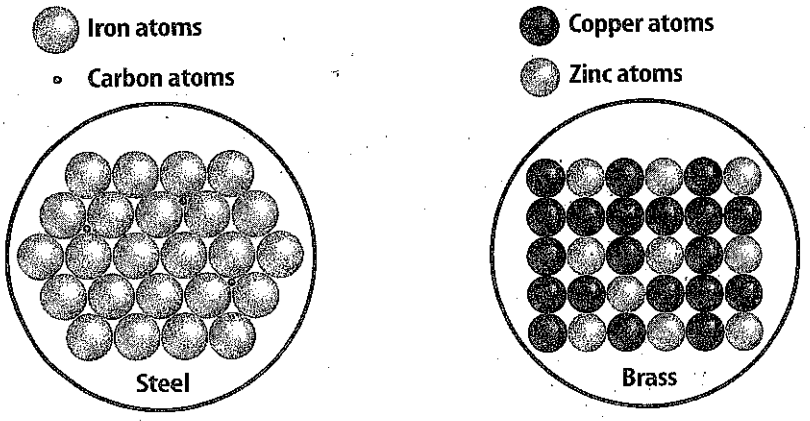
**Liquid-Gas** Carbonated drinks are examples of solutions with liquid solvents and gas solutes. The gas solute is carbon dioxide. Water is the liquid solvent. Carbon dioxide gives the drinks their fizz.

**Liquid-Liquid** Vinegar is an example of a liquid-liquid solution. Water is the liquid solvent and acetic acid is the liquid solute. In vinegar, only 5 percent of the solution is acetic acid. Water makes up 95 percent of the solution.

## Gaseous and Solid Solutions

**Gas Solutions** Sometimes, a small amount of one gas is dissolved in a larger amount of another gas. This is a gaseous solution, also called a gas-gas solution. The air you breathe is a gaseous solution. About 78 percent of air is nitrogen, which is the solvent. About 20 percent of air is oxygen, which is one of the solutes. Other solutes in air are carbon dioxide, argon, and some other gases in small amounts.

**Solid Solutions** There are also solid solutions. In a solid solution, the solvent is solid. The solute can be a solid, liquid, or gas. The most common solid solutions are solid-solid solutions. Both the solvent and solute are solids. Steel is a solution of carbon dissolved in iron. A solid-solid solution made from two or more metals is called an alloy. Brass is an alloy of zinc dissolved in copper. The figure shows what microscopic views of steel and brass might look like. ☑




**Reading Check**

7. **Identify** What states can the solutes be in a solid solution?

_____

_____

**Applying Math**

8. **Interpret a Scientific Illustration** Look at the sample of brass in the figure. What is the ratio of copper atoms to the total number of atoms?

_____

# After You Read

## Mini Glossary

**heterogeneous mixture:** a mixture where the substances are not mixed evenly

**homogeneous mixture:** a mixture that has two or more substances in which the molecules mix evenly, but do not bond together

**precipitate:** a solid that forms when solutions are mixed and a chemical change happens

**solute:** the substance in a solution that dissolves, or seems to disappear

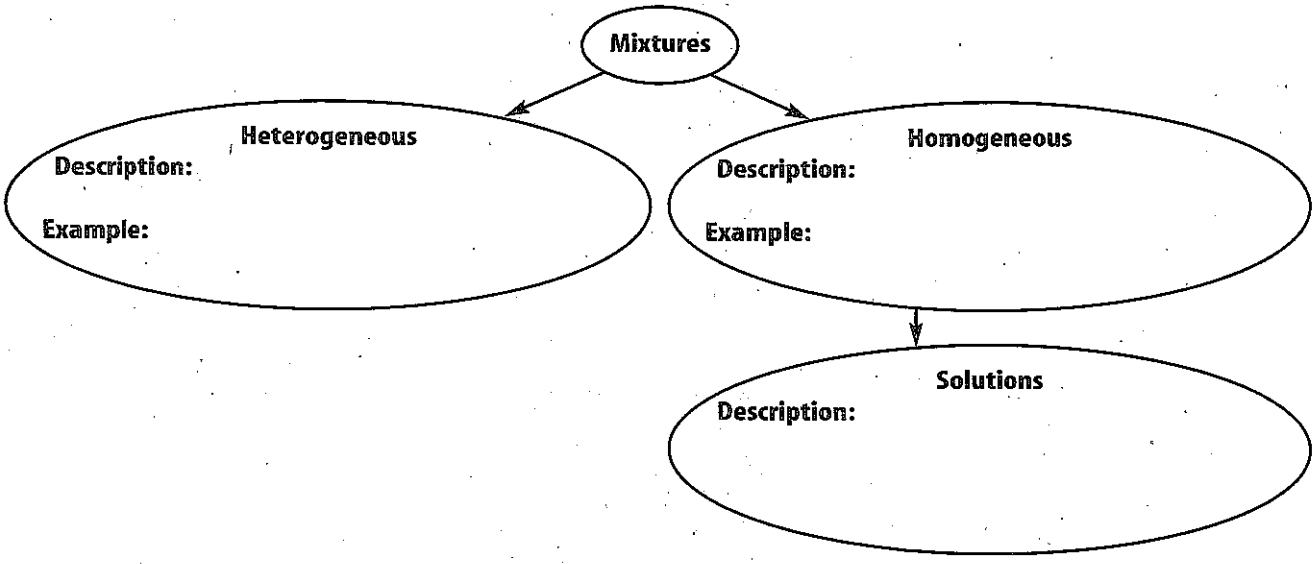
**solution:** another name for a homogeneous mixture

**solvent:** the substance that dissolves the solute in a solution

**substance:** matter that has the same fixed makeup and properties throughout

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using at least one glossary term to describe the mixture of vegetables in a salad.

2. Fill in the graphic organizer with important facts about mixtures and solutions




3. As you read this section, you underlined words and sentences that you thought were important. How did you decide what to underline?

End of Section

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# Chapter 11 Substances, Mixtures, and Solubility

## Section 2 Solubility

**PS 3.1b:** Solubility can be affected by the nature of the solute and solvent, temperature, and pressure. The rate of solution can be affected by the size of the particles, stirring, temperature, and the amount of solute already dissolved. **Also covered:** PS 4.2e

### Before You Read

What happens when you put one teaspoon of sugar in a glass of water? What would happen if you put one cup of sugar in a glass of water?

_____

_____

### What You'll Learn

- why water is a good solvent
- how much of a solute will dissolve in a solvent
- how temperature affects chemical reactions

### Read to Learn

## Water—The Universal Solvent

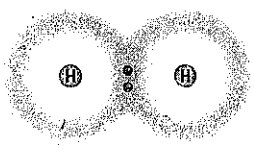
Water is a solvent for many solutions, including fruit juice and vinegar. A solution in which water is the solvent is called an **aqueous** (A kwee us) solution. Water dissolves things so well it is often called the universal solvent.

### What are molecular compounds?

You know that atoms can join with other atoms to form compounds. When certain atoms form compounds, they share electrons. Sharing electrons is called covalent (co VAY lent) bonding. Compounds that have covalent bonds are called molecular compounds, or molecules.

**Nonpolar Molecules** In some molecules, the atoms share their electrons equally. When the electrons are shared evenly, the molecule is called nonpolar. Look at the hydrogen molecule. A hydrogen molecule is nonpolar.

**Hydrogen Molecule**

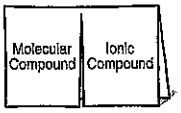



Study Coach

**Make Flash Cards** As you read, write important questions on note cards. Write the answer to each question on the back of the card. After you read, see if you can answer your questions without looking at the answers.

FOLDABLES

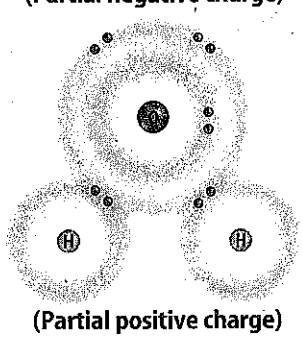
**B Compare and Contrast** Make the following Foldable to show how molecular compounds and ionic compounds are alike and different.



## Picture This

1. **Circle** the shared electrons in the figure.

**Polar Molecules** The atoms in some molecules do not share their electrons equally. Look at the water molecule. Two hydrogen atoms share electrons with one oxygen atom. But, the electrons spend more time around the oxygen atom than they spend around the hydrogen atom. This makes the oxygen part of the water molecule have a slightly negative charge. The hydrogen parts have a slightly positive charge. The total charge of the water molecule is neutral. Molecules that have slightly positive and slightly negative charges are called polar molecules. The bonds between its atoms are called polar covalent bonds.




## What are ionic bonds?

Some atoms do not share electrons when they join to form compounds. Instead, these atoms lose or gain electrons making the number of protons and electrons in the atom no longer equal. The atom becomes either positively charged or negatively charged. Atoms with a charge are called ions. Bonds between ions are called ionic bonds. The compound that is formed is called an ionic compound. Table salt is an ionic compound. It is made of sodium ions and chloride ions. Each sodium atom loses an electron to a chlorine atom and becomes positively charged. The chlorine atoms gain the electrons from the sodium atoms and become negatively charged. ☑

**Reading Check**

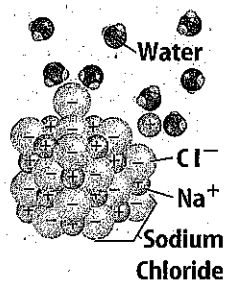
2. **Summarize** Write the correct words to complete the sentence on the lines below: Atoms in an ionic compound ___a.___ or ___b.___ electrons.

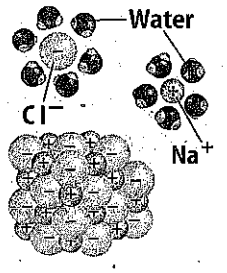
a. _____

b. _____

## How does water dissolve ionic compounds?

Remember that a water molecule is polar. It attracts positive and negative ions. Look at the figure. When sodium chloride, or table salt, is added to water, the sodium (Na) ions and chloride (Cl) ions are attracted by the water molecules. The slightly negative end of a water molecule attracts positive sodium ions ($Na^+$). The slightly positive end of a water molecule attracts negative chloride ions ($Cl^-$). When an ionic compound is mixed with water, the ions are pulled apart, or dissolved, by the water molecules.




## Picture This

3. **Highlight** Use a highlighter to circle the part of the figure that shows the dissolved table salt.

### How does water dissolve molecular compounds?

Water does dissolve molecular compounds, like sugar, that are not made of ions. But, water does not break sugar molecules apart as it does in ionic compounds. Sugar molecules are polar, like water molecules. Polar water molecules are attracted to the positive and negative ends of the sugar molecules. The water molecules move in between sugar molecules and spread them apart. When this happens, the sugar dissolves.

## What will dissolve?

When you put a teaspoon of sugar in iced tea and stir it, what happens? The sugar dissolves. Why doesn't the spoon dissolve? A substance that dissolves in another substance is soluble, or able to be dissolved in that substance. Sugar is soluble in water. You would say the metal of the spoon is insoluble in water because it does not dissolve.

### What does "like dissolves like" mean?

Chemists use the phrase "like dissolves like" to remember which solvents can dissolve which solutes. "Like dissolves like" means polar solvents dissolve polar solutes. Also, nonpolar solvents dissolve nonpolar solutes. Sugar and water are both polar, so water dissolves sugar. Why does water dissolve sodium chloride? Remember, the sodium and chloride ions have charges like polar molecules. So, water reacts with these ions in the same way it reacts with other polar molecules. ☑

Have you ever mixed oil and water in a glass? They do not form a solution. Instead, the two liquids separate and form layers in the glass. Oil molecules are nonpolar. Polar water molecules are not attracted to them. So, oil will not dissolve in water.

## How much will dissolve?

**Solubility** (sahl yuh BIH luh tee) is the measurement that describes how much solute dissolves in a given amount of solvent. Usually, solubility is the amount of solute that can dissolve in 100 g of solvent at a certain temperature. Some solutes are highly soluble. This means that a large amount of solute can be dissolved in 100 g of solvent. For example, 63 g of potassium chromate will dissolve in 100 g of water at 25°C. But, some solutes are not very soluble. Only 0.00025 g of barium sulfate will dissolve in 100 g of water at 25°C. This solubility is so low that it is called insoluble.

**Reading Check**

4. **Recall** What does "like dissolves like" mean?

_____

_____

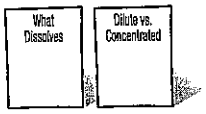
_____

_____

**FOLDABLES**

**Organize Information**

Use two quarter-sheets of paper to write information about solutions and how they dissolve.



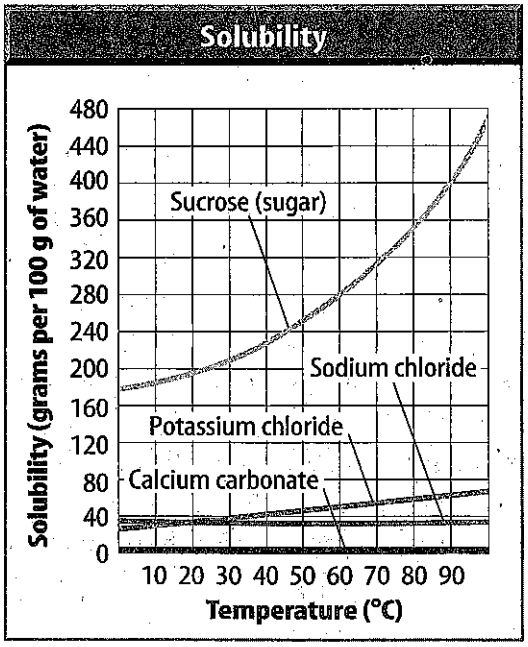
## How does temperature affect solubility?

The solubility of many solutes changes with the temperature of the solvent. Sugar dissolves faster in hot tea than it does in iced tea. Also, more sugar can dissolve in hot tea than in iced tea. The solubility and the rate that sugar dissolves in water increases as temperature increases.

This is not true of all solutes. The graph shows the solubility at different temperatures of several solutes in water. An increase in temperature decreases the solubility of a gas in a liquid-gas solution. That is why cold sodas fizz less than warm sodas when you open them.

**Applying Math**

5. **Interpret Data** How many grams of sugar will dissolve in 100 g of water at 60°C?




## What are saturated solutions?

If you add potassium chromate to 100 g of water at 25°C, only 63 g of it will dissolve. A solution that contains all of the solute that it can hold under the given conditions is **saturated.** When a solution has less solute than what is needed to become saturated, it is called an unsaturated solution. Look at the graph above. A saturated sugar water solution would contain about 204 g of sugar in 100 g of water at 25°C. If less sugar is used, the solution is unsaturated.

A hot solvent usually can hold more solute that a cold solvent. When a saturated solution cools, some of the solute usually falls out of solution. But, if a saturated solution is cooled slowly, sometimes the extra solute can stay dissolved. This is called a supersaturated solution.

**Think it Over**

6. **Apply** Tell whether this solution is saturated or unsaturated: 50 g of sugar in 100 g of water at 25°C.

## Rate of Dissolving

A solute dissolves faster when the solution is shaken or stirred or heated. These actions make the surfaces of the solute come into contact with the solvent more quickly. You can do the same thing by breaking up or grinding the solute into smaller pieces. For example, granules of sugar dissolve more quickly than sugar cubes. Grinding increases the surface area of the solute that is exposed to the solvent.

Chemical reactions happen when molecules bump into each other. At colder temperatures, chemical reactions happen more slowly. Refrigerators slow the chemical reactions that cause food to spoil. So, food stays fresh longer in a refrigerator than at room temperature.

## Concentration

The **concentration** of a solution tells you how much solute is in a solution compared to the amount of solvent. A concentrated solution has a lot of solute for a given amount of solvent. A dilute solution has little solute for a given amount of solvent.

### How do you measure concentration?

Doctors need to give the exact concentration of medicines so patients will be treated correctly. One way to give an exact concentration is to give the percentage of the volume of the solution that is made of solute. The label of a fruit juice container might say, "contains 10 percent juice." This means that 10 percent of the container is the solute: juice. Ninety percent is the solvent: water and other substances like sugar.

### How do solute particles affect solvents?

Solutes often change the freezing and boiling points of solvents. When liquids freeze, their molecules arrange themselves in certain ways. Solute particles can change the way the molecules arrange themselves and lower the freezing point.

When liquids boil, their molecules gain enough energy to move from the liquid state to the gaseous state. Solute particles can interfere with the change from liquid to gaseous state. More energy is needed to make the solvent particles escape from the liquid. This increases the boiling point. ☑

**Think it Over**

**7. Infer** A metal worker needs an acid to dissolve metal. Does she probably need an acid that is concentrated or dilute?

_____

**Reading Check**

**8. Determine** What do solutes often change in solvents?

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_____

# After You Read

## Mini Glossary

**aqueous:** a solution in which water is the solvent

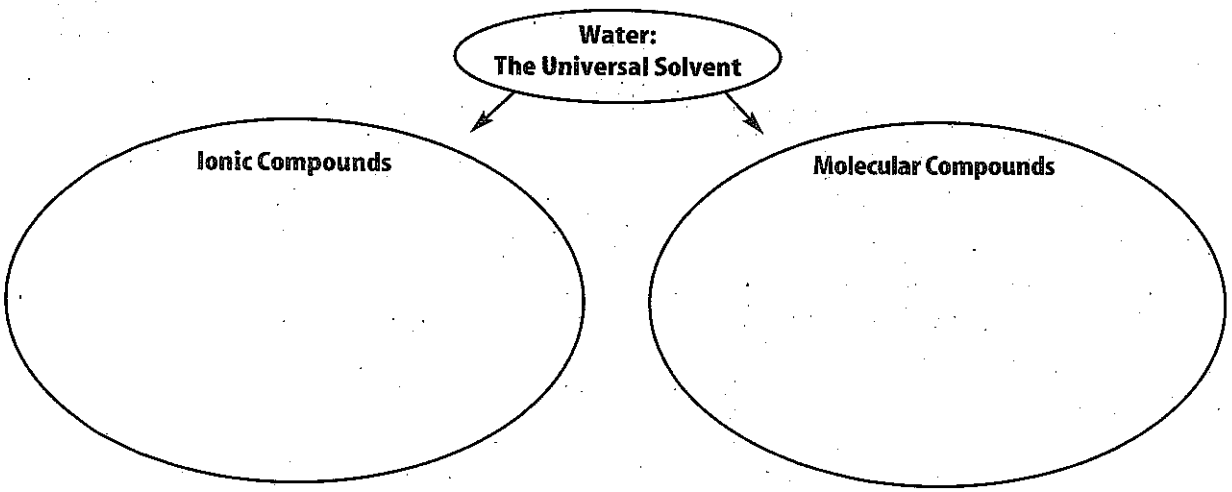
**concentration:** how much solute is in a solution compared to the amount of solvent

**saturated:** a solution that contains of all the solute that it can hold under given conditions

**solubility:** the measurement that describes how much solute dissolves in a given amount of solvent

1. Review the terms and their definitions in the Mini Glossary. Use two of the terms in one or two sentences to describe a bottle of orange juice.

2. In the graphic organizer, explain how water dissolves the types of compounds shown.




3. How could you use lemonade to teach others about the concentrations of solutions?

End of Section

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