The Properties of Water

Reading Preview

Key Concepts

- How does the chemical structure of water molecules cause them to stick together?
- What are some of water's unusual properties?
- What are the three states in which water exists on Earth?

Key Terms

- polar molecule
- capillary action
- surface tension
- solution
- solvent
- specific heat
- evaporation
- condensation

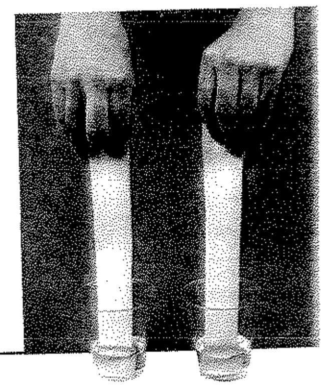
Target Reading Skill

Building Vocabulary A definition states the meaning of a word or phrase by telling about its most important feature or function. After you read this section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone Discover Activity

What Are Some Properties of Water?

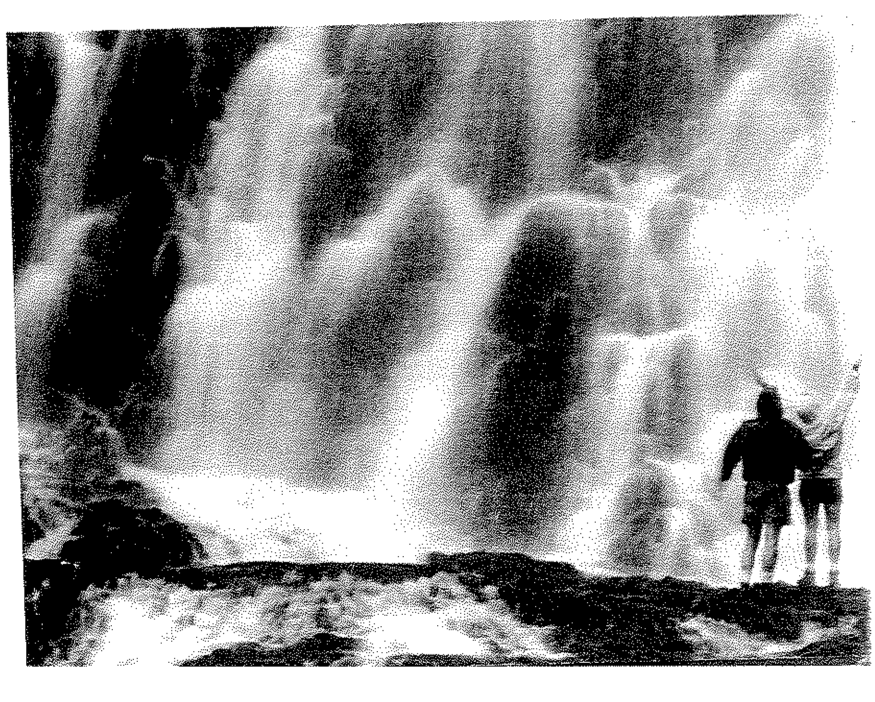
1. Pour a small amount of water into a plastic cup. Pour an equal amount of vegetable oil into a second cup.
2. Cut two strips of paper towel. Hold the strips so that the bottom of one strip is in the water and the other is in the oil.
3. After one minute, measure how high each substance rose up the paper towel.
4. Using plastic droppers, place equal-sized drops of water and oil next to each other on wax paper.
5. Observe the shape of the two drops from the side.
6. Follow your teacher's instructions for disposing of the oil.



Think It Over

Observing What differences do you notice between the water and the oil in each experiment?

How would you describe water to someone who had never see[n] it before? You might say that pure water has no color, no tast[e] and no odor. You might even say that water is a rather plai[n] ordinary substance. But if you asked a chemist to describe wate[r] the chemist would say that water is very unusual. Its properti[es] differ from those of most other familiar substances.



Hikers awed by waterfalls in Yosemite National Park ▶

The Structure of Water

Could you and the chemist possibly be talking about the same substance? To understand the chemist's description of water, you need to know something about water's chemical structure.

Like all matter, water is made up of atoms. Just as the 26 letters of the alphabet combine in different ways to form all the words in the English language, about 100 types of atoms combine in different ways to form all types of matter.

Atoms attach together, or bond, to form molecules. Two hydrogen atoms bonded to an oxygen atom form a water molecule. A short way of writing this is to use the chemical formula for water, H_2O.

Figure 1 shows how the hydrogen and oxygen atoms are arranged in a water molecule. Each end of the molecule has a slight electric charge. The oxygen end has a slight negative charge. The hydrogen ends have a slight positive charge. A molecule that has electrically charged areas is a **polar molecule.** Because water consists of polar water molecules, it is called a polar substance.

Have you ever played with bar magnets? If so, then you know that the opposite poles of two magnets attract each other. The same is true with polar molecules, except that an electric force rather than a magnetic force causes the attraction. **The positive hydrogen ends of one water molecule attract the negative oxygen ends of nearby water molecules. As a result, the water molecules tend to stick together.**

Reading Checkpoint **Describe the arrangement of the atoms in a water molecule.**

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FIGURE 1
The Structure of Water
Each water molecule has two positive ends and one negative end. The positive ends of one water molecule are attracted to the negative end of another molecule.
Classifying *What makes water a polar substance?*

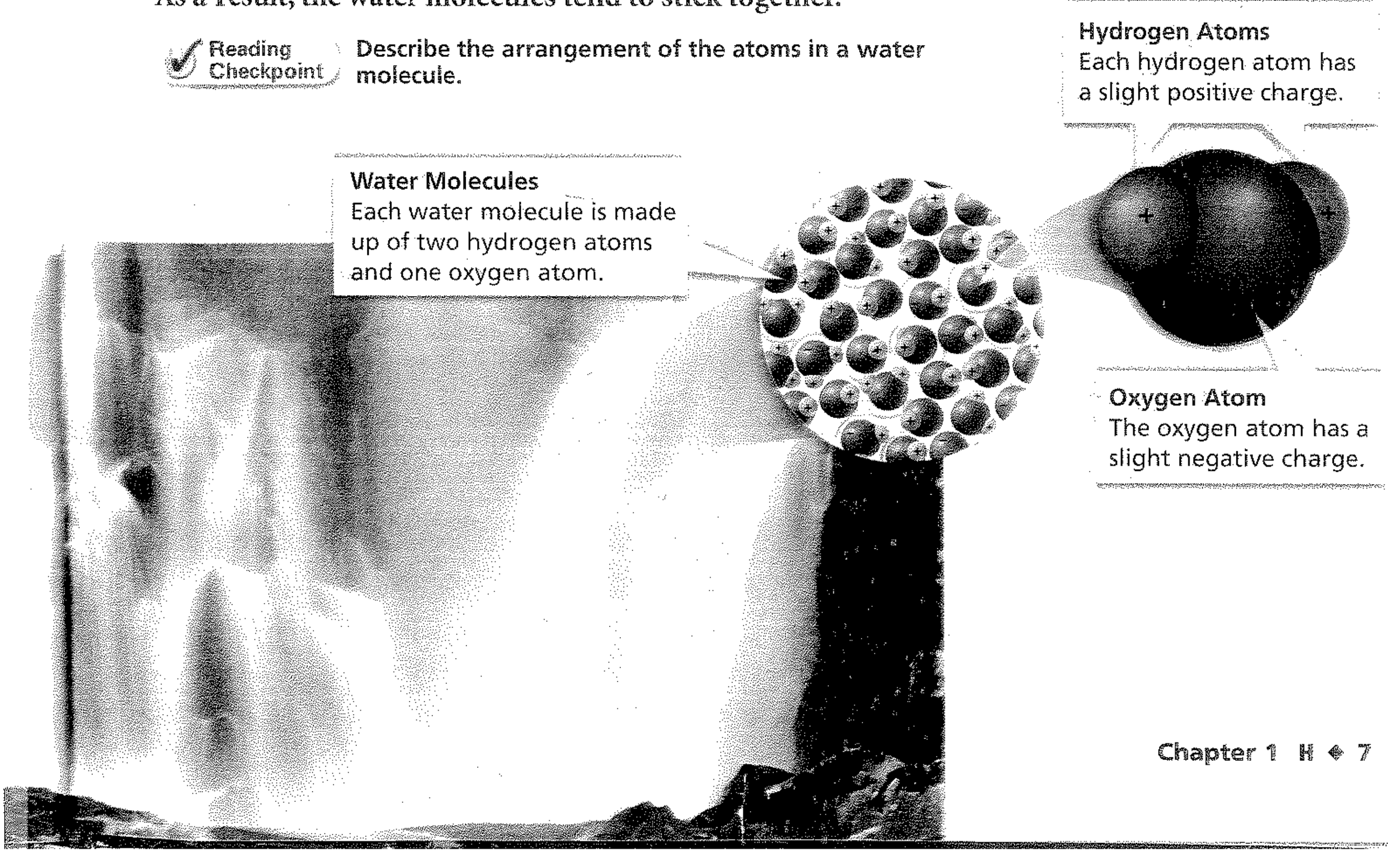
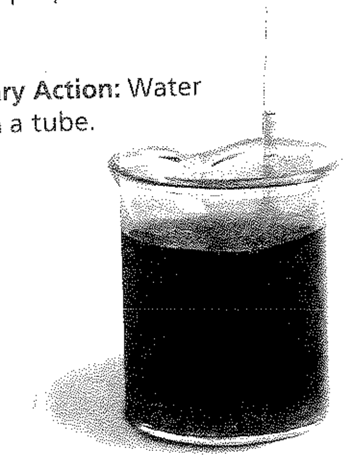


FIGURE 2

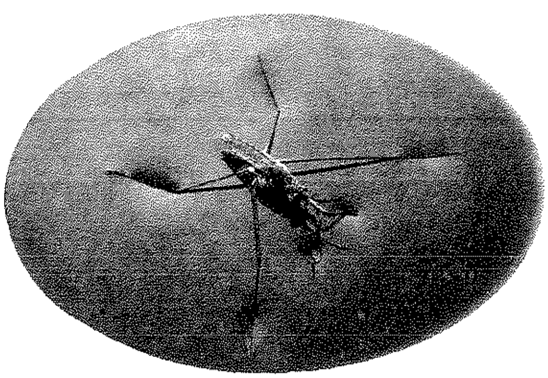
Three Properties of Water

The attraction among the polar water molecules is responsible for water's unusual properties.

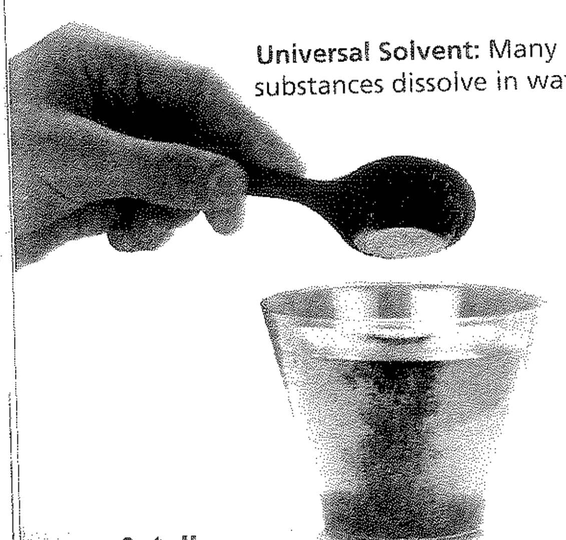
Capillary Action: Water rises in a tube.



Surface Tension: The tightness of the water's surface keeps a water strider from sinking.



Universal Solvent: Many substances dissolve in water.



Key Properties of Water

Many of water's unusual properties occur because of the attraction among the polar water molecules. **The properties of water include capillary action, surface tension, the ability to dissolve many substances, and high specific heat.**

Capillary Action Just as water molecules stick to one another, they also stick to the sides of a tube, such as a straw. The next time you see a drink with a straw in it, look closely at the level of the liquid outside and inside the straw. You will see that the liquid rises higher inside the straw. As water molecules are attracted to the straw, they pull other water molecules up with them. Similarly, water will climb up into the pores of a brick or a piece of wood.

The combined force of attraction among water molecules and with the molecules of surrounding materials is called **capillary action.** Capillary action allows water to move through materials with pores inside.

Capillary action also causes water molecules to cling to the fibers of materials like paper and cloth. You may have seen outdoor or athletic clothing that claims to "wick moisture away from the skin." Capillary action along the cloth's fibers pulls water away from your skin. By pulling the water away from your skin, the fibers keep you dry.

Surface Tension Have you ever watched water striders skate across the surface of a pond without sinking? They are supported by the surface tension of the water. **Surface tension** is the tightness across the surface of water that is caused by the polar molecules pulling on one another. The molecules at the surface are being pulled by the molecules next to them and below them. The pulling forces the surface of the water into a curved shape. Surface tension also causes raindrops to form round beads when they fall onto a car windshield.

Universal Solvent What happens when you make a fruit drink from a powdered mix? As you stir the powder into the water, the powder seems to disappear. When you make the fruit drink, you are making a solution. A **solution** is a mixture that forms when one substance dissolves another. The substance that does the dissolving is called the **solvent.** In this example, the water is the solvent.

Many substances dissolve in water because water is polar. The charged ends of the water molecule attract the molecules of other polar substances. Water dissolves so many substances that it is called the "universal solvent." It can dissolve solids, such as sugar, and liquids, such as bleach. Water can also dissolve many gases, including oxygen and carbon dioxide. Substances that have molecules with no charged regions are called nonpolar substances. Nonpolar substances do not dissolve well in water.

Specific Heat It is a steamy summer day. The air is hot, the sidewalk is hot, and the sandy beach is hot. But when you jump into the ocean, the water is surprisingly cool! If you go for an evening swim, however, the water is warmer than the cool air.

You feel this difference in temperature because of water's unusually high specific heat. **Specific heat** is the amount of heat needed to increase the temperature of a certain mass of a substance by 1°C. Compared to other substances, water requires a lot of heat to increase its temperature.

Water's high specific heat is due to the strong attraction among water molecules. Other substances, such as air and rocks, have weaker attractions between their molecules. The temperature of each of these substances rises more quickly than that of water that is heated the same amount.

One effect of water's high specific heat is that land areas located near large bodies of water experience less dramatic temperature changes than areas far inland. In summer, the sun's heat warms the land more quickly than the water. The warm land heats the air above it to a higher temperature than the air over the ocean. As a result, the air is warmer inland than on the coast. The opposite effect occurs in winter—land loses heat more quickly than water, so the air above the land is cooler.

Reading Checkpoint Why does water have a high specific heat?

Lab zone Try This Activity

Follow That String

Do this activity over a sink.

1. Cut a piece of string as long as your arm. Wet the string.
2. Fill a pitcher with water. Tie the string to the handle.
3. Drape the string across the spout and let the other end dangle into a plastic cup. Tape the end of the string inside the cup.

4. Hold the cup below the pitcher so that the string is pulled tight. As your partner gently pours the water into the cup, slowly move the cup to the right of the spout, keeping the string tight.

Inferring How do water's polar molecules cause it to follow the string?

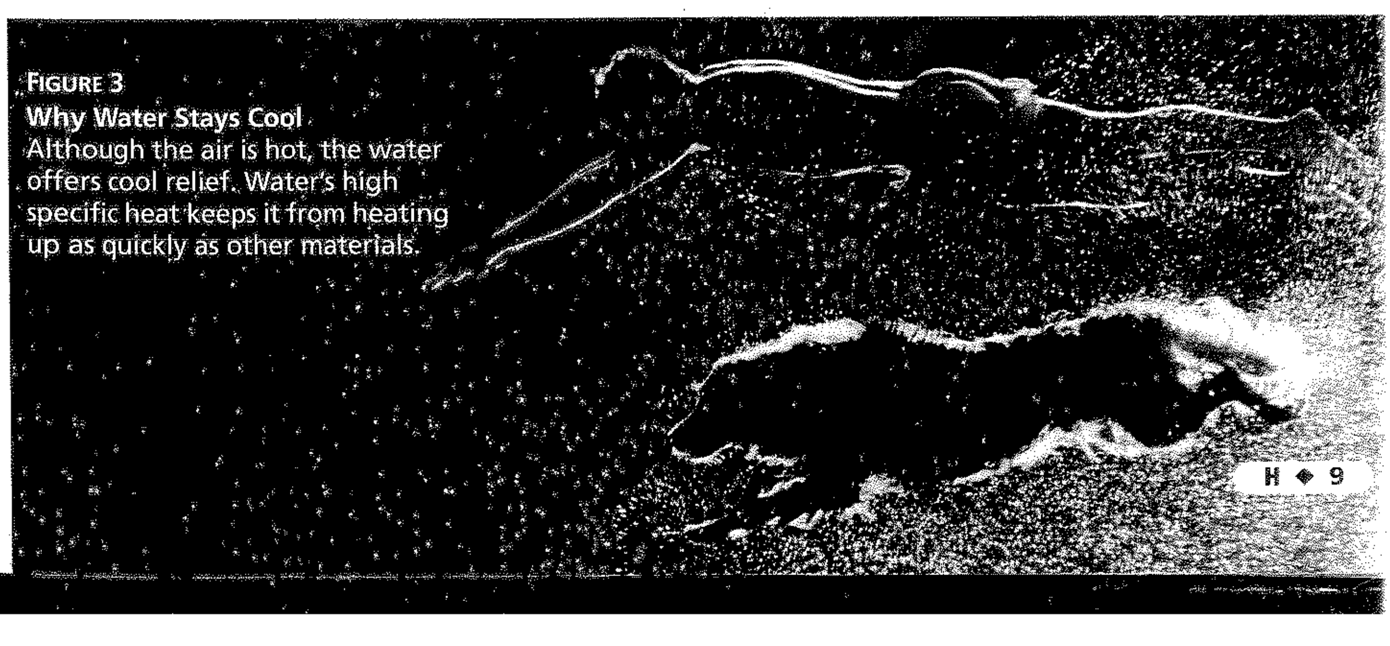
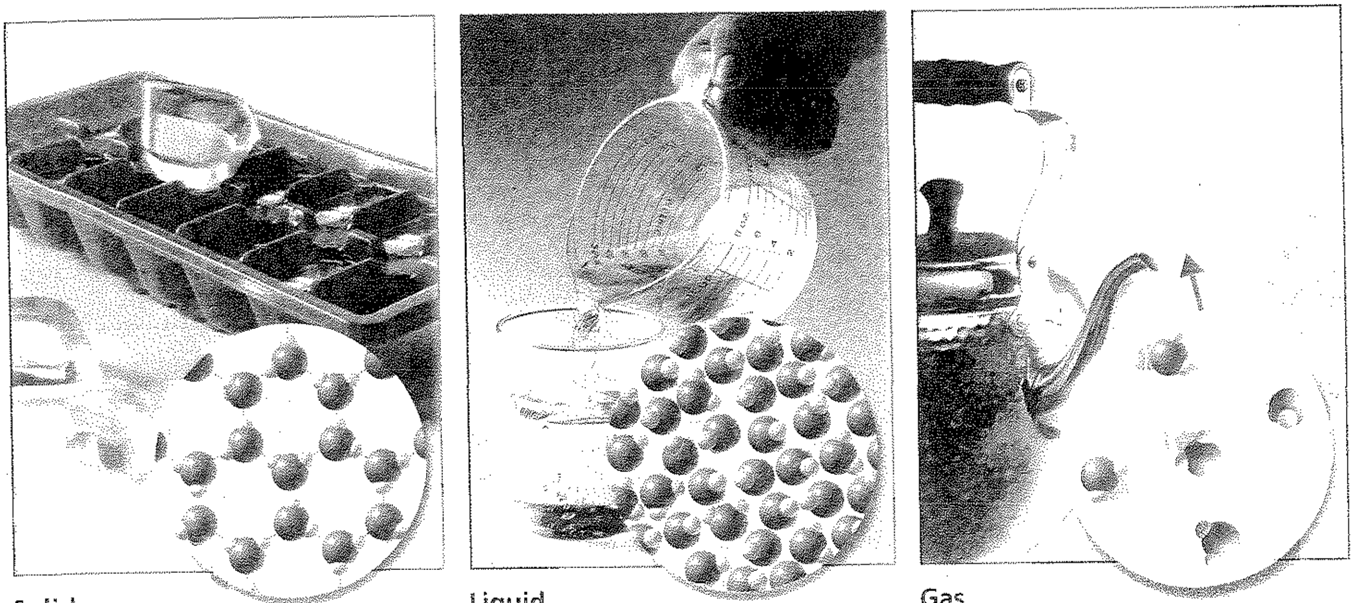


FIGURE 3
Why Water Stays Cool
Although the air is hot, the water offers cool relief. Water's high specific heat keeps it from heating up as quickly as other materials.



Solid
The molecules in solid ice are close together and form a rigid structure.

Liquid
The molecules move more freely, and the water takes the shape of its container.

Gas
The molecules in water vapor move very freely and spread out to fill a space.

FIGURE 4
The Three States of Water
Water commonly exists as a solid, a liquid, and a gas.
Comparing and Contrasting
In which state do the molecules move the slowest? The fastest?

Changing State

It's a hot, humid summer day. To cool down, you put some ice cubes in a glass and add cold water. You are interacting with water in three different states, or forms: solid, liquid, and gas. **The ice is solid water, the familiar form of water is a liquid, and the water vapor in the air is a gas.** Water is the only substance on Earth that commonly exists in all of these different states. Figure 4 shows how the arrangement of the water molecules differs in each state.

Boiling and Evaporation If you've ever poured water into a pot, you've seen how the liquid takes the shape of the container. This is true because the molecules in liquid water move freely, bouncing off one another.

What happens if you place the pot of water on a stove and heat it? As more energy is added to the liquid water, the speed of the molecules increases and the temperature rises. At 100°C, the water boils and a change of state occurs. The molecules have enough energy to escape the liquid and become invisible water vapor. The molecules in a gas move even more freely than those in a liquid.

Another way that liquid water can become a gas is through evaporation. **Evaporation** is the process by which molecules at the surface of a liquid absorb enough energy to change to the gaseous state. If you let your hair air-dry after going swimming, you are taking advantage of evaporation.

Condensation As water vapor cools down, it releases some of its energy to the surroundings. The molecules slow down and the temperature decreases. As the temperature of the gas reaches 100°C, the water vapor begins to change back to the liquid state. The process by which a gas changes to a liquid is called **condensation.** When you fog up a window by breathing on it, you are seeing the effects of condensation. The invisible water vapor in your breath is cooled by the window and forms drops of liquid water.

Freezing If those drops of liquid water cooled, the molecules would lose energy. They would start to move more and more slowly. At 0°C, the liquid water freezes, changing into solid ice. If you have ever observed an icicle forming from water dripping off a roof, you have seen this change of state in progress.

Melting Suppose that you put an ice cube in a pot and place it on the stove. As you heated it, the molecules in the ice would start moving faster. The temperature would rise. When the temperature reached 0°C, the solid ice would melt and become liquid water.

Reading Checkpoint What is condensation?

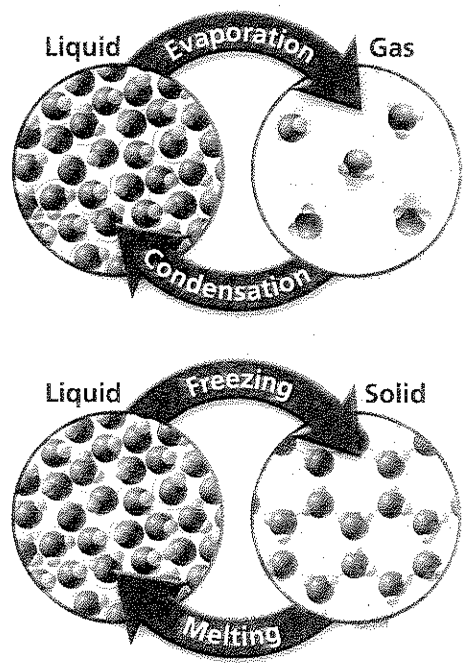


FIGURE 5
Changing State
Water moves between the liquid and gaseous states by evaporation and condensation. Water moves between the liquid and solid states by freezing and melting.

Section 1 Assessment

Target Reading Skill Building Vocabulary Use your definitions to help answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What atoms make up a water molecule?
   b. **Describing** Describe the electric charge on each end of a water molecule.
   c. **Relating Cause and Effect** What causes water molecules to be attracted to one another?
2. a. **Listing** Name four unusual properties that water exhibits.
   b. **Explaining** Briefly explain why water exhibits each property.
   c. **Predicting** Oil is a nonpolar molecule. Would it dissolve in water? Why or why not?
3. a. **Identifying** What are the three states in which water exists on Earth?
   b. **Sequencing** Describe how water changes state as a patch of ice is heated by the sun.

Lab zone At-Home Activity

Observing Water's Properties Put a penny on a piece of paper. With a plastic dropper or a toothpick, have a family member place a single drop of water on the penny. Ask the person to predict how many more drops he or she can add before the water spills off the penny. Have the person add drops one at a time until the water overflows. How does the result differ from the prediction? Explain what property of water accounts for the results.