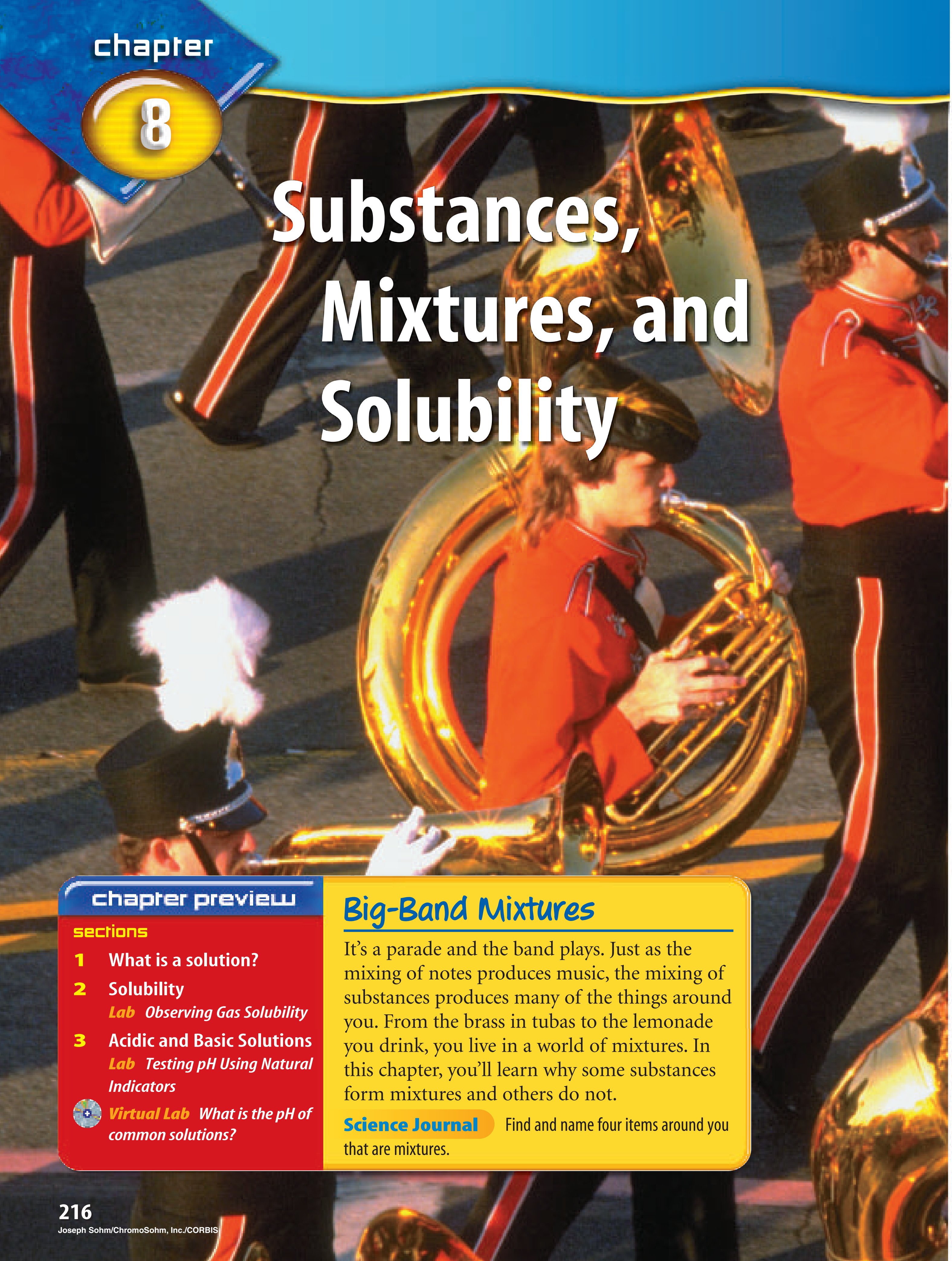
chapter 8



# Substances, Mixtures, and Solubility

## chapter preview

### sections



## Big-Band Mixtures

It's a parade and the band plays. Just as the mixing of notes produces music, the mixing of substances produces many of the things around you. From the brass in tubas to the lemonade you drink, you live in a world of mixtures. In this chapter, you'll learn why some substances form mixtures and others do not.

**Science Journal** Find and name four items around you that are mixtures.



Joseph Sohm/ChromoSohm, Inc./CORBIS

# Start-Up Activities

## Launch Lab

### Particle Size and Dissolving Rates

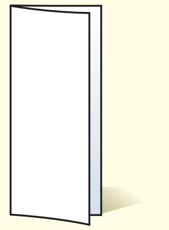
Why do drink mixes come in powder form? What would happen if you dropped a big chunk of drink mix into the water? Would it dissolve quickly? Powdered drink mix dissolves faster in water than chunks do because it is divided into smaller particles, exposing more of the mix to the water. See for yourself how particle size affects the rate at which a substance dissolves.

1. Pour 400 mL of water into each of two 600-mL beakers.
2. Carefully grind a bouillon cube into powder using a mortar and pestle.
3. Place the bouillon powder into one beaker and drop a whole bouillon cube into the second beaker.
4. Stir the water in each beaker for 10 s and observe.
5. **Think Critically** Write a paragraph in your Science Journal comparing the color of the two liquids and the amount of undissolved bouillon at the bottom of each beaker. How does the particle size affect the rate at which a substance dissolves?

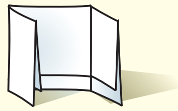
## Foldables™ Study Organizer

**Solutions** Make the following Foldable to help classify solutions based on their common features.

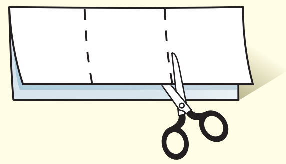
**STEP 1** **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



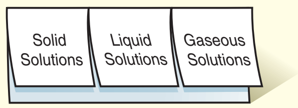
**STEP 2** **Turn** lengthwise and **fold** into thirds.



**STEP 3** **Unfold and cut** only the top layer along both folds to make three tabs.



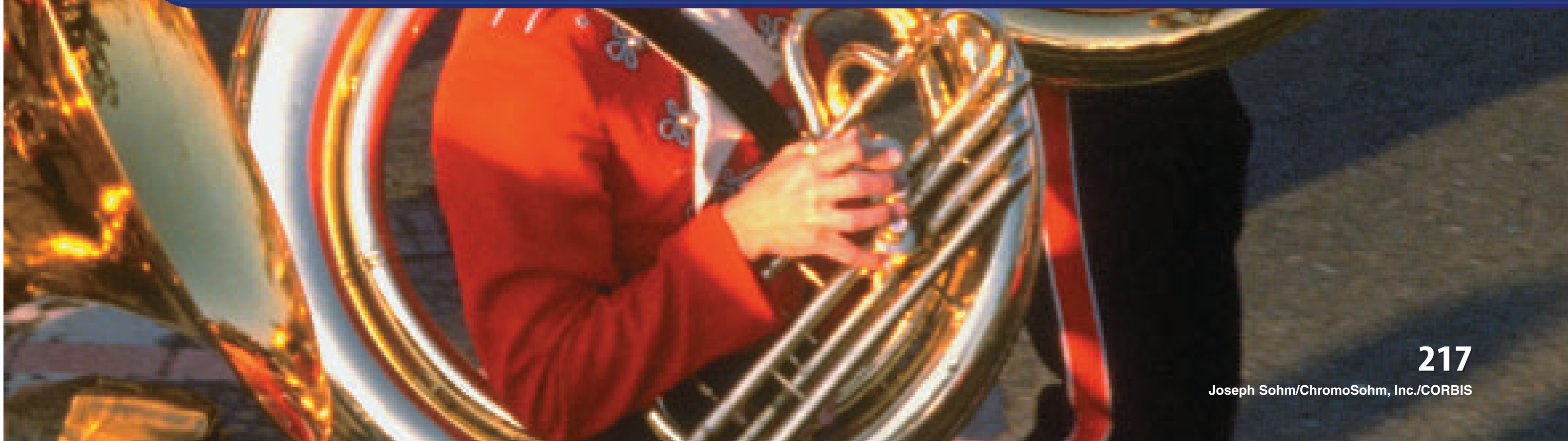
**STEP 4** **Label** each tab as shown.




**Find Main Ideas** As you read the chapter, classify solutions based on their states and list them under the appropriate tabs. On your Foldable, circle the solutions that are acids and underline the solutions that are bases.

Science Online

Preview this chapter's content and activities at ips.msscience.com





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section 1

# What is a solution?

as you read

## What You'll Learn

- **Distinguish** between substances and mixtures.
- **Describe** two different types of mixtures.
- **Explain** how solutions form.
- **Describe** different types of solutions.

## Why It's Important

The air you breathe, the water you drink, and even parts of your body are all solutions.

**Review Vocabulary**

**proton:** positively charged particle located in the nucleus of an atom

**New Vocabulary**

- substance
- heterogeneous mixture
- homogeneous mixture
- solution
- solvent
- solute
- precipitate

## Substances

Water, salt water, and pulpy orange juice have some obvious differences. These differences can be explained by chemistry. Think about pure water. No matter what you do to it physically—freeze it, boil it, stir it, or strain it—it still is water. On the other hand, 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 compositions of the materials.

**Atoms and Elements** Recall that atoms are the basic building blocks of matter. Each atom has unique chemical and physical properties which are determined by the number of protons it has. For example, all atoms that have eight protons are oxygen atoms. A **substance** is matter that has the same fixed composition and properties. It can't be broken down into simpler parts by ordinary physical processes, such as boiling, grinding, or filtering. Only a chemical process can change a substance into one or more new substances. **Table 1** lists some examples of physical and chemical processes. An element is an example of a pure substance; it cannot be broken down into simpler substances. The number of protons in an element, like oxygen, are fixed—it cannot change unless the element changes.

**Table 1 Examples of Physical and Chemical Processes**

| Physical Processes | Chemical Processes |
|---|---|
| Boiling | Burning |
| Changing pressure | Reacting with other chemicals |
| Cooling | Reacting with light |
| Sorting | |

**Compounds** Water is another example of a substance. It is always water even when you boil it or freeze it. Water, however, is not an element. It is an example of a compound which is made of two or more elements that are chemically combined. Compounds also have fixed compositions. The ratio of the atoms in a compound is always the same. For example, when two hydrogen atoms combine with one oxygen atom, water is formed. All water—whether it's in the form of ice, liquid, or steam—has the same ratio of hydrogen atoms to oxygen atoms.

Separation by magnetism    Separation by straining

**Figure 1** Mixtures can be separated by physical processes.
**Explain** *why the iron-sand mixture and the pulpy lemonade are not pure substances.*

## Mixtures

Imagine drinking a glass of salt water. You would know right away that you weren't drinking pure water. Like salt water, many things are not pure substances. Salt water is a mixture of salt and water. Mixtures are combinations of substances that are not bonded together and can be separated by physical processes. For example, you can boil salt water to separate the salt from the water. If you had a mixture of iron filings and sand, you could separate the iron filings from the sand with a magnet. **Figure 1** shows some mixtures being separated.

Unlike compounds, mixtures do not always contain the same proportions of the substances that they are composed of. Lemonade is a mixture that can be strong tasting or weak tasting, depending on the amounts of water and lemon juice that are added. It also can be sweet or sour, depending on how much sugar is added. But whether it is strong, weak, sweet, or sour, it is still lemonade.

**Heterogeneous Mixtures** It is easy to tell that some things are mixtures just by looking at them. A watermelon is a mixture of fruit and seeds. The seeds are not evenly spaced through the whole melon—one bite you take might not have any seeds in it and another bite might have several seeds. A type of mixture where the substances are not mixed evenly is called a **heterogeneous** (he tuh ruh JEE nee us) **mixture.** The different areas of a heterogeneous mixture have different compositions. The substances in a heterogeneous mixture are usually easy to tell apart, like the seeds from the fruit of a watermelon. Other examples of heterogeneous mixtures include a bowl of cold cereal with milk and the mixture of pens, pencils, and books in your backpack.

**Science Online**

**Topic: Desalination**
Visit ips.msscience.com for Web links to information about how salt is removed from salt water to provide drinking water.

**Activity** Compare and contrast the two most common methods used for desalination.

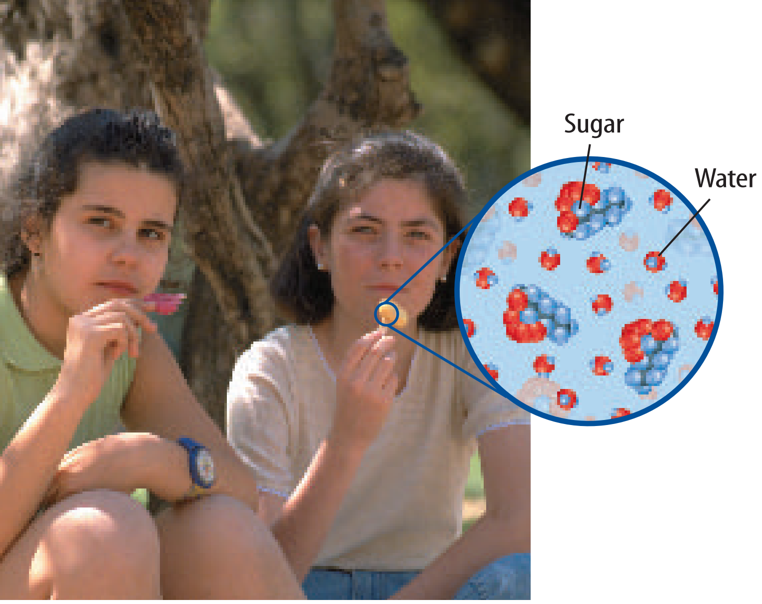



**Figure 2** Molecules of sugar and water are evenly mixed in frozen pops.

**Homogeneous Mixtures** Your shampoo contains many ingredients, but you can't see them when you look at the shampoo. It is the same color and texture throughout. Shampoo is an example of a homogeneous (hoh muh JEE nee us) mixture. A **homogeneous mixture** contains two or more substances that are evenly mixed on a molecular level but still are not bonded together. Another name for a homogeneous mixture is a **solution.** The sugar and water in the frozen pops shown in **Figure 2,** are a solution—the sugar is evenly distributed in the water, and you can't see the sugar.

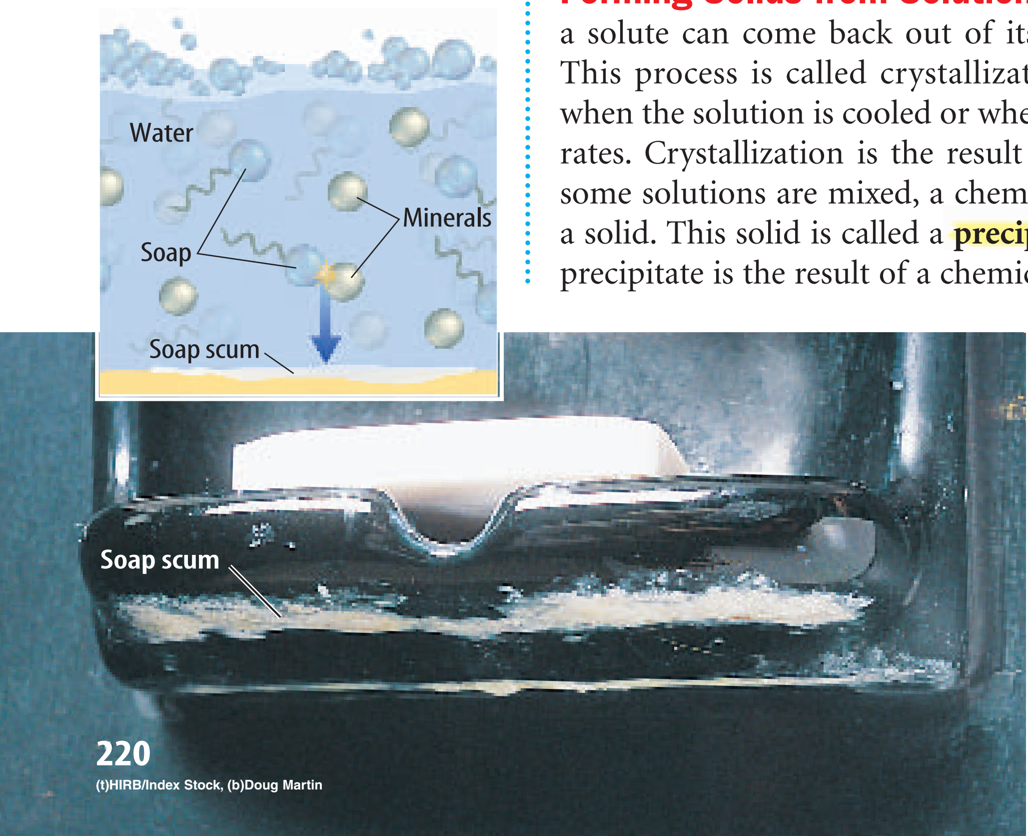
**Reading Check** *What is another name for a homogeneous mixture?*

## How Solutions Form

How do you make sugar water for a hummingbird feeder? You might add sugar to water and heat the mixture until the sugar disappears. The sugar molecules would spread out until they were evenly spaced throughout the water, forming a solution. This is called dissolving. The substance that dissolves—or seems to disappear—is called the **solute.** The substance that dissolves the solute is called the **solvent.** In the hummingbird feeder solution, the solute is the sugar and the solvent is water. The substance that is present in the greatest quantity is the solvent.

**Forming Solids from Solutions** Under certain conditions, a solute can come back out of its solution and form a solid. This process is called crystallization. Sometimes this occurs when the solution is cooled or when some of the solvent evaporates. Crystallization is the result of a physical change. When some solutions are mixed, a chemical reaction occurs, forming a solid. This solid is called a **precipitate** (prih SIH puh tayt). A precipitate is the result of a chemical change. Precipitates probably have formed in your sink or shower because of chemical reactions. Minerals that are dissolved in tap water react chemically with soap. The product of this reaction leaves the water as a precipitate called soap scum, shown in **Figure 3.**

**Figure 3** Minerals and soap react to form soap scum, which comes out of the water solution and coats the tiles of a shower.



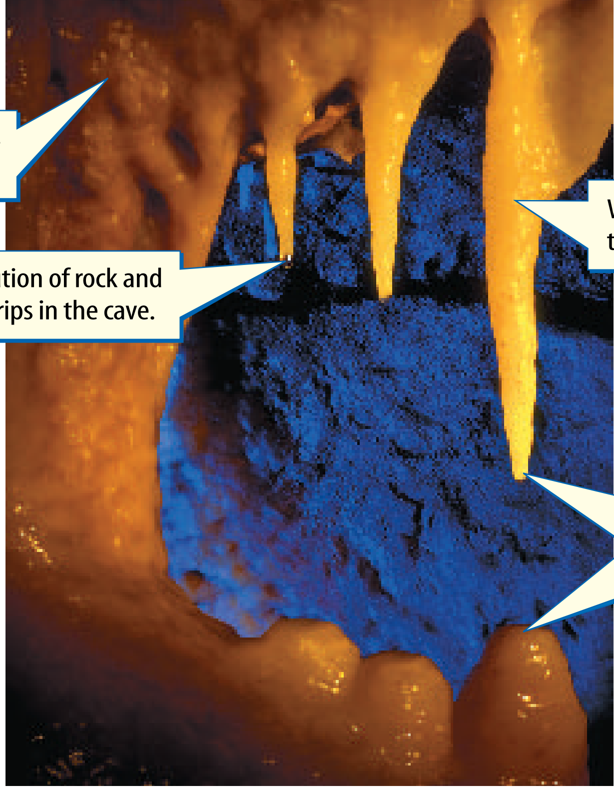



**Figure 4** Orange and blue lights illuminate this cave. Stalactites and stalagmites form when dissolved solids crystallize and build up over time.

INTEGRATE Environment

Stalactites and stalagmites in caves are formed from solutions, as shown in **Figure 4.** First, minerals dissolve in water as it flows through rocks at the top of the cave. This solution of water and dissolved minerals drips from the ceiling of the cave. When drops of the solution evaporate from the roof of the cave, the minerals are left behind. They create the hanging rock formations called stalactites. When drops of the solution fall onto the floor of the cave and evaporate, they form stalagmites. Very often, a stalactite develops downward while a stalagmite develops upward until the two meet. One continuous column of minerals is formed. This process will be discussed later.

## Types of Solutions

So far, you've learned about types of solutions in which a solid solute dissolves in a liquid solvent. But solutions can be made up of different combinations of solids, liquids, and gases, as shown in **Table 2.**

**Table 2 Examples of Common Solutions**

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


**Figure 5** Acetic acid (a liquid), carbon dioxide (a gas), and drink-mix crystals (a solid) can be dissolved in water (a liquid). **Determine** *whether one liquid solution could contain all three different kinds of solute.*

## Liquid Solutions

You're probably most familiar with liquid solutions like the ones shown in **Figure 5,** in which the solvent is a liquid. The solute can be another liquid, a solid, or even a gas. You've already learned about liquid-solid solutions such as sugar water and salt water. When discussing solutions, the state of the solvent usually determines the state of the solution.

**Liquid-Gas Solutions** Carbonated beverages are liquid-gas solutions—carbon dioxide is the gaseous solute, and water is the liquid solvent. The carbon dioxide gas gives the beverage its fizz and some of its tartness. The beverage also might contain other solutes, such as the compounds that give it its flavor and color.

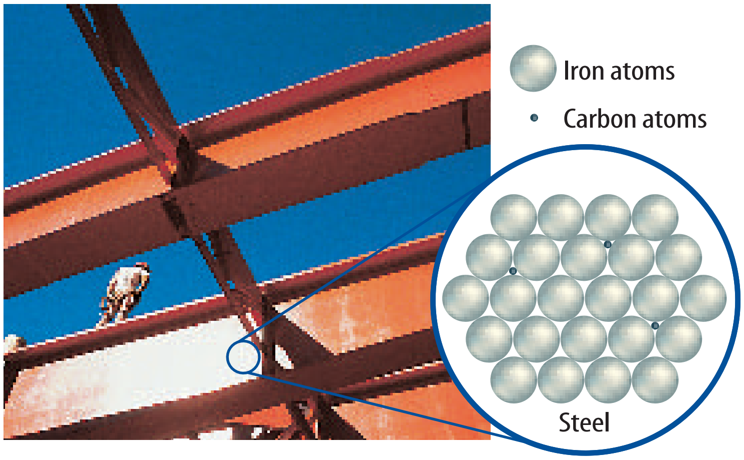
**Reading Check** ***What are the solutes in a carbonated beverage?***

**Liquid-Liquid Solutions** In a liquid-liquid solution, both the solvent and the solute are liquids. Vinegar, which you might use to make salad dressing, is a liquid-liquid solution made of 95 percent water (the solvent) and 5 percent acetic acid (the solute).

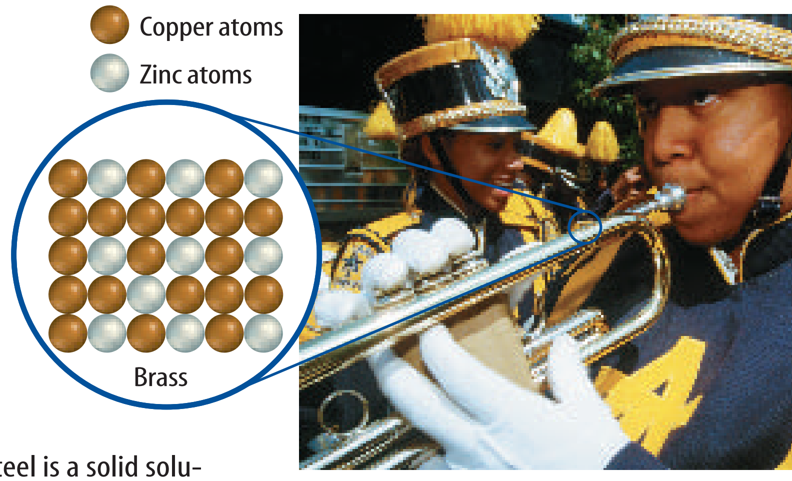
## Gaseous Solutions

In gaseous solutions, a smaller amount of one gas is dissolved in a larger amount of another gas. This is called a gas-gas solution because both the solvent and solute are gases. The air you breathe is a gaseous solution. Nitrogen makes up about 78 percent of dry air and is the solvent. The other gases are the solutes.

**Figure 6** Metal alloys can contain either metal or nonmetal solutes dissolved in a metal solvent.




Steel is a solid solution of the metal iron and the nonmetal carbon.




Brass is a solid solution made of copper and zinc.

**Solid Solutions** In solid solutions, the solvent is a solid. The solute can be a solid, liquid, or gas. The most common solid solutions are solid-solid solutions—ones in which the solvent and the solute are solids. A solid-solid solution made from two or more metals is called an alloy. It's also possible to include elements that are not metals in alloys. For example, steel is an alloy that has carbon dissolved in iron. The carbon makes steel much stronger and yet more flexible than iron. Two alloys are shown in **Figure 6.**

## section 1 review

### Summary

**Substances**

- Elements are substances that cannot be broken down into simpler substances.
- A compound is made up of two or more elements bonded together.

**Mixtures and Solutions**

- Mixtures are either heterogeneous or homogeneous.
- Solutions have two parts—solute and solvent.
- Crystallization and precipitation are two ways that solids are formed from solutions.

**Types of Solutions**

- The solutes and solvents can be solids, liquids, or gases.

### Self Check

1. **Compare and contrast** substances and mixtures. Give two examples of each.
2. **Describe** how heterogeneous and homogeneous mixtures differ.
3. **Explain** how a solution forms.
4. **Identify** the common name for a solid-solid solution of metals.
5. **Think Critically** The tops of carbonated-beverage cans usually are made with a different aluminum alloy than the pull tabs are made with. Explain.

**Applying Skills**

6. **Compare and contrast** the following solutions: a helium-neon laser, bronze (a copper-tin alloy), cloudy ice cubes, and ginger ale.

section 2

# Solubility

as you read

## *What* You'll Learn

- **Explain** why water is a good general solvent.
- **Describe** how the structure of a compound affects which solvents it dissolves in.
- **Identify** factors that affect how much of a substance will dissolve in a solvent.
- **Describe** how temperature affects reaction rate.
- **Explain** how solute particles affect physical properties of water.

## *Why* It's Important

How you wash your hands, clothes, and dishes depends on which substances can dissolve in other substances.

**Review Vocabulary**

**polar bond:** a bond resulting from the unequal sharing of electrons

**New Vocabulary**

- aqueous
- solubility
- saturated
- concentration

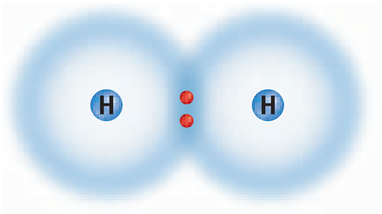
## Water—The Universal Solvent

In many solutions, including fruit juice and vinegar, water is the solvent. A solution in which water is the solvent is called an **aqueous** (A kwee us) solution. Because water can dissolve so many different solutes, chemists often call it the universal solvent. To understand why water is such a great solvent, you must first know a few things about atoms and bonding.

**Molecular Compounds** When certain atoms form compounds, they share electrons. Sharing electrons is called covalent bonding. Compounds that contain covalent bonds are called molecular compounds, or molecules.

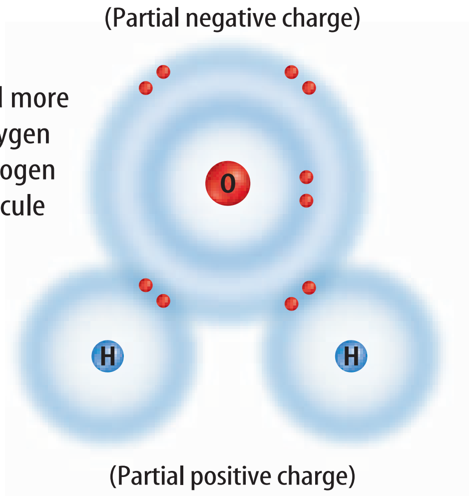
If a molecule has an even distribution of electrons, like the one in **Figure 7,** it is called nonpolar. The atoms in some molecules do not have an even distribution of electrons. For example, in a water molecule, two hydrogen atoms share electrons with a single oxygen atom. However, as **Figure 7** shows, the electrons spend more time around the oxygen atom than they spend around the hydrogen atoms. As a result, the oxygen portion of the water molecule has a partial negative charge and the hydrogen portions have a partial positive charge. The overall charge of the water molecule is neutral. Such a molecule is said to be polar, and the bonds between its atoms are called polar covalent bonds.

**Figure 7** Some atoms share electrons to form covalent bonds.




Two atoms of hydrogen share their electrons equally. Such a molecule is nonpolar.

The electrons spend more time around the oxygen atom than the hydrogen atoms. Such a molecule is polar.



**Ionic Bonds** Some atoms do not share electrons when they join with other atoms to form compounds. Instead, these atoms lose or gain electrons. When they do, the number of protons and electrons within an atom are no longer equal, and the atom becomes positively or negatively charged. Atoms with a charge are called ions. Bonds between ions that are formed by the transfer of electrons are called ionic bonds, and the compound that is formed is called an ionic compound. Table salt is an ionic compound that is made of sodium ions and chloride ions. Each sodium atom loses one electron to a chlorine atom and becomes a positively charged sodium ion. Each chlorine atom gains one electron from a sodium atom, becoming a negatively charged chloride ion.

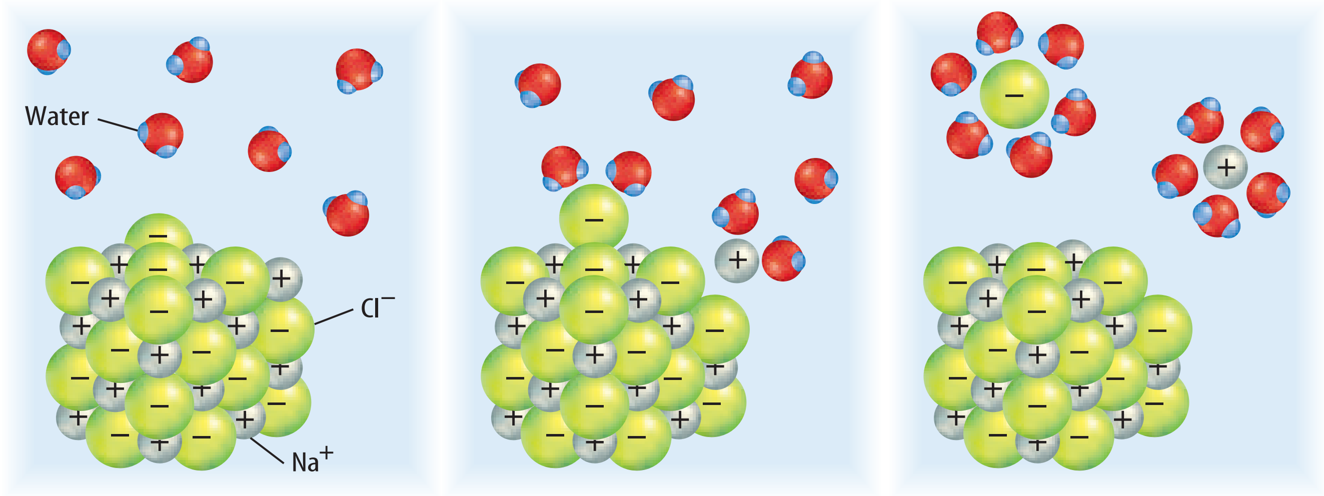
**Reading Check** *How does an ionic compound differ from a molecular compound?*

**How Water Dissolves Ionic Compounds** Now think about the properties of water and the properties of ionic compounds as you visualize how an ionic compound dissolves in water. Because water molecules are polar, they attract positive and negative ions. The more positive part of a water molecule—where the hydrogen atoms are—is attracted to negatively charged ions. The more negative part of a water molecule—where the oxygen atom is—attracts positive ions. When an ionic compound is mixed with water, the different ions of the compound are pulled apart by the water molecules. **Figure 8** shows how sodium chloride dissolves in water.

**INTEGRATE Environment**

**Solutions** Seawater is a solution that contains nearly every element found on Earth. Most elements are present in tiny quantities. Sodium and chloride ions are the most common ions in seawater. Several gases, including oxygen, nitrogen, and carbon dioxide, also are dissolved in seawater.

**Figure 8** Water dissolves table salt because its partial charges are attracted to the charged ions in the salt.




The partially negative oxygen in the water molecule is attracted to a positive sodium ion.

The partially positive hydrogen atoms in another water molecule are attracted to a negative chloride ion.

The sodium and chloride ions are pulled apart from each other, and more water molecules are attracted to them.

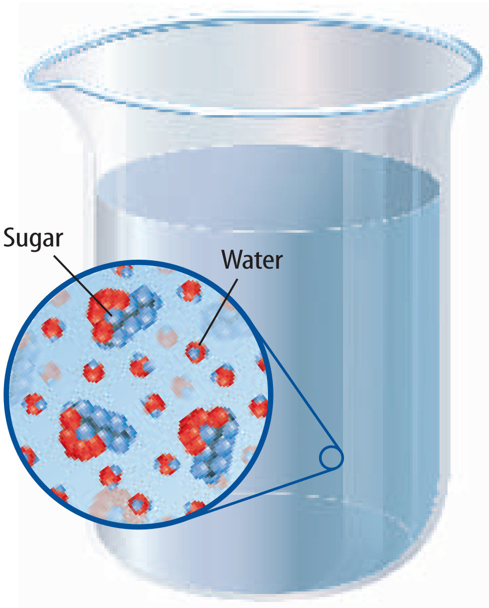



**Figure 9** Sugar molecules that are dissolved in water spread out until they are spaced evenly in the water.

### How Water Dissolves Molecular Compounds

Can water also dissolve molecular compounds that are not made of ions? Water does dissolve molecular compounds, such as sugar, although it doesn't break each sugar molecule apart. Water simply moves between different molecules of sugar, separating them. Like water, a sugar molecule is polar. Polar water molecules are attracted to the positive and negative portions of the polar sugar molecules. When the sugar molecules are separated by the water and spread throughout it, as **Figure 9** shows, they have dissolved.

## What will dissolve?

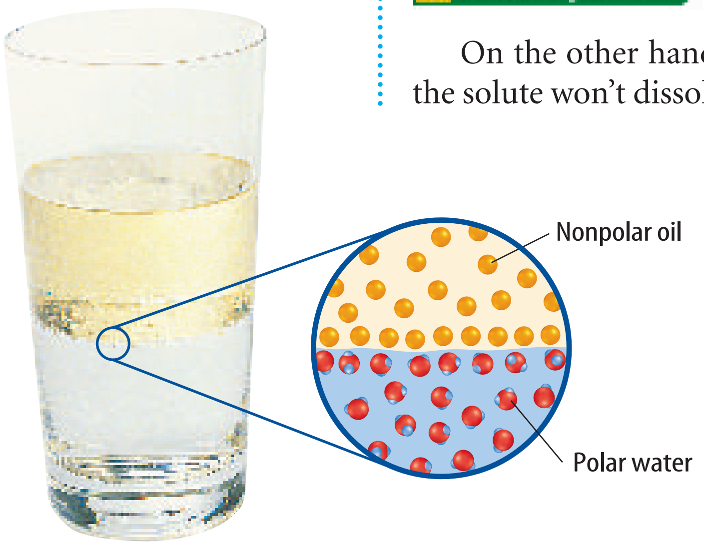
When you stir a spoonful of sugar into iced tea, all of the sugar dissolves but none of the metal in the spoon does. Why does sugar dissolve in water, but metal does not? A substance that dissolves in another is said to be soluble in that substance. You would say that the sugar is soluble in water but the metal of the spoon is insoluble in water, because it does not dissolve readily.

**Like Dissolves Like** When trying to predict which solvents can dissolve which solutes, chemists use the rule of "like dissolves like." This means that polar solvents dissolve polar solutes and nonpolar solvents dissolve nonpolar solutes. In the case of sugar and water, both are made up of polar molecules, so sugar is soluble in water. In the case of salt and water, the sodium and chloride ion pair is like the water molecule because it has a positive charge at one end and a negative charge at the other end.

**Reading Check** *What does "like dissolves like" mean?*

On the other hand, if a solvent and a solute are not similar, the solute won't dissolve. For example, oil and water do not mix. Oil molecules are nonpolar, so polar water molecules are not attracted to them. If you pour vegetable oil into a glass of water, the oil and the water separate into layers instead of forming a solution, as shown in **Figure 10.** You've probably noticed the same thing about the oil-and-water mixtures that make up some salad dressings. The oil stays on the top. Oils generally dissolve better in solvents that have nonpolar molecules.

**Figure 10** Water and oil do not mix because water molecules are polar and oil molecules are nonpolar.





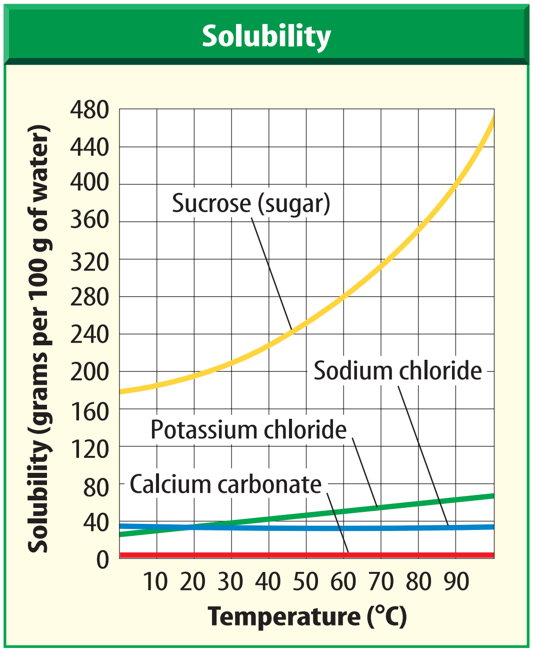
John Evans

## How much will dissolve?

Even though sugar is soluble in water, if you tried to dissolve 1 kg of sugar into one small glass of water, not all of the sugar would dissolve. **Solubility** (sahl yuh BIH luh tee) is a measurement that describes how much solute dissolves in a given amount of solvent. The solubility of a material has been described as the amount of the material that can dissolve in 100 g of solvent at a given temperature. Some solutes are highly soluble, meaning that a large amount of solute can be dissolved in 100 g of solvent. For example, 63 g of potassium chromate can be dissolved in 100 g of water at 25°C. On the other hand, some solutes are not very soluble. For example, only 0.00025 g of barium sulfate will dissolve in 100 g of water at 25°C. When a substance has an extremely low solubility, like barium sulfate does in water, it usually is considered insoluble.

**Reading Check** *What is an example of a substance that is considered to be insoluble in water?*

**Figure 11** The solubility of some solutes changes as the temperature of the solvent increases.
**Use a Graph** *According to the graph, is it likely that warm ocean water contains any more sodium chloride than cold ocean water does?*




**Solubility in Liquid-Solid Solutions** Did you notice that the temperature was included in the explanation about the amount of solute that dissolves in a quantity of solvent? The solubility of many solutes changes if you change the temperature of the solvent. For example, if you heat water, not only does the sugar dissolve at a faster rate, but more sugar can dissolve in it. However, some solutes, like sodium chloride and calcium carbonate, do not become more soluble when the temperature of water increases. The graph in **Figure 11** shows how the temperature of the solvent affects the solubility of some solutes.

**Solubility in Liquid-Gas Solutions** Unlike liquid-solid solutions, an increase in temperature decreases the solubility of a gas in a liquid-gas solution. You might notice this if you have ever opened a warm carbonated beverage and it bubbled up out of control while a chilled one barely fizzed. Carbon dioxide is less soluble in a warm solution. What keeps the carbon dioxide from bubbling out when it is sitting at room temperature on a supermarket shelf? When a bottle is filled, extra carbon dioxide gas is squeezed into the space above the liquid, increasing the pressure in the bottle. This increased pressure increases the solubility of gas and forces most of it into the solution. When you open the cap, the pressure is released and the solubility of the carbon dioxide decreases.

**Reading Check** *Why does a bottle of carbonated beverage go "flat" after it has been opened for a few days?*

## Mini LAB

### Observing Chemical Processes

**Procedure**

1. Pour **two small glasses of milk.**
2. Place one glass of milk in the **refrigerator.** Leave the second glass on the counter.
3. Allow the milk to sit overnight. **WARNING:** *Do not drink the milk that sat out overnight.*
4. On the following day, smell both glasses of milk. Record your observations.

**Analysis**

1. Compare and contrast the smell of the refrigerated milk to the nonrefrigerated milk.
2. Explain why refrigeration is needed.

Try at Home

**Saturated Solutions** If you add calcium carbonate to 100 g of water at 25°C, only 0.0014 g of it will dissolve. Additional calcium carbonate will not dissolve. Such a solution—one that contains all of the solute that it can hold under the given conditions—is called a **saturated** solution. **Figure 12** shows a saturated solution. If a solution is a liquid-solid solution, the extra solute that is added will settle to the bottom of the container. It's possible to make solutions that have less solute than they would need to become saturated. Such solutions are unsaturated. An example of an unsaturated solution is one containing 50 g of sugar in 100 g of water at 25°C. That's much less than the 204 g of sugar the solution would need to be saturated.

A hot solvent usually can hold more solute than a cool solvent can. When a saturated solution cools, some of the solute usually falls out of the solution. But if a saturated solution is cooled slowly, sometimes the excess solute remains dissolved for a period of time. Such a solution is said to be supersaturated, because it contains more than the normal amount of solute.

## Rate of Dissolving

Solubility does not tell you how fast a solute will dissolve—it tells you only how much of a solute will dissolve at a given temperature. Some solutes dissolve quickly, but others take a long time to dissolve. A solute dissolves faster when the solution is stirred or shaken or when the temperature of the solution is increased. These methods increase the rate at which the surfaces of the solute come into contact with the solvent. Increasing the area of contact between the solute and the solvent can also increase the rate of dissolving. This can be done by breaking up the solute into smaller pieces, which increases the surface area of the solute that is exposed to the solvent.

INTEGRATE Chemistry

Molecules are always moving and colliding. The collisions must take place for chemical processes to occur. The chemical processes take place at a given rate of reaction. Temperature has a large effect on that rate. The higher the temperature, the more collisions occur and the higher the rate of reaction. The opposite is also true. The lower the temperature, the less collisions occur and the lower the rate of reaction. Refrigerators are an example of slowing the reaction rate—and therefore the chemical process—down to prevent food spoilage.

**Figure 12** The Dead Sea has an extremely high concentration of dissolved minerals. When the water evaporates, the minerals are left behind and form pillars.

## Concentration

What makes strong lemonade strong and weak lemonade weak? The difference between the two drinks is the amount of water in each one compared to the amount of lemon. The lemon is present in different concentrations in the solution. The **concentration** of a solution tells you how much solute is present compared to the amount of solvent. You can give a simple description of a solution's concentration by calling it either concentrated or dilute. These terms are used when comparing the concentrations of two solutions with the same type of solute and solvent. A concentrated solution has more solute per given amount of solvent than a dilute solution.

**Measuring Concentration** Can you imagine a doctor ordering a dilute intravenous, or IV, solution for a patient? Because dilute is not an exact measurement, the IV could be made with a variety of amounts of medicine. The doctor would need to specify the exact concentration of the IV solution to make sure that the patient is treated correctly.

INTEGRATE Career

**Pharmacist** Doctors rely on pharmacists to formulate IV solutions. Pharmacists begin with a concentrated form of the drug, which is supplied by pharmaceutical companies. This is the solute of the IV solution. The pharmacist adds the correct amount of solvent to a small amount of the solute to achieve the concentration requested by the doctor. There may be more than one solute per IV solution in varying concentrations.

## Applying Science

### How can you compare concentrations?

A solute is a substance that can be dissolved in another substance called a solvent. Solutions vary in concentration, or strength, depending on the amount of solute and solvent being used. Fruit drinks are examples of such a solution. Stronger fruit drinks appear darker in color and are the result of more drink mix being dissolved in a given amount of water. What would happen if more water were added to the solution?

**Glucose Solutions (g/100 mL)**

| Solute Glucose (g) | Solvent Water (mL) | Solution Concentration of Glucose (%) |
|---|---|---|
| 2 | 100 | 2 |
| 4 | 100 | 4 |
| 10 | 100 | 10 |
| 20 | 100 | 20 |

### Identifying the Problem

The table on the right lists different concentration levels of glucose solutions, a type of carbohydrate your body uses as a source of energy. The glucose is measured in grams, and the water is measured in milliliters.

### Solving the Problem

A physician writes a prescription for a patient to receive 1,000 mL of a 20 percent solution of glucose. How many grams of glucose must the pharmacist add to 1,000 mL of water to prepare this 20 percent concentration level?

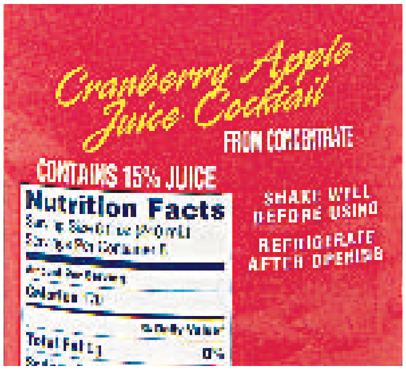



**Figure 13** Concentrations can be stated in percentages.
**Identify** *the percentage of this fruit drink that is water, assuming there are no other dissolved substances.*

One way of giving the exact concentration is to state the percentage of the volume of the solution that is made up of solute. Labels on fruit drinks show their concentration like the one in **Figure 13.** When a fruit drink contains 15 percent fruit juice, the remaining 85 percent of the drink is water and other substances such as sweeteners and flavorings. This drink is more concentrated than another brand that contains 10 percent fruit juice, but it's more dilute than pure juice, which is 100 percent juice. Another way to describe the concentration of a solution is to give the percentage of the total mass that is made up of solute.

**Effects of Solute Particles** All solute particles affect the physical properties of the solvent, such as its boiling point and freezing point. The effect that a solute has on the freezing or boiling point of a solvent depends on the number of solute particles.

When a solvent such as water begins to freeze, its molecules arrange themselves in a particular pattern. Adding a solute such as sodium chloride to this solvent changes the way the molecules arrange themselves. To overcome this interference of the solute, a lower temperature is needed to freeze the solvent.

When a solvent such as water begins to boil, the solvent molecules are gaining enough energy to move from the liquid state to the gaseous state. When a solute such as sodium chloride is added to the solvent, the solute particles interfere with the evaporation of the solvent particles. More energy is needed for the solvent particles to escape from the liquid, and the boiling point of the solution will be higher.

## section 2 review

### Summary

**The Universal Solvent**

- Water is known as the universal solvent.
- A molecule that has an even distribution of electrons is a nonpolar molecule.
- A molecule that has an uneven distribution of electrons is a polar molecule.
- A compound that loses or gains electrons is an ionic compound.

**Dissolving a Substance**

- Chemists use the rule "like dissolves like."

**Concentration**

- Concentration is the quantity of solute present compared to the amount of solvent.

### Self Check

1. **Identify** the property of water that makes it the universal solvent.
2. **Describe** the two methods to increase the rate at which a substance dissolves.
3. **Infer** why it is important to add sodium chloride to water when making homemade ice cream.
4. **Think Critically** Why can the fluids used to dry-clean clothing remove grease even when water cannot?

**Applying Skills**

5. **Recognize Cause and Effect** Why is it more important in terms of reaction rate to take groceries straight home from the store when it is 25°C than when it is 2°C?


Science Online ips.msscience.com/self_check_quiz

# LAB

# Observing Gas Solubility

On a hot day, a carbonated beverage will cool you off. If you leave the beverage uncovered at room temperature, it quickly loses its fizz. However, if you cap the beverage and place it in the refrigerator, it will still have its fizz hours later. In this lab you will explore why this happens.

## Real-World Question

What effect does temperature have on the fizz, or carbon dioxide, in your carbonated beverage?

### Goals

- **Observe** the effect that temperature has on solubility.
- **Compare** the amount of carbon dioxide released at room temperature and in hot tap water.

### Materials

carbonated beverages in plastic bottles, thoroughly chilled (2)
balloons (2)
tape
fabric tape measure
*string
*ruler
container
hot tap water
*Alternative materials*

### Safety Precautions

**WARNING:** *DO NOT point the bottles at anyone at any time during the lab.*

## Procedure

1. Carefully remove the caps from the thoroughly chilled plastic bottles one at a time. Create as little agitation as possible.
2. Quickly cover the opening of each bottle with an uninflated balloon.
3. Use tape to secure and tightly seal the balloons to the top of the bottles.
4. Gently agitate one bottle from side to side for two minutes. Measure the circumference of the balloon.

**WARNING:** *Contents under pressure can cause serious accidents. Be sure to wear safety goggles, and DO NOT point the bottles at anyone.*

5. Gently agitate the second bottle in the same manner as in step 4. Then, place the bottle in a container of hot tap water for ten minutes. Measure the circumference of the balloon.

## Conclude and Apply

1. **Compare and contrast** the relative amounts of carbon dioxide gas released from the cold and the warm carbonated beverages.
2. **Infer** Why does the warmed carbonated beverage release a different amount of carbon dioxide than the chilled one?

### Communicating Your Data

Compare the circumferences of your balloons with those of members of your class. **For more help, refer to the Science Skill Handbook.**

section 3

# Acidic and Basic Solutions

**as you read**

### *What* You'll Learn

- **Compare** acids and bases and their properties.
- **Describe** practical uses of acids and bases.
- **Explain** how pH is used to describe the strength of an acid or base.
- **Describe** how acids and bases react when they are brought together.

### *Why* It's Important

Many common products, such as batteries and bleach, work because of acids or bases.

**Review Vocabulary**

**physical property:** any characteristic of a material that can be seen or measured without changing the material

**New Vocabulary**

- acid
- hydronium ion
- base
- pH
- indicator
- neutralization

## Acids

What makes orange juice, vinegar, dill pickles, and grapefruit tangy? Acids cause the sour taste of these and other foods. **Acids** are substances that release positively charged hydrogen ions, $H^+$, in water. When an acid mixes with water, the acid dissolves, releasing a hydrogen ion. The hydrogen ion then combines with a water molecule to form a hydronium ion, as shown in **Figure 14.** **Hydronium ions** are positively charged and have the formula $H_3O^+$.

**Properties of Acidic Solutions** Sour taste is one of the properties of acidic solutions. The taste allows you to detect the presence of acids in your food. However, even though you can identify acidic solutions by their sour taste, you should never taste anything in the laboratory, and you should never use taste to test for the presence of acids in an unknown substance. Many acids can cause serious burns to body tissues.

Another property of acidic solutions is that they can conduct electricity. The hydronium ions in an acidic solution can carry the electric charges in a current. This is why some batteries contain an acid. Acidic solutions also are corrosive, which means they can break down certain substances. Many acids can corrode fabric, skin, and paper. The solutions of some acids also react strongly with certain metals. The acid-metal reaction forms metallic compounds and hydrogen gas, leaving holes in the metal in the process.

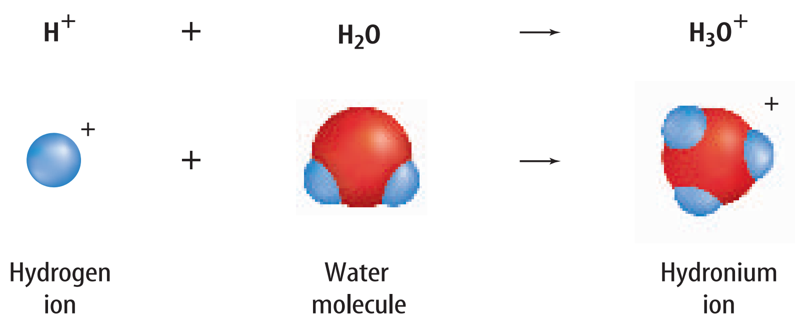



**Figure 14** One hydrogen ion can combine with one water molecule to form one positively charged hydronium ion.
**Identify** *what kinds of substances are sources of hydrogen ions.*


**Figure 15** Each of these products contains an acid or is made with the help of an acid.
**Describe** *how your life would be different if acids were not available to make these products.*

**Uses of Acids** You're probably familiar with many acids. Vinegar, which is used in salad dressing, contains acetic acid. Lemons, limes, and oranges have a sour taste because they contain citric acid. Your body needs ascorbic acid, which is vitamin C. Ants that sting inject formic acid into their victims.

**Figure 15** shows other products that are made with acids. Sulfuric acid is used in the production of fertilizers, steel, paints, and plastics. Acids often are used in batteries because their solutions conduct electricity. For this reason, it sometimes is referred to as battery acid. Hydrochloric acid, which is known commercially as muriatic acid, is used in a process called pickling. Pickling is a process that removes impurities from the surfaces of metals. Hydrochloric acid also can be used to clean mortar from brick walls. Nitric acid is used in the production of fertilizers, dyes, and plastics.

**Acid in the Environment** Carbonic acid plays a key role in the formation of caves and of stalactites and stalagmites. Carbonic acid is formed when carbon dioxide in soil is dissolved in water. When this acidic solution comes in contact with calcium carbonate—or limestone rock—it can dissolve it, eventually carving out a cave in the rock. A similar process occurs when acid rain falls on statues and eats away at the stone, as shown in **Figure 16.** When this acidic solution drips from the ceiling of the cave, water evaporates and carbon dioxide becomes less soluble, forcing it out of solution. The solution becomes less acidic and the limestone becomes less soluble, causing it to come out of solution. These solids form stalactites and stalagmites.

## Mini LAB

### Observing a Nail in a Carbonated Drink

**Procedure**

1. Observe the initial appearance of an **iron nail.**
2. Pour enough **carbonated soft drink** into a **cup or beaker** to cover the nail.
3. Drop the nail into the soft drink and observe what happens.
4. Leave the nail in the soft drink overnight and observe it again the next day.

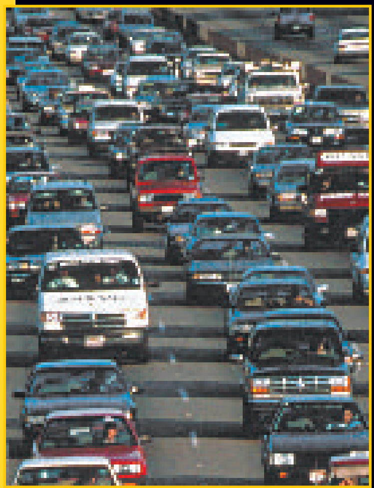
**Analysis**

1. Describe what happened when you first dropped the nail into the soft drink and the appearance of the nail the following day.
2. Based upon the fact that the soft drink was carbonated, explain why you think the drink reacted with the nail as you observed.

# NATIONAL GEOGRAPHIC VISUALIZING ACID PRECIPITATION

## Figure 16

When fossil fuels such as coal and oil are burned, a variety of chemical compounds are produced and released into the air. In the atmosphere, some of these compounds form acids that mix with water vapor and fall back to Earth as acid precipitation—rain, sleet, snow, or fog. The effects of acid precipitation on the environment can be devastating. Winds carry these acids hundreds of miles from their source, damaging forests, corroding statues, and endangering human health.



**B** Sulfur dioxide and nitrogen oxides react with water vapor in the air to form highly acidic solutions of nitric acid ($HNO_3$) and sulfuric acid ($H_2SO_4$). These solutions eventually return to Earth as acid precipitation.

**C** Some acid rain in the United States has a pH as low as 2.3—close to the acidity of stomach acid.

**A** Power plants and cars burn fossil fuels to generate energy for human use. In the process, sulfur dioxide ($SO_2$) and nitrogen oxides are released into the atmosphere.



(l)Joe Sohm, Chromosohm/Stock Connection/PictureQuest, (c)Andrew Popper/Phototake/PictureQuest, (r)A. Wolf/Explorer, Photo Researchers

## Bases

People often use ammonia solutions to clean windows and floors. These solutions have different properties from those of acidic solutions. Ammonia is called a base. **Bases** are substances that can accept hydrogen ions. When bases dissolve in water, some hydrogen atoms from the water molecules are attracted to the base. A hydrogen atom in the water molecule leaves behind the other hydrogen atom and oxygen atom. This pair of atoms is a negatively charged ion called a hydroxide ion. A hydroxide ion has the formula $OH^-$. Most bases contain a hydroxide ion, which is released when the base dissolves in water. For example, sodium hydroxide is a base with the formula NaOH. When NaOH dissolves in water, a sodium ion and the hydroxide ion separate.

**Properties of Basic Solutions** Most soaps are bases, so if you think about how soap feels, you can figure out some of the properties of basic solutions. Basic solutions feel slippery. Acids in water solution taste sour, but bases taste bitter—as you know if you have ever accidentally gotten soap in your mouth.

Like acids, bases are corrosive. Bases can cause burns and damage tissue. You should never touch or taste a substance to find out whether it is a base. Basic solutions contain ions and can conduct electricity. Basic solutions are not as reactive with metals as acidic solutions are.

**Uses of Bases** Many uses for bases are shown in **Figure 17.** Bases give soaps, ammonia, and many other cleaning products some of their useful properties. The hydroxide ions produced by bases can interact strongly with certain substances, such as dirt and grease.

Chalk and oven cleaner are examples of familiar products that contain bases. Your blood is a basic solution. Calcium hydroxide, often called lime, is used to mark the lines on athletic fields. It also can be used to treat lawns and gardens that have acidic soil. Sodium hydroxide, known as lye, is a strong base that can cause burns and other health problems. Lye is used to make soap, clean ovens, and unclog drains.

**Science Online**

**Topic: Calcium Hydroxide**
Visit ips.msscience.com for Web links to information about the uses for calcium hydroxide.

**Activity** Describe the chemical reaction that converts limestone (calcium carbonate) to calcium hydroxide.


**Figure 17** Many products, including soaps, cleaners, and plaster contain bases or are made with the help of bases.

John Evans

**INTEGRATE Life Science**

**pH Levels** Most life-forms can't exist at extremely low pH levels. However, some bacteria thrive in acidic environments. Acidophils are bacteria that exist at low pH levels. These bacteria have been found in the Hot Springs of Yellowstone National Park in areas with pH levels ranging from 1 to 3.

## What is pH?

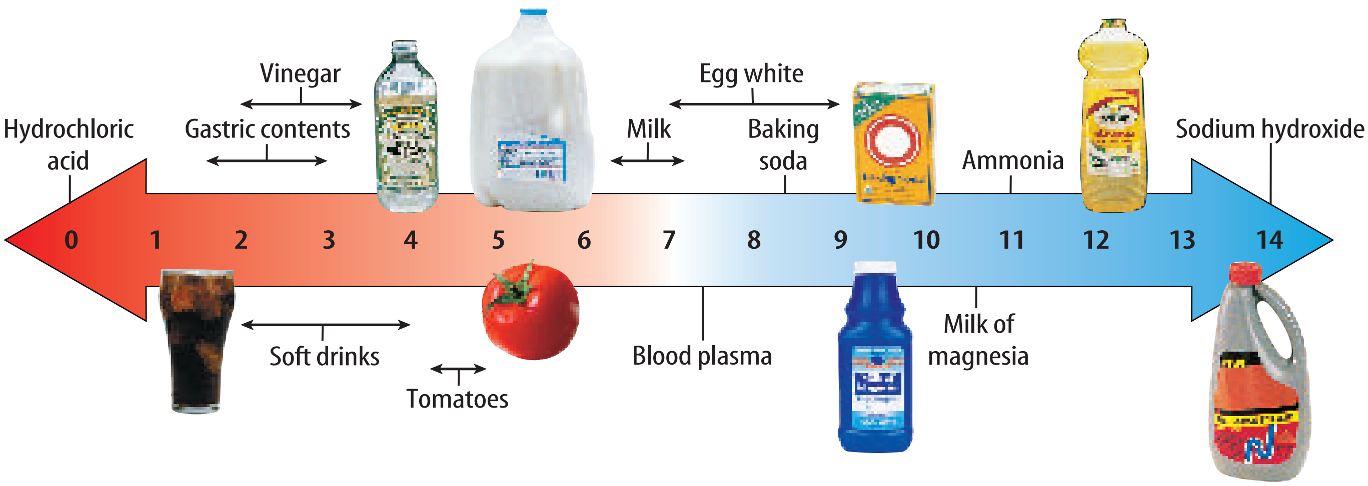
You've probably heard of pH-balanced shampoo or deodorant, and you might have seen someone test the pH of the water in a swimming pool. **pH** is a measure of how acidic or basic a solution is. The pH scale ranges from 0 to 14. Acidic solutions have pH values below 7. A solution with a pH of 0 is very acidic. Hydrochloric acid can have a pH of 0. A solution with a pH of 7 is neutral, meaning it is neither acidic nor basic. Pure water is neutral. Basic solutions have pH values above 7. A solution with a pH of 14 is very basic. Sodium hydroxide can have a pH of 14. **Figure 18** shows where various common substances fall on the pH scale.

The pH of a solution is related directly to its concentrations of hydronium ions ($H_3O^+$) and hydroxide ions ($OH^-$). Acidic solutions have more hydronium ions than hydroxide ions. Neutral solutions have equal numbers of the two ions. Basic solutions have more hydroxide ions than hydronium ions.

**Reading Check** *In a neutral solution, how do the numbers of hydronium ions and hydroxide ions compare?*

**pH Scale** The pH scale is not a simple linear scale like mass or volume. For example, if one book has a mass of 2 kg and a second book has a mass of 1 kg, the mass of the first book is twice that of the second. However, a change of 1 pH unit represents a tenfold change in the acidity of the solution. For example, if one solution has a pH of 1 and a second solution has a pH of 2, the first solution is not twice as acidic as the second—it is ten times more acidic. To determine the difference in pH strength, use the following calculation: $10^n$, where $n$ = the difference between pHs. For example: pH3 − pH1 = 2, $10^2 = 100$ times more acidic.

**Figure 18** The pH scale classifies a solution as acidic, basic, or neutral.



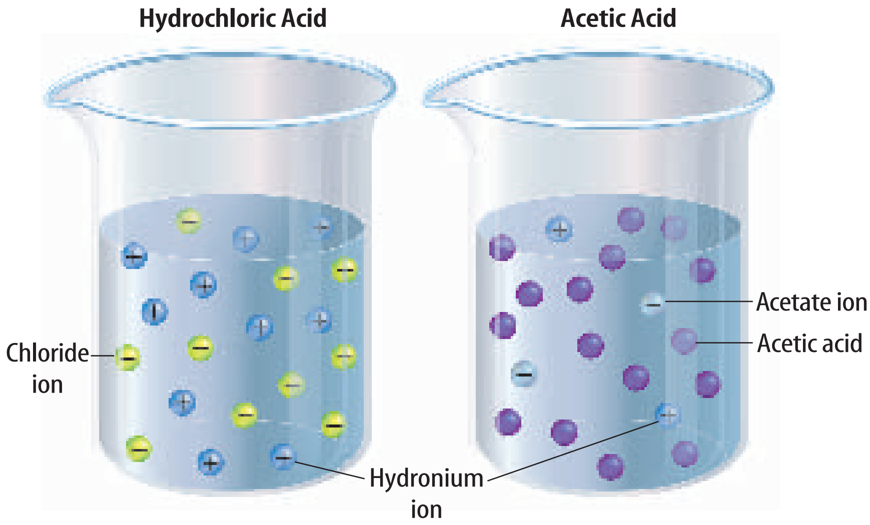



**Figure 19** Hydrochloric acid separates into ions more readily than acetic acid does when it dissolves in water. Therefore, hydrochloric acid exists in water as separated ions. Acetic acid exists in water almost entirely as molecules.

**Strengths of Acids and Bases** You've learned that acids give foods a sour taste but also can cause burns and damage tissue. The difference between food acids and the acids that can burn you is that they have different strengths. The acids in food are fairly weak acids, while the dangerous acids are strong acids. The strength of an acid is related to how easily the acid separates into ions, or how easily a hydrogen ion is released, when the acid dissolves in water. Look at **Figure 19.** In the same concentration, a strong acid—like hydrochloric acid—forms more hydronium ions in solution than a weak acid does—like acetic acid. More hydronium ions means the strong-acid solution has a lower pH than the weak-acid solution. Similarly, the strength of a base is related to how easily the base separates into ions, or how easily a hydroxide ion is released, when the base dissolves in water. The relative strengths of some common acids and bases are shown in **Table 3.**

**Reading Check** *What determines the strength of an acid or a base?*

An acid containing more hydrogen atoms, such as carbonic acid, $H_2CO_3$, is not necessarily stronger than an acid containing fewer hydrogen atoms, such as nitric acid, $HNO_3$. An acid's strength is related to how easily a hydrogen ion separates—not to how many hydrogen atoms it has. For this reason, nitric acid is stronger than carbonic acid.

**Table 3 Strengths of Some Acids and Bases**

| | Acid | Base |
|---|---|---|
| **Strong** | hydrochloric ($HCl$)<br>sulfuric ($H_2SO_4$)<br>nitric ($HNO_3$) | sodium hydroxide ($NaOH$)<br>potassium hydroxide ($KOH$) |
| **Weak** | acetic ($CH_3COOH$)<br>carbonic ($H_2CO_3$)<br>ascorbic ($H_2C_6H_6O_6$) | ammonia ($NH_3$)<br>aluminum hydroxide ($Al(OH)_3$)<br>iron (III) hydroxide ($Fe(OH)_3$) |

## Indicators

What is a safe way to find out how acidic or basic a solution is? **Indicators** are compounds that react with acidic and basic solutions and produce certain colors, depending on the solution's pH.

Because they are different colors at different pHs, indicators can help you determine the pH of a solution. Some indicators, such as litmus, are soaked into paper strips. When litmus paper is placed in an acidic solution, it turns red. When placed in a basic solution, litmus paper turns blue. Some indicators can change through a wide range of colors, with each different color appearing at a different pH value.

**Science Online**

**Topic: Indicators**

Visit ips.msscience.com for Web links to information about the types of pH indicators.

**Activity** Describe how plants can act as indicators in acidic and basic solutions.

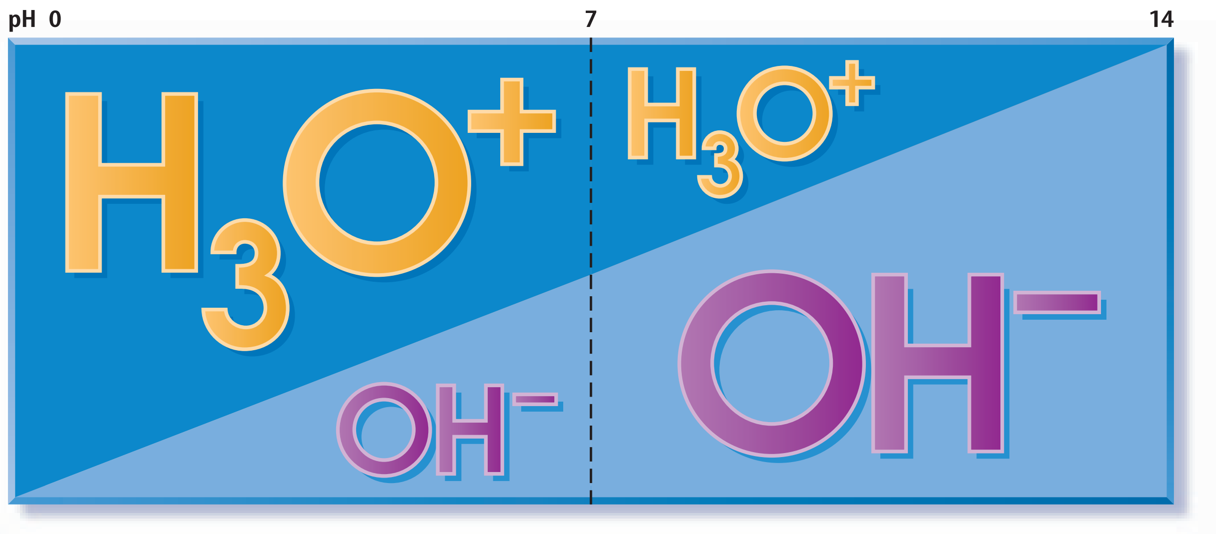
## Neutralization

Perhaps you've heard someone complain about heartburn or an upset stomach after eating spicy food. To feel better, the person might have taken an antacid. Think about the word *antacid* for a minute. How do antacids work?

Heartburn or stomach discomfort is caused by excess hydrochloric acid in the stomach. Hydrochloric acid helps break down the food you eat, but too much of it can irritate your stomach or digestive tract. An antacid product, often made from the base magnesium hydroxide, $Mg(OH)_2$, neutralizes the excess acid. **Neutralization** (new truh luh ZAY shun) is the reaction of an acid with a base. It is called this because the properties of both the acid and base are diminished, or neutralized. In most cases, the reaction produces a water and a salt. **Figure 20** illustrates the relative amounts of hydronium and hydroxide ions between pH 0 and pH 14.

**Reading Check** *What are the products of neutralization?*

**Figure 20** The pH of a solution is more acidic when greater amounts of hydronium ions are present.
**Define** *what makes a pH 7 solution neutral.*



$$H_3O^+ + OH^- \rightarrow 2H_2O$$

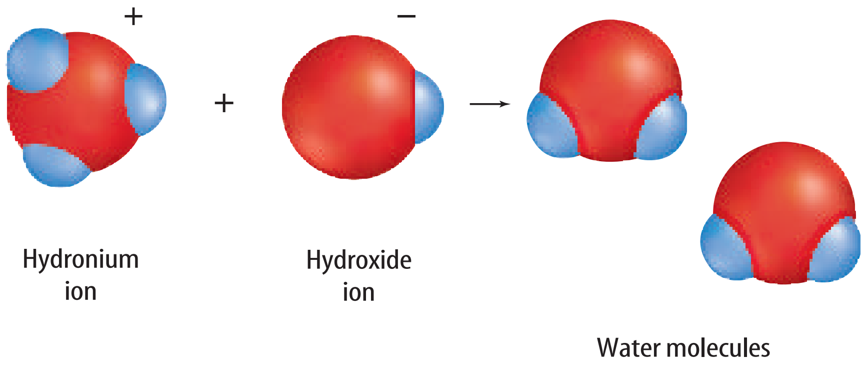



**Figure 21** When acidic and basic solutions react, hydronium and hydroxide ions react to form water.
**Determine** *why the pH of the solution changes.*

**How does neutralization occur?** Recall that every water molecule contains two hydrogen atoms and one oxygen atom. As **Figure 21** shows, when one hydronium ion reacts with one hydroxide ion, the product is two water molecules. This reaction occurs during acid-base neutralization. Equal numbers of hydronium ions from the acidic solution and hydroxide ions from the basic solution react to produce water. Pure water has a pH of 7, which means that it's neutral.

**Reading Check** *What happens to acids and bases during neutralization?*

## section 3 review

### Summary

#### Acids and Bases

- Acids are substances that release positively charged hydrogen ions in water.
- Substances that accept hydrogen ions in water are bases.
- Acidic and basic solutions can conduct electricity.

#### pH

- pH measures how acidic or basic a solution is.
- The scale ranges from 0 to 14.

#### Neutralization

- Neutralization is the interaction between an acid and a base to form water and a salt.

### Self Check

1. **Identify** what ions are produced by acids in water and bases in water. Give two properties each of acids and bases.
2. **Name** three acids and three bases and list an industrial or household use of each.
3. **Explain** how the concentration of hydronium ions and hydroxide ions are related to pH.
4. **Think Critically** In what ways might a company that uses a strong acid handle an acid spill on the factory floor?

**Applying Math**

5. **Solve One-Step Equations** How much more acidic is a solution with a pH of 2 than one with a pH of 6? How much more basic is a solution with a pH of 13 than one with a pH of 10?

LAB

# Testing pH Using Natural Indicators

## Goals

- **Determine** the relative acidity or basicity of several common solutions.
- **Compare** the strengths of several common acids and bases.

## Materials

small test tubes (9)
test-tube rack
concentrated red cabbage juice in a dropper bottle
labeled bottles containing: household ammonia, baking soda solution, soap solution, 0.1*M* hydrochloric acid solution, white vinegar, colorless carbonated soft drink, borax soap solution, distilled water
grease pencil
droppers (9)

## Safety Precautions

**WARNING:** *Many acids and bases are poisonous, can damage your eyes, and can burn your skin. Wear goggles and gloves AT ALL TIMES. Tell your teacher immediately if a substance spills. Wash your hands after you finish but before removing your goggles.*

## Real-World Question

You have learned that certain substances, called indicators, change color when the pH of a solution changes. The juice from red cabbage is a natural indicator. How do the pH values of various solutions compare to each other? How can you use red cabbage juice to determine the relative pH of several solutions?

## Procedure

1. **Design** a data table to record the names of the solutions to be tested, the colors caused by the added cabbage juice indicator, and the relative strengths of the solutions.
2. Mark each test tube with the identity of the acid or base solution it will contain.
3. Half-fill each test tube with the solution to be tested.
**WARNING:** *If you spill any liquids on your skin, rinse the area immediately with water. Alert your teacher if any liquid spills in the work area or on your skin.*



KS Studios

4. Add ten drops of the cabbage juice indicator to each of the solutions to be tested. Gently agitate or wiggle each test tube to mix the cabbage juice with the solution.
5. **Observe** and record the color of each solution in your data table.

**Determining pH Values**

| Cabbage Juice Color | Relative Strength of Acid or Base |
|---|---|
| | strong acid |
| | medium acid |
| | weak acid |
| | neutral |
| | weak base |
| | medium base |
| | strong base |

## Analyze Your Data

1. **Compare** your observations with the table above. Record in your data table the relative acid or base strength of each solution you tested.
2. **List** the solutions by pH value starting with the most acidic and finishing with the most basic.

## Conclude and Apply

1. **Classify** which solutions were acidic and which were basic.
2. **Identify** which solution was the weakest acid. The strongest base? The closest to neutral?
3. **Predict** what ion might be involved in the cleaning process based upon your data for the ammonia, soap, and borax soap solutions.

## Form a Hypothesis

Form a hypothesis that explains why the borax soap solution was less basic than an ammonia solution of approximately the same concentration.

### Communicating Your Data

Use your data to create labels for the solutions you tested. Include the relative strength of each solution and any other safety information you think is important on each label. **For more help, refer to the Science Skill Handbook.**

# SCIENCE Stats

# Salty Solutions

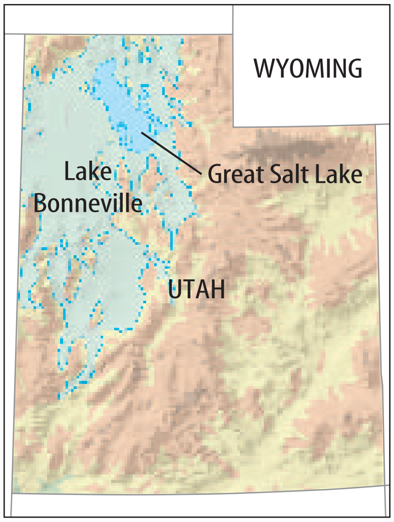
## Did you know...

**...Seawater is certainly a salty solution.** Ninety-nine percent of all salt ions in the sea are sodium, chlorine, sulfate, magnesium, calcium, and potassium. The major gases in the sea are nitrogen, oxygen, carbon dioxide, argon, neon, and helium.

**...Tears and saliva have a lot in common.** Both are salty solutions that protect you from harmful bacteria, keep tissues moist, and help spread nutrients. Bland-tasting saliva, however, is 99 percent water. The remaining one percent is a combination of many ions, including sodium and several proteins.

**...The largest salt lake** in the United States is the Great Salt Lake. It covers more than 4,000 km$^2$ in Utah and is up to 13.4 m deep. The Great Salt Lake and the Salt Lake Desert were once part of the enormous, prehistoric Lake Bonneville, which was 305 m deep at some points.

**Applying Math** At its largest, Lake Bonneville covered about 32,000 km$^2$. What percentage of that area does the Great Salt Lake now cover?




**...Salt can reduce pain.** Gargled salt water is a disinfectant; it fights the bacteria that cause some sore throats.

## Graph It

**Visit ips.msscience.com/science_stats to research and learn about other elements in seawater. Create a graph that shows the amounts of the ten most common elements in 1 L of seawater.**



CORBIS

## Reviewing Main Ideas

### Section 1 What is a solution?

1. Elements and compounds are pure substances, because their compositions are fixed. Mixtures are not pure substances.
2. Heterogeneous mixtures are not mixed evenly. Homogeneous mixtures, also called solutions, are mixed evenly on a molecular level.
3. Solutes and solvents can be gases, liquids, or solids, combined in many different ways.

### Section 2 Solubility

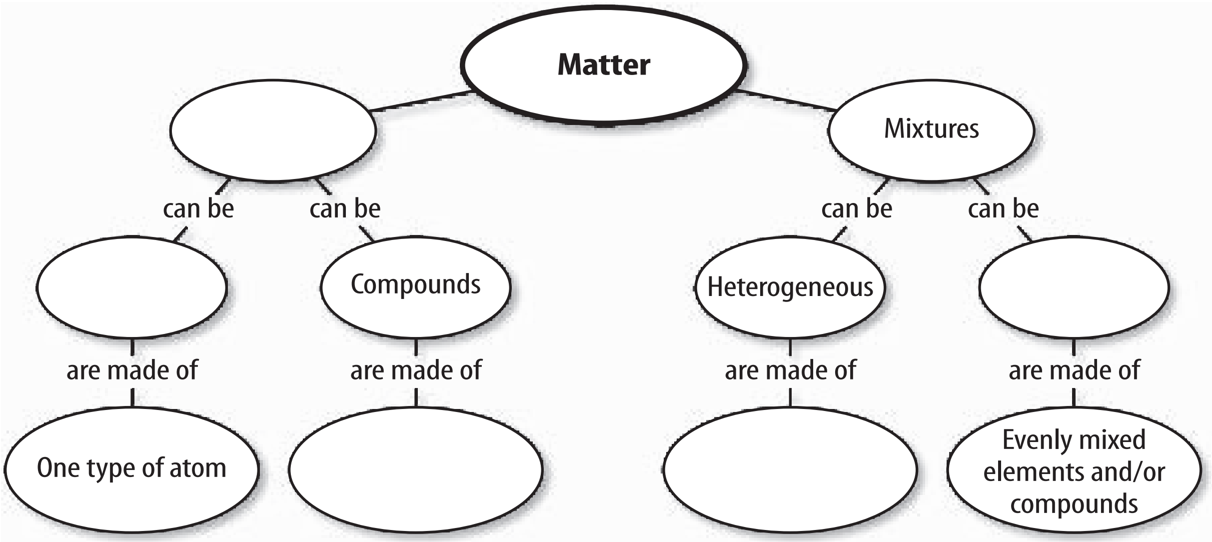
1. Because water molecules are polar, they can dissolve many different solutes. Like dissolves like.
2. Temperature and pressure can affect solubility.
3. Solutions can be unsaturated, saturated, or supersaturated, depending on how much solute is dissolved compared to the solubility of the solute in the solvent.
4. The concentration of a solution is the amount of solute in a particular volume of solvent.

### Section 3 Acidic and Basic Solutions

1. Acids release H+ ions and produce hydronium ions when they are dissolved in water. Bases accept H+ ions and produce hydroxide ions when dissolved in water.
2. pH expresses the concentrations of hydronium ions and hydroxide ions in aqueous solutions.
3. In a neutralization reaction, an acid reacts with a base to form water and a salt.

## Visualizing Main Ideas

*Copy and complete the concept map on the classification of matter.*



# chapter 8 Review

## Using Vocabulary

acid p. 232
aqueous p. 224
base p. 235
concentration p. 229
heterogeneous mixture p. 219
homogeneous mixture p. 220
hydronium ion p. 232
indicator p. 238
neutralization p. 238
pH p. 236
precipitate p. 220
saturated p. 228
solubility p. 227
solute p. 220
solution p. 220
solvent p. 220
substance p. 218

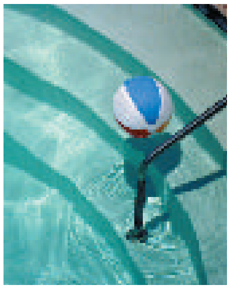
*Fill in the blanks with the correct vocabulary word.*

1. A base has a(n) _________ value above 7.
2. A measure of how much solute is in a solution is its _________.
3. The amount of a solute that can dissolve in 100 g of solvent is its _________.
4. The _________ is the substance that is dissolved to form a solution.
5. The reaction between an acidic and basic solution is called _________.
6. A(n) _________ has a fixed composition.

## Checking Concepts

*Choose the word or phrase that best answers the question.*

7. Which of the following is a solution?
   **A)** pure water
   **B)** an oatmeal-raisin cookie
   **C)** copper
   **D)** vinegar
8. What type of compounds will not dissolve in water?
   **A)** polar **C)** nonpolar
   **B)** ionic **D)** charged
9. What type of molecule is water?
   **A)** polar **C)** nonpolar
   **B)** ionic **D)** precipitate
10. When chlorine compounds are dissolved in pool water, what is the water?



   **A)** the alloy
   **B)** the solvent
   **C)** the solution
   **D)** the solute
11. A solid might become less soluble in a liquid when you decrease what?
   **A)** particle size **C)** temperature
   **B)** pressure **D)** container size
12. Which acid is used in the industrial process known as pickling?
   **A)** hydrochloric **C)** sulfuric
   **B)** carbonic **D)** nitric
13. A solution is prepared by adding 100 g of solid sodium hydroxide, NaOH, to 1,000 mL of water. What is the solid NaOH called?
   **A)** solution **C)** solvent
   **B)** solute **D)** mixture
14. Given equal concentrations, which of the following will produce the most hydronium ions in an aqueous solution?
   **A)** a strong base **C)** a strong acid
   **B)** a weak base **D)** a weak acid
15. Bile, an acidic body fluid used in digestion, has a high concentration of hydronium ions. Predict its pH.
   **A)** 11 **C)** less than 7
   **B)** 7 **D)** greater than 7
16. When you swallow an antacid, what happens to your stomach acid?
   **A)** It is more acidic.
   **B)** It is concentrated.
   **C)** It is diluted.
   **D)** It is neutralized.



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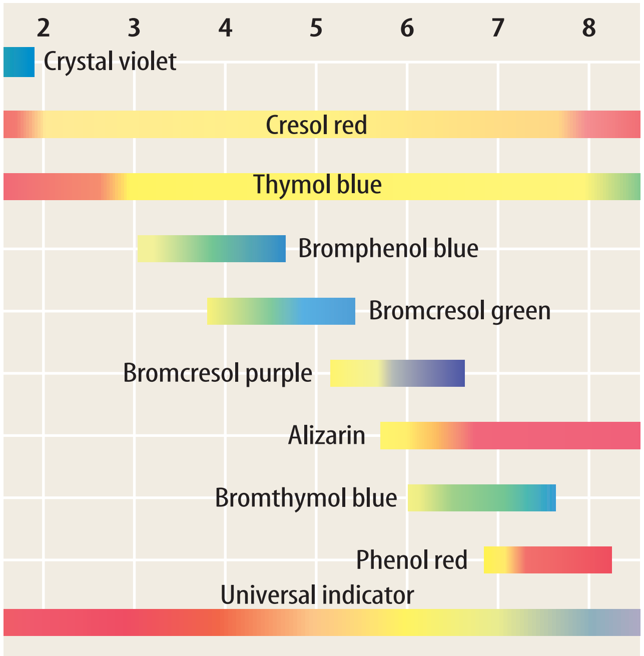
## Thinking Critically

17. **Infer** why deposits form in the steam vents of irons in some parts of the country.

18. **Explain** if it is possible to have a dilute solution of a strong acid.

19. **Draw Conclusions** Antifreeze is added to water in a car's radiator to prevent freezing in cold months. It also prevents overheating or boiling. Explain how antifreeze does both.

**Use the illustration below to answer question 20.**




20. **Interpret** Chemists use a variety of indicators. Using the correct indicator is important. The color change must occur at the proper pH or the results could be misleading. Looking at the indicator chart, what indicators could be used to produce a color change at both pH 2 and pH 8?

21. **Explain** Water molecules can break apart to form $H^+$ ions and $OH^-$ ions. Water is known as an amphoteric substance, which is something that can act as an acid or a base. Explain how this can be so.

22. **Describe** how a liquid-solid solution forms. How is this different from a liquid-gas solution? How are these two types of solutions different from a liquid-liquid solution? Give an example of each with your description.

23. **Compare and contrast** examples of heterogeneous and homogeneous mixtures from your daily life.

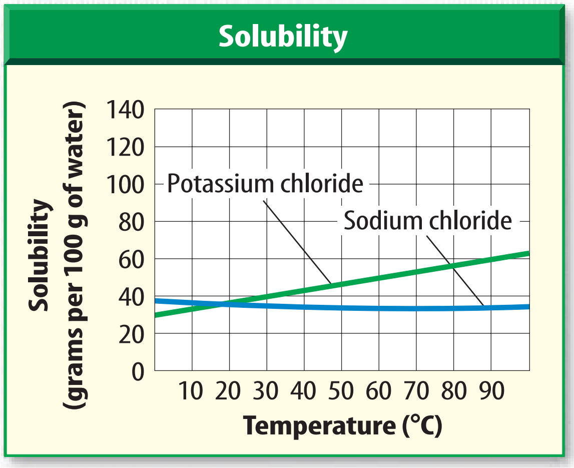
24. **Form a Hypotheses** A warm carbonated beverage seems to fizz more than a cold one when it is opened. Explain this based on the solubility of carbon dioxide in water.

## Performance Activities

25. **Poem** Write a poem that explains the difference between a substance and a mixture.

## Applying Math

**Use the graph below to answer question 26.**



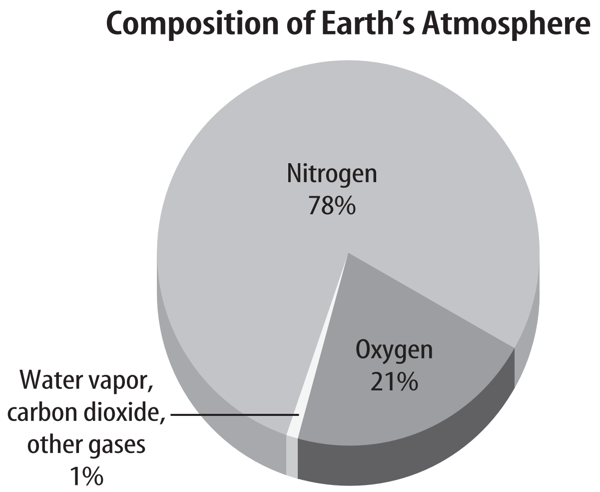

26. **Solubility** Using the solubility graph above, estimate the solubilities of potassium chloride and sodium chloride in grams per 100 g of water at 80°C.

27. **Juice Concentration** You made a one-liter (1,000 mL) container of juice. How much concentrate, in mL, did you add to make a concentration of 18 percent?

## Part 1 Multiple Choice

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

**Use the illustration below to answer questions 1 and 2.**




1. Which term best describes Earth's atmosphere?
   **A.** saturated
   **B.** solution
   **C.** precipitate
   **D.** indicator

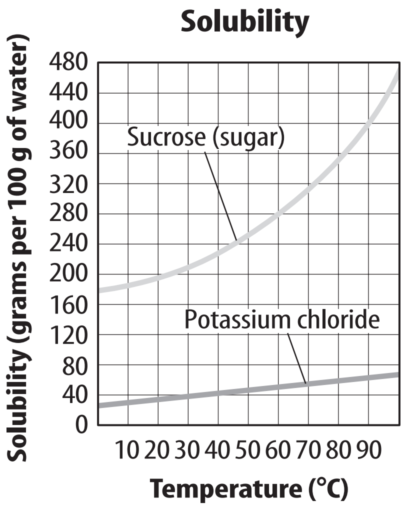
2. Which of these is the solvent in Earth's atmosphere?
   **A.** nitrogen
   **B.** oxygen
   **C.** water vapor
   **D.** carbon dioxide

3. What characteristic do aqueous solutions share?
   **A.** They contain more than three solutes.
   **B.** No solids or gases are present as solutes in them.
   **C.** All are extremely concentrated.
   **D.** Water is the solvent in them.

**Test-Taking Tip**

**Start the Day Right** The morning of the test, eat a healthy breakfast with a balanced amount of protein and carbohydrates.

**Use the illustration below to answer questions 4 and 5.**




4. How does the solubility of sucrose change as the temperature increases?
   **A.** It increases.
   **B.** It does not change.
   **C.** It decreases.
   **D.** It fluctuates randomly.

5. Which statement is TRUE?
   **A.** Potassium chloride is more soluble in water than sucrose.
   **B.** As water temperature increases, the solubility of potassium chloride decreases.
   **C.** Sucrose is more soluble in water than potassium chloride.
   **D.** Water temperature has no effect on the solubility of these two chemicals.

6. Which of these is a property of acidic solutions?
   **A.** They taste sour.
   **B.** They feel slippery.
   **C.** They are in many cleaning products.
   **D.** They taste bitter.

## Part 2 Short Response/Grid In

*Record your answers on the answer sheet provided by your teacher or on a sheet of paper.*

7. Identify elements present in the alloy steel. Compare the flexibility and strength of steel and iron.

**Use the illustration below to answer questions 8 and 9.**

8. How can you tell that the matter in this bowl is a mixture?
9. What kind of mixture is this? Define this type of mixture, and give three additional examples.
10. Explain why a solute broken into small pieces will dissolve more quickly than the same type and amount of solute in large chunks.
11. Compare the concentration of two solutions: Solution A is composed of 5 grams of sodium chloride dissolved in 100 grams of water. Solution B is composed of 27 grams of sodium chloride dissolved in 100 grams of water.
12. Give the pH of the solutions vinegar, blood plasma, and ammonia. Compare the acidities of soft drinks, tomatoes, and milk.
13. Describe how litmus paper is used to determine the pH of a solution.

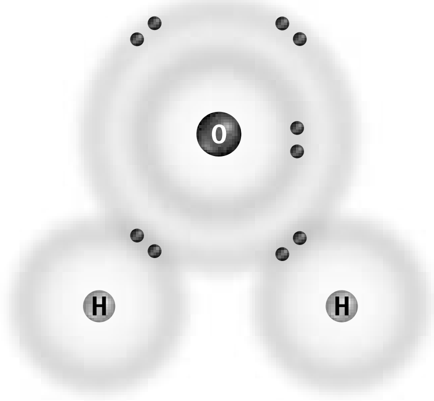
## Part 3 Open Ended

*Record your answers on a sheet of paper.*

14. Compare and contrast crystallization and a precipitation reaction.
15. Why is a carbonated beverage defined as a liquid-gas solution? In an open container, the ratio of liquid solvent to gas solute changes over time. Explain.

**Use the illustration below to answer questions 16 and 17.**

(Partial negative charge)




(Partial positive charge)

16. The diagram shows a water molecule. Use the distribution of electrons to describe this molecule's polarity.
17. Explain how the polarity of water molecules makes water effective in dissolving ionic compounds.
18. Marble statues and building facades in many of the world's cities weather more quickly today than when first constructed. Explain how the pH of water plays a role in this process.
19. Acetic acid, $CH_3COOH$, has more hydrogen atoms than the same concentration of hydrochloric acid, HCl. Hydrogen ions separate more easily from hydrochloric than acetic acid. Which acid is strongest? Why?



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