SECTION 1

The Nature of Water

As You Read

What You'll Learn

- **Describe** how water exists on Earth in three states.
- **Explain** the polarity of water molecules.
- **Describe** several unique properties of water.

Vocabulary

density
cohesion
polar molecule
specific heat

Why It's Important

The unique properties of water allow life to exist on Earth.

Forms of Water

Think about the water you use every day. When you drink a glass of water, you use it in liquid form. When you put ice in a drink, you're using it in solid form. Even when you breathe, you are using water. Along with the oxygen, nitrogen, and other gases from Earth's atmosphere, you inhale gaseous water with every breath you take.

The fact that water exists on Earth's surface as a liquid, a gas, and a solid is one of its unique properties. Water is a simple molecule composed of two hydrogen atoms bonded to one oxygen atom. Yet water has several unusual properties that make it extremely useful here on Earth. Indeed, without water, this planet would be a different place from what is seen in **Figure 1.**

Reading Check *Which two atoms can be found in molecules of water?*

Figure 1
Water might be the most important compound on Earth.
Where do you see water in this photograph?

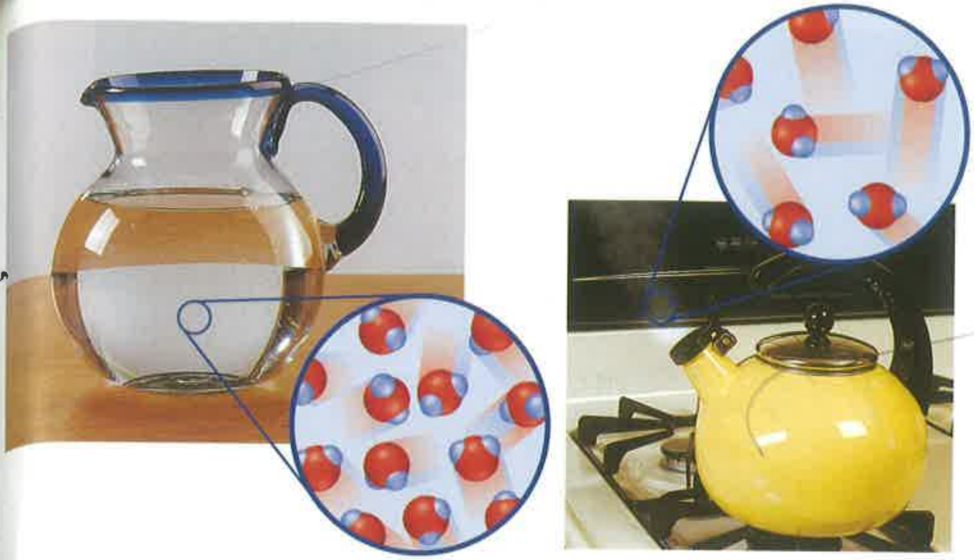


Figure 2
Water molecules in the liquid state are held close together by weak bonds. When water changes to steam, the molecules move farther apart. It takes energy to break weak bonds and separate the molecules.

Changing Forms of Water One of the reasons you can find water on Earth in all three states is the narrow temperature range between its freezing and boiling points. Under standard conditions, pure water freezes at 0°C and boils at 100°C.

Water molecules are connected by weak bonds. In order to change from solid to liquid or to change from liquid to gas, bonds must be broken. Breaking bonds requires energy, as shown in **Figure 2.**

When the state changes go the other direction, water gives off energy. The same amount of heat needed to change liquid to gas, for example, is given off when the gas changes back to liquid.

Latent Heat

Would you try to boil a pan of water over a candle? Of course not. Clearly a candle does not give off enough heat. Each molecule of water is attracted weakly to other water molecules. All those attractions mean that you need a high amount of heat to boil the water in your pan—definitely more than a candle's worth. Changing the state of water, either from liquid to gas or from solid to liquid, takes more energy than you might think.

Chemistry INTEGRATION The heat energy needed to change water from solid to liquid is called the latent heat of fusion. Heat can be measured using a unit called the joule. It takes about 335 joules to melt a single gram of ice at 0°C. On the other hand, 335 joules of heat will escape when a single gram of water freezes into ice at 0°C. It might surprise you to know that the temperature does not change while the freezing or melting is going on. During freezing and melting, energy is changing the state of the water but not the temperature.

SCIENCE Online

Research Visit the Glencoe Science Web site at **science.glencoe.com** for more information about the effects of weak bonding in water. Summarize what you learn in your Science Journal.

Figure 3
Temperature does not change as water changes to steam. The latent heat of vaporization is used to change the water's form.

Time Requirements

These processes take time. Water won't freeze the instant it goes into the freezer, and ice won't melt immediately when you place an ice cube on the counter. Ice is a stable form of water. A large amount of heat loss must occur to make ice in the first place. After water is frozen, it takes far more energy to melt the ice than it does to heat the resulting liquid water to almost boiling.

Heat of Vaporization

It takes even more heat energy to change liquid water to gas, or water vapor. The amount of heat needed to change water from liquid to gas is called the latent heat of vaporization. Each gram of liquid water needs 2,260 joules of heat to change to water vapor at 100°C. Likewise, each gram of water vapor that changes back to liquid at 100°C releases 2,260 joules of heat. During both of these processes, no increase or decrease in temperature occurs, just a change in form, as shown in **Figure 3.**

Reading Check ***Why doesn't temperature change when water boils?***

You might have experienced latent heat of vaporization if you've ever felt a chill after getting out of a swimming pool. When you first emerged from the pool, your skin was covered with some water. As the water evaporated into the air and became water vapor, it took heat from your body and made you feel cold. Can you think of a way that evaporating water could be used to cool other things, such as a desert home?

Life Science INTEGRATION

Citrus farmers often protect their crop on cold nights by spraying water on the orange or grapefruit trees. If the temperature drops below freezing, the water freezes. Explain in your Science Journal how freezing water could keep citrus trees warmer.

Density Which has more mass—a kilogram of plastic foam or a kilogram of lead? They're the same, of course, but you will need a much bigger container to hold the plastic foam. The volume of the lead will be smaller because lead has more mass for its size than plastic foam. In other words, the lead has greater density. **Density** is the amount of mass in a unit of volume. The density of pure water is 1.0 g/cm^3 at 4°C. Adding another substance to the water, such as salt, changes the density. Freshwater will float on top of denser salt water, just as olive oil rides atop the denser vinegar in salad dressing. This situation is found in nature where rivers run into the ocean. The freshwater stays on top until waves and currents mix it with the seawater.

Temperature also affects the density of water. As freshwater heats up above 4°C, the water molecules gain energy and move apart. In the same volume of water, warm water has fewer molecules than cold water does. Therefore, warm water has lower density than cold water and will float on top of it, as shown in **Figure 4.** You might have experienced this while swimming in a pond or lake during the summer. The water on top is fairly warm. However, if you dive down, you suddenly feel the colder, denser water below. The difference in density between warm and cold water has an important effect in the ocean. These differences cause currents in the water.

Reading Check ***What do you think would happen to cold water at the surface of the ocean?***

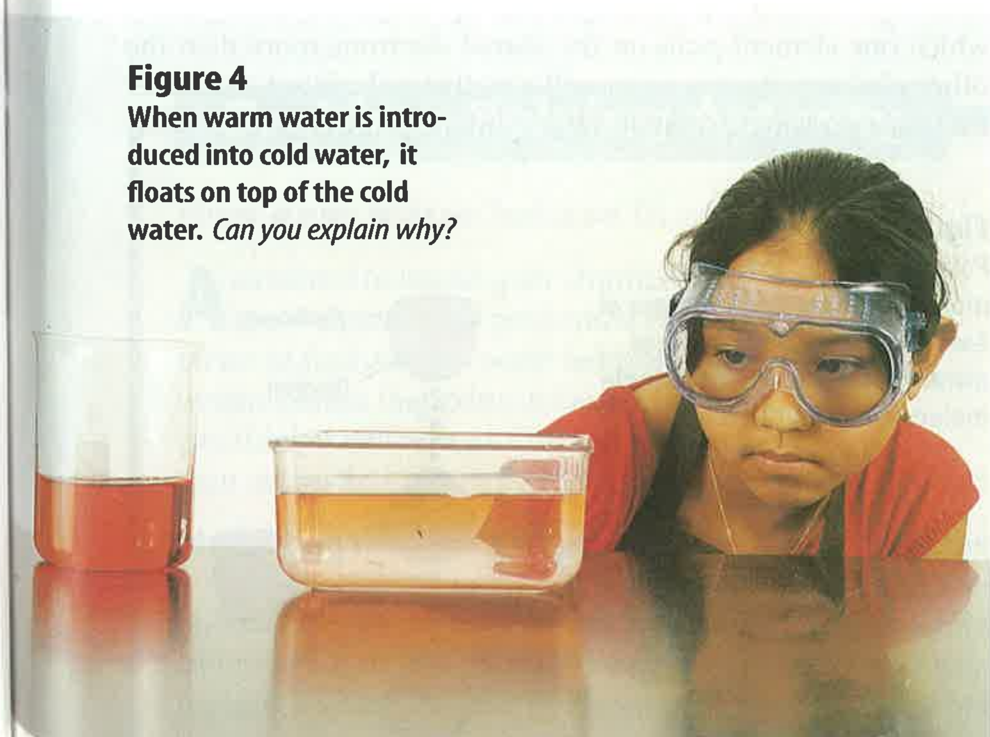


Figure 4
When warm water is introduced into cold water, it floats on top of the cold water. *Can you explain why?*

Mini LAB

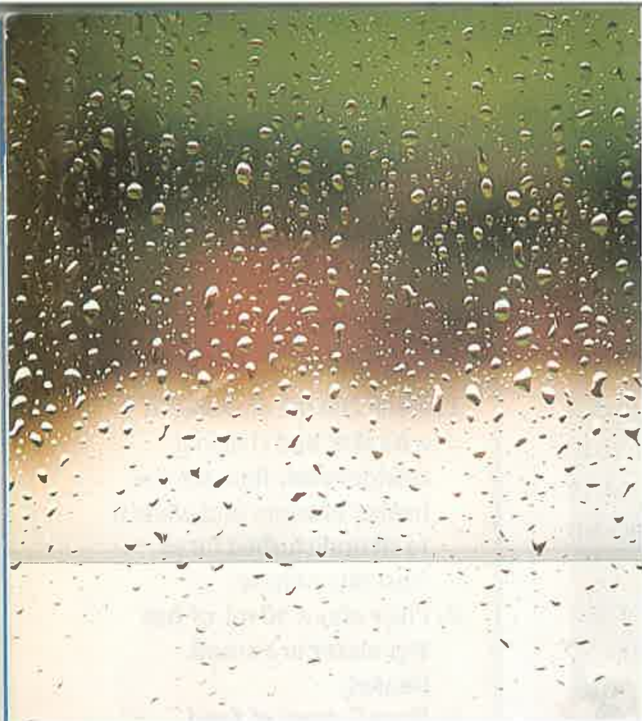
Examining Density Differences

Procedure

1. Place 200 mL of **water** in a **beaker** and chill in a **refrigerator.** Remove the beaker of water and allow it to sit undisturbed for at least one minute.
2. Place about 30 mL of **hot tap water** in a **small beaker.**
3. Place 5 drops of **food coloring** into the hot water to make it easy to see.
4. Use a **pipette** to slowly place several milliliters of the hot water into the bottom of the beaker of cold water. Be careful not to stir the cold water.

Analysis

1. How does the hot water behave when added to the cold water?
2. A few minutes after the hot water has been added to the cold water, observe the container. Explain the cause of what you observe.



A Polar Molecule

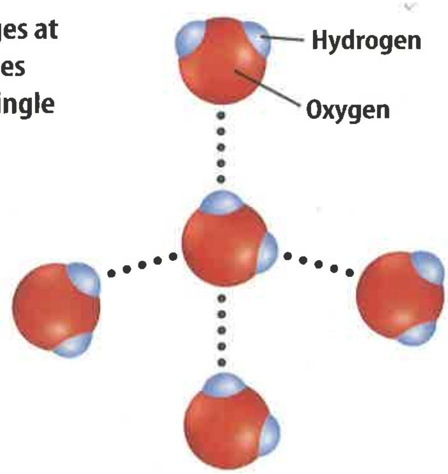
You might have noticed how water can bulge from the end of a graduated cylinder for a moment before it finally comes pouring out. That's due to the special property of water called cohesion. **Cohesion** is the attraction between water molecules. It's what allows water to form into drops, as shown in **Figure 5,** as well as keeping it liquid at room temperature. If not for cohesion, water molecules would fly off into the air. Molecules like carbon dioxide and nitrogen, which are close in mass to water molecules, vaporize at room temperature. If water molecules also vaporized, Earth would be a different, far drier place.

Reading Check ***What property of water allows it to form into drops?***

Figure 5
Cohesion causes water to form drops on a window.

Here's how cohesion works. As you know, a water molecule is made of two hydrogen atoms and one oxygen atom. These atoms share their electrons in covalent bonds. But the oxygen atom pulls more powerfully on the negatively charged electrons than the hydrogen atoms do. This gives the oxygen end of the molecule a partial negative charge and the hydrogen side of the molecule a partial positive charge. The molecule then acts like a tiny magnet, attracting other water molecules into weak bonds. Each water molecule links with about four other water molecules that way, as shown in **Figure 6.** Due to this behavior, the water molecule is considered a polar molecule. A **polar molecule** is one in which one element pulls on the shared electrons more than the other element. As you soon will see, this polarity of the water molecule explains several of water's unique properties.

Figure 6
Polar molecules, like water molecules, have weak charges at each end. These weak charges attract opposites and let a single molecule bond with others.



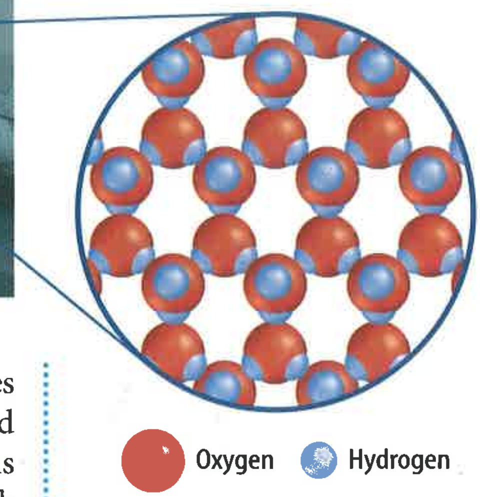


Figure 7
Water molecules are farther apart in ice than in liquid water. This causes ice to float on water.

Effects of Bonding The polarity of water molecules makes water great for dissolving other substances, such as sea salts and substances that travel through your body. Polarity also means that ice will float on liquid water. As water freezes, the weak bonds between the molecules form an open arrangement of molecules, as seen in **Figure 7.**

The molecules, therefore, are farther apart when they are frozen than they were as liquid. This results in ice having a lower density than liquid water, letting it float on water. In large bodies of water, floating ice insulates the water below, which remains liquid. If lakes froze from the bottom up, they would freeze solid every winter, killing all living things inside.

Problem-Solving Activity

How does water behave in space?

Astronauts onboard space shuttles and space stations have performed experiments to find out how water behaves in the weightlessness that exists in Earth orbit. Do you think water behaves differently in space than on Earth?

Identifying the Problem

The photograph to the right was taken onboard *Skylab*, a former United States space laboratory. It shows astronaut Joseph Kerwin forming a sphere of water by blowing droplets of water through a straw.

Solving the Problem

1. Why does the water drop remain suspended?
2. Why would water form nearly spherical drops onboard the space shuttle or an orbiting space station?

Chemistry INTEGRATION

You place a pair of silver eyeglasses on the windowsill on a hot, sunny day. When you go back later to pick up the glasses, you note that the glass lenses do not feel as hot as the silver frame. Based on this, infer which of the materials—the glass or the silver—has a higher specific heat. Write your answer in your Science Journal.

Specific Heat Have you ever burned your feet running across the sand on a beach? You make a mad dash for the water, where you can be sure to cool them off. But think about this: the same hot Sun is shining down on the water, too. Why is the water so cool? One reason is water's high specific heat. **Specific heat** is the amount of energy that is needed to raise the temperature of 1 kg of a substance 1°C. The same amount of energy raises the temperature of the sand much more than the temperature of the water. In fact, when you compare water with all other naturally occurring materials, it will increase its temperature the least when heat is added. In other words, water has the highest specific heat.

Reading Check *What is the definition of specific heat?*

High specific heat means water also will cool off slower when the energy is taken away. Go back to the beach at night and you can find this out yourself. At night the water feels warmer than the sand does.

This property is the reason water often is used as a coolant. Water in a car's radiator helps cool the engine by carrying away heat energy without heating up too much itself. The specific heat of water is just one more of the characteristics that make it so important to life. In the next section, you will learn some of the ways the special properties of water can be put to work.

Section 1 Assessment

1. List the three states of water and give examples of where water could be found in each of these states.
2. What is the latent heat of fusion? What is the latent heat of vaporization?
3. Why does hot water float on colder water? Why does freshwater float on salt water?
4. Why does ice float on liquid water? How does this keep ponds from freezing solid?
5. **Thinking Critically** Water molecules have positively and negatively charged ends. How does this property help water dissolve other substances made of charged atoms?

Skill Builder Activities

6. **Predicting** Predict what would happen to the level of water in a bowl if you were to set it out on the counter for several days. **For more help, refer to the Science Skill Handbook.**
7. **Solving One-Step Equations** It takes 335 joules of heat at 0°C to change 1 g of ice to liquid water. It takes 2,260 joules of heat at 100°C to change 1 g of liquid water to water vapor. Also, about 4 joules of heat is needed to raise the temperature of 1 g of liquid water 1°C. About how much heat is needed to change 1 g of ice to water vapor? **For more help, refer to the Math Skill Handbook.**