LEARN ABOUT

The Forms of Matter

FIND OUT

- about molecules
- what the states of matter are
- how matter changes between states

VOCABULARY

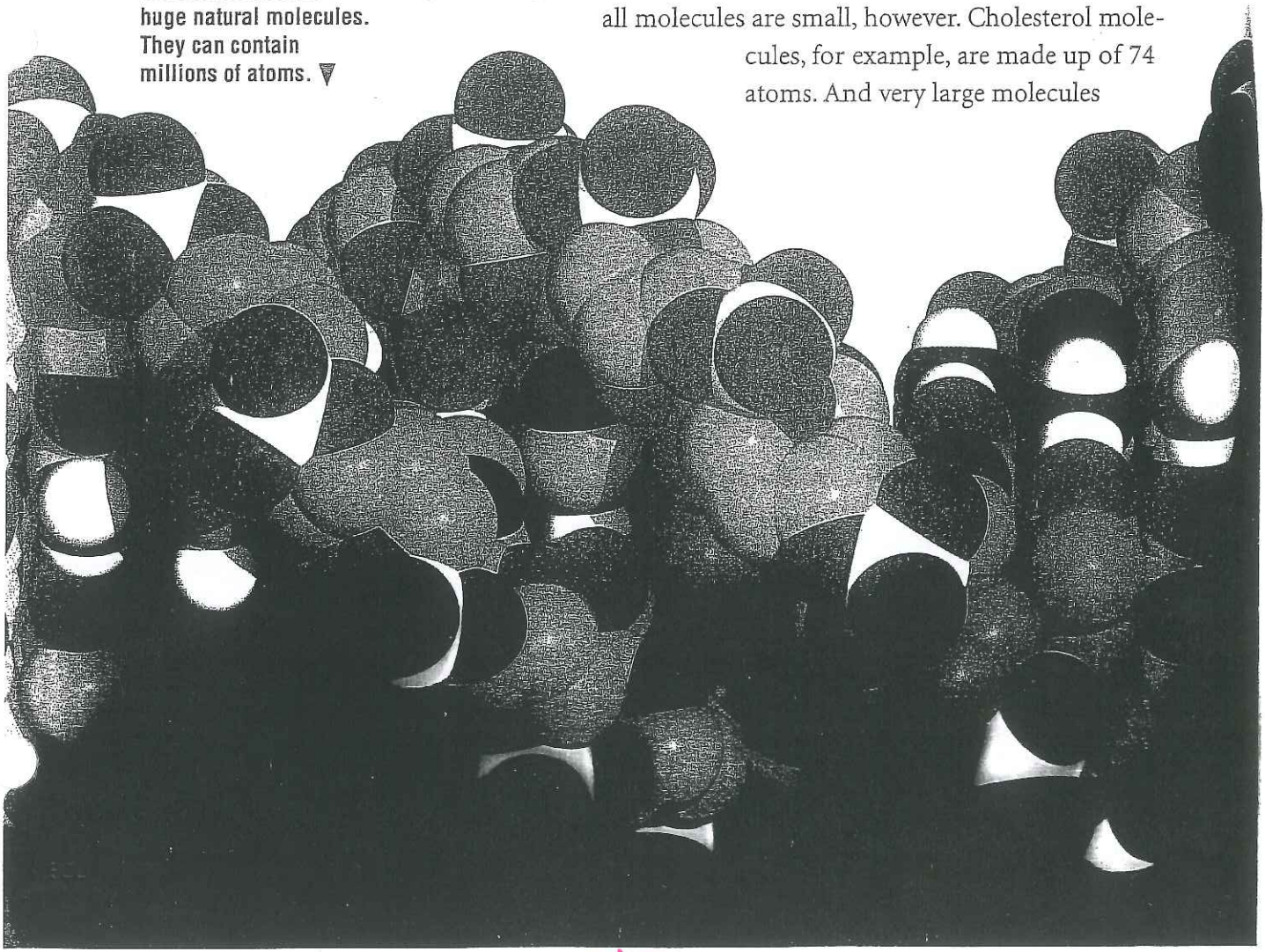
solid
liquid
gas

Molecules

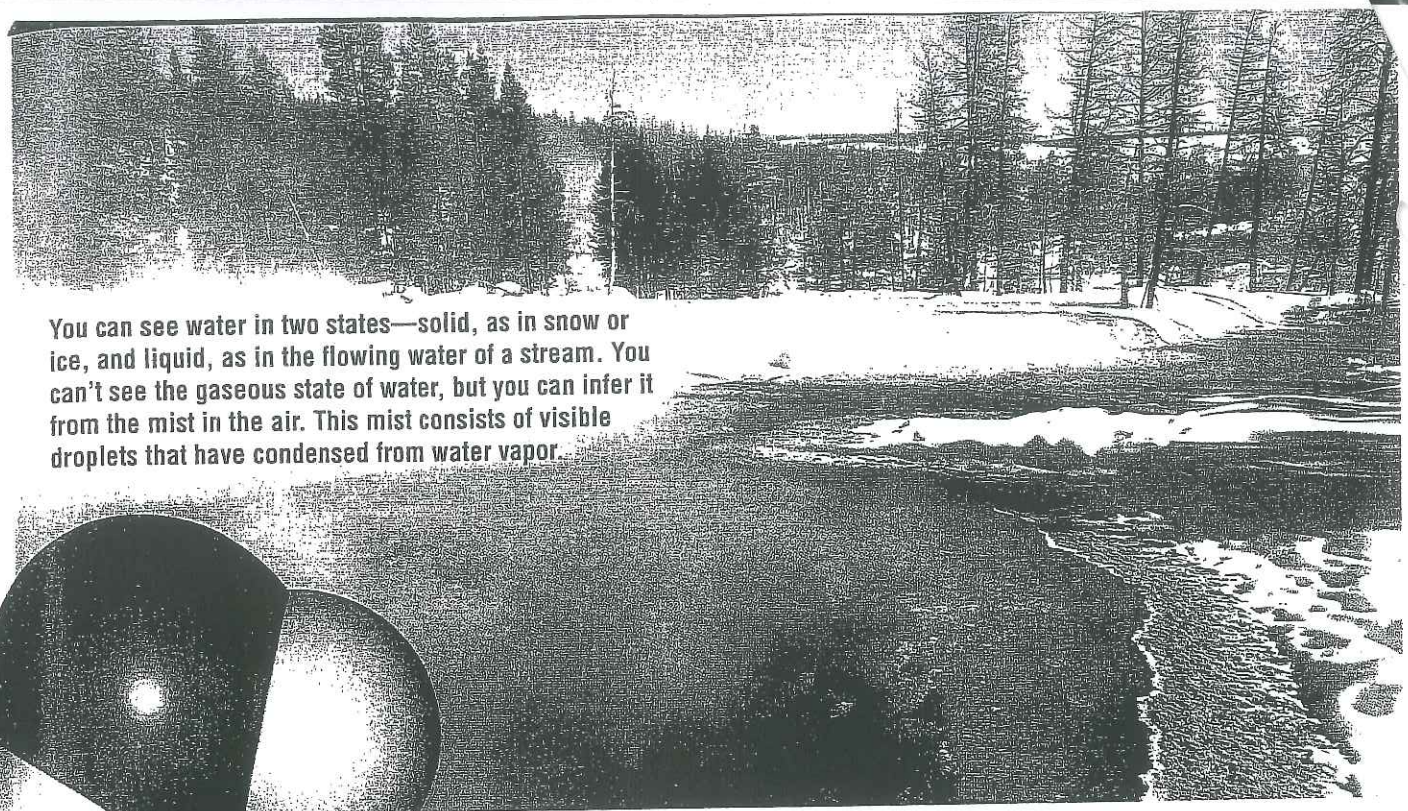
As you've learned, an element consists of only one kind of atom. However, often atoms bond, or join, together and form larger units called *molecules.* Molecules are units formed of two or more atoms. In the air that you breathe, oxygen exists as molecules that are each formed of two bonded oxygen atoms. Carbon dioxide is a molecule formed of three atoms bonded together—one atom of carbon and two atoms of oxygen.

Molecules form when electrons in two or more atoms are attracted to the nuclei of both atoms, not just to one nucleus. This attraction holds the nuclei of the atoms together. The atoms act and move as a single particle, a molecule. Molecules are not easily separated into the individual atoms that form them.

The smallest molecules, such as oxygen molecules, are made up of two atoms. In fact, many of the elements that are gases, such as hydrogen, nitrogen, and chlorine, exist as molecules of just two atoms. Not all molecules are small, however. Cholesterol molecules, for example, are made up of 74 atoms. And very large molecules



DNA molecules are huge natural molecules. They can contain millions of atoms. ▼



You can see water in two states—solid, as in snow or ice, and liquid, as in the flowing water of a stream. You can't see the gaseous state of water, but you can infer it from the mist in the air. This mist consists of visible droplets that have condensed from water vapor.

A water molecule is made up of two hydrogen atoms and one oxygen atom.

called *polymers* can contain hundreds or thousands of atoms. Many plastics, such as polyethylene, are polymers.

✓ **What holds the atoms of a molecule together?**

States of Matter

Matter exists in three states you know about. A substance in a **solid** state has a definite shape and volume. In a **liquid** state, a substance has a definite volume but no definite shape. It takes on the shape of whatever container it is in. As a **gas**, a substance has no definite shape or volume. It takes on the shape of its container and expands or contracts to fill the container. In all three states of matter, the atoms or molecules are constantly moving.

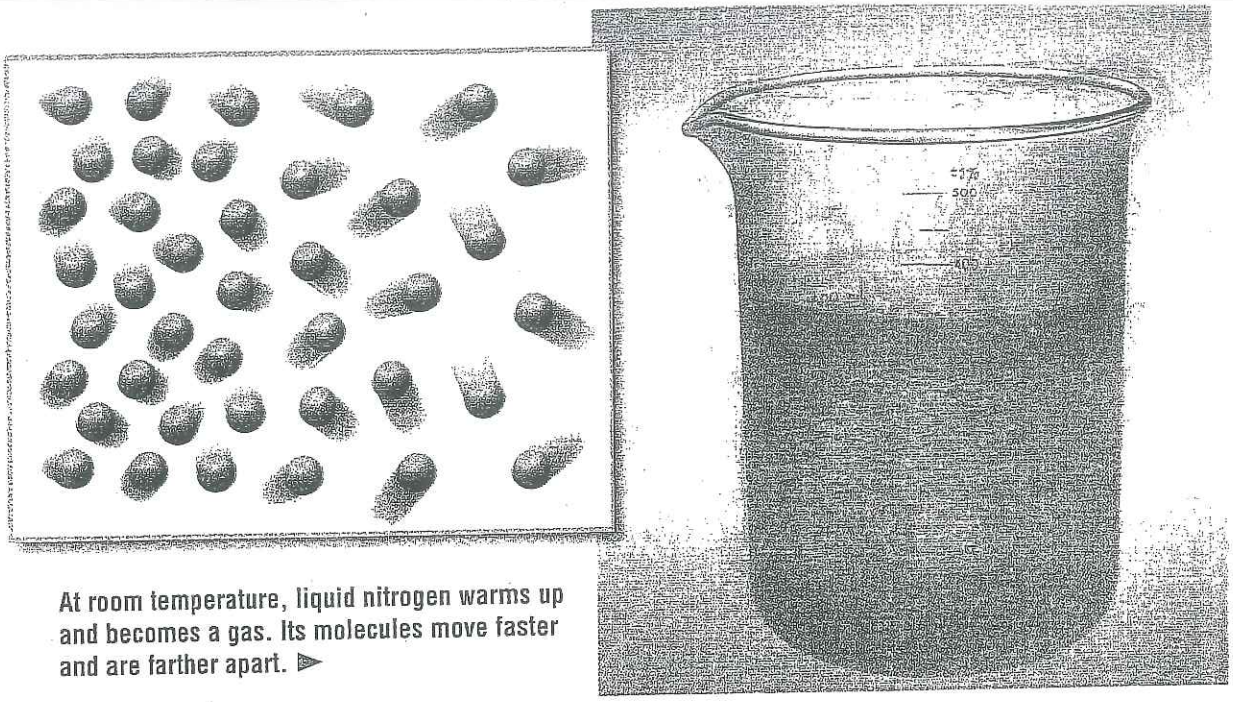
One substance that is familiar in all three states of matter is water. As a solid, it is ice. As a liquid, it is water. As a gas, it is water vapor.

Water is made up of water molecules. The way the molecules act together determines what state the water is in. The molecules in ice—a solid—are held tightly in place in a definite pattern. Although each atom vibrates, it does so in its fixed position. Since the atoms do not move from their positions, the solid has a definite shape.

In the liquid state, water molecules are not held in fixed positions. As in solids, the molecules are close together, but they can move freely, sliding over one another. This is why liquid water can flow or be poured. The closeness of the molecules, however, keeps them together and gives the water a definite volume. Like a solid, a liquid is very difficult to compress into a smaller volume.

Like liquid water, water vapor can also flow. Its molecules are farther apart from one another than in the liquid state. The molecules can move freely. They fill the container they are in, allowing the gas to take the shape of the container. Because of the space between the molecules, gases are easily compressed. In fact, a tank that's about 1.5 m (5 ft) tall with a diameter of about 0.3 m (1 ft) can hold enough compressed helium gas to fill almost a thousand balloons.

✓ **What are three states of matter?**



At room temperature, liquid nitrogen warms up and becomes a gas. Its molecules move faster and are farther apart. ►

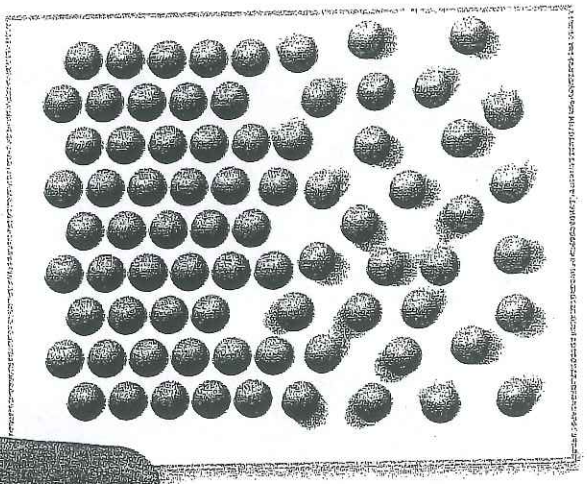
Changes of State

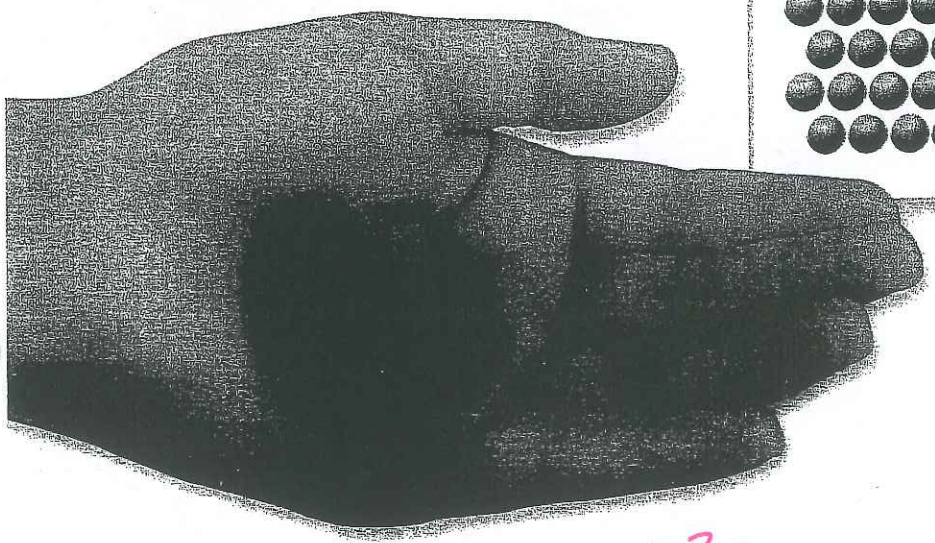
In solids, atoms and molecules of a substance vibrate in fixed positions. If energy is added, the speed of vibration increases. With enough energy, the atoms and molecules vibrate fast enough to shake apart and move more freely. The solid becomes a liquid. Adding energy can make the atoms and molecules move even faster, and the liquid becomes a gas.

Taking energy away from a substance has the opposite effect. A gas changes to a liquid and then to a solid. Most substances can exist in any of the three states of matter if enough energy is added or taken away. The changes between gas, liquid, and solid are called *changes of state.*

Usually, a change of state is caused by adding or taking away heat. If you take ice cubes out of the freezer, heat from the room is added to them and they melt. If you put a tray of water in the freezer, heat is taken away from it and it freezes.

If you put water in a pan on the stove, you can add heat to it. When the water boils, you'll probably see mist form. The mist seems to dissolve into the air. What you're seeing is water in its liquid state (the mist that you see) becoming water vapor in the air.





◄ Chocolate changes from a solid to a liquid as heat causes its particles to move faster. From this picture, what can you tell about the temperature at which chocolate melts?

The temperatures at which matter changes state vary from substance to substance. But every substance has two fixed temperatures at which it changes state.

The temperature at which a substance changes from a solid to a liquid is called its *melting point.* This is the same temperature at which the substance changes from a liquid to a solid, so it is sometimes called the freezing point.

The temperature at which a substance changes from a liquid to a gas is called its *boiling point.* This is the same temperature at which the substance condenses from a gas to a liquid.

Different substances have different melting points and boiling points. Substances with a strong attraction between their particles have melting points and boiling points that are high. Copper, for example, melts at 1083°C (about 1981°F) and boils at 2567°C (about 4652°F). Substances with a weak attraction between particles have low melting points and boiling points. Rubbing alcohol, for example, boils at 78.5°C (173.3°F). Its melting point is -117°C (-178.6°F).

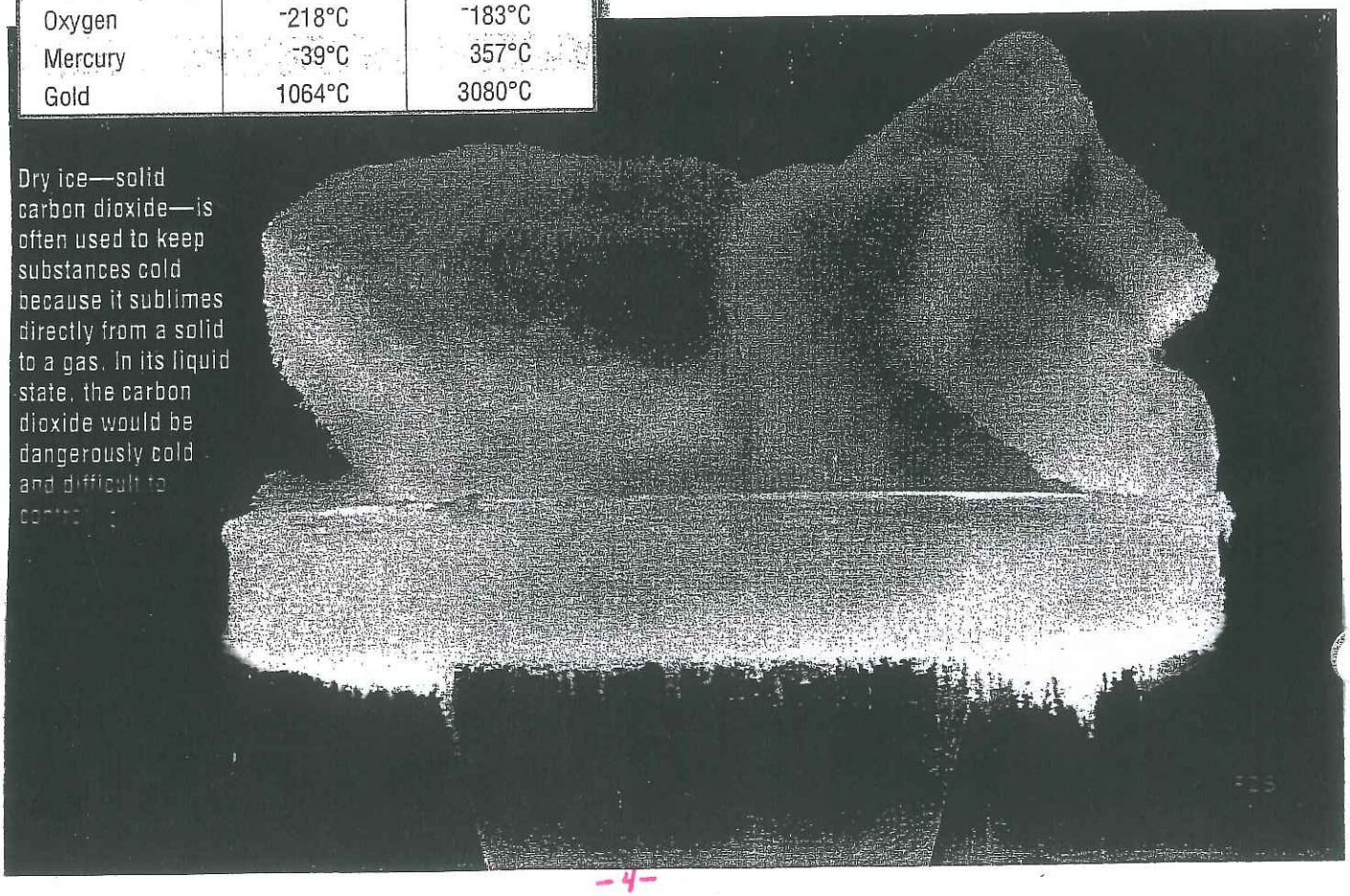
Certain substances can change states directly from solid to gas. This is called *sublimation.* Solid carbon dioxide, or dry ice, sublimes at room temperature, changing to carbon dioxide gas without becoming a liquid first.

Adding or taking away heat isn't the only way to change the state of a substance. Changes in the pressure on a substance may also cause a change of its state. Compressing a gas causes its particles to get closer to each other—possibly close enough for the gas to become a liquid. Reducing pressure can cause a liquid to boil at well below its usual boiling point. In fact, reducing the pressure enough can make water boil at its freezing point. The bubbles that form as it boils are made of ice!

✓ **When will matter undergo a change of state?**

Melting Points and Boiling Points

Substance	Melting Point	Boiling Point
Water	0°C	100°C
Sodium chloride (table salt)	801°C	1413°C
Oxygen	-218°C	-183°C
Mercury	-39°C	357°C
Gold	1064°C	3080°C



Dry ice—solid carbon dioxide—is often used to keep substances cold because it sublimes directly from a solid to a gas. In its liquid state, the carbon dioxide would be dangerously cold and difficult to contain.

Plasma

The substances you see in your everyday life are mainly solids, liquids, and gases. But those states of matter make up only a tiny fraction of the matter in the universe. Nearly all the matter in the universe, including all the stars, is in a state called *plasma*.

A plasma is a gas in which some of the electrons have been removed from the atoms or molecules. The gas has free electrons, which are negatively charged, and positively charged ions. The gas as a whole is electrically neutral, since it contains equal numbers of positive and negative charges. Unlike gases, plasmas readily conduct electricity.

The stars, including our sun, are composed of plasma because of their temperatures. Stars have such high temperatures that electrons are removed from the atoms in the gases that the stars are made of. Plasma can be made on Earth, too, by heating gases. At temperatures greater than 2000°C (about 3632°F), water vapor changes to plasma.

Natural plasmas can be seen on Earth in lightning and in the northern lights. The electric energy of lightning produces plasma in the air that it travels through. The northern lights are seen when electrons from outer space bombard layers of low-temperature plasmas in the upper atmosphere. A plasma that you can see close up is in the inner core of flames.

Fluorescent lights, neon signs, and the vapor lamps in street lights also form plasmas inside their bulbs. The electricity flowing through gases in these lamps removes electrons from some of the atoms, causing the atoms to give off light.

Lighting isn't the only practical use of plasmas. Plasmas are used to make computer chips. They are used in some types of welding to join steel. Scientists are trying to find a new power source by causing fusion—or joining—of nuclei in plasmas.

✓ **What is plasma?**

The core of a fire and the stars in the sky are both examples of plasma.

Summary

The atoms in some substances join to form molecules whose electrons are attracted to the nucleus of more than one atom. The way that particles of matter act together determines whether the state of the matter is solid, liquid, or gas. Changes of state are generally caused by heat or changes in pressure. The fourth state of matter—plasma—is a gas with free electrons and positive ions.

Review

1. What is a molecule?
2. Why do liquids flow but solids do not?
3. What change occurs when a substance is heated to its boiling point?
4. **Critical Thinking** In hydraulic machines a liquid that has filled a pipe is pushed at one end of the pipe. The liquid then pushes a machine part located at the other end of the pipe. Why isn't gas used in the pipe instead of liquid?
5. **Test Prep** Most of the matter in the universe exists as —

   A a solid C a gas

   B a liquid D a plasma

LINKS

MATH LINK

Volume A gas expands to fill its container. Suppose a helium gas tank is a cylinder with a radius of 7 cm and a height of 100 cm. What is the volume of the gas when the tank is full? When it's half full? (Note: The volume of a cylinder is found using the formula $V = \pi r^2 h$ where r is the radius and h is the height of the cylinder. Use $\pi = \frac{22}{7}$.)

WRITING LINK

Expressive Writing—Poem Read "Stopping by Woods on a Snowy Evening," a poem in which Robert Frost describes snow. Then write a poem of your own for your classmates that describes one of the states of water.

SOCIAL STUDIES LINK

Communities Find out how water, in each of its three states, is both helpful and harmful in a community. What do communities do to protect their environments from too much water (in different states of matter)?

TECHNOLOGY LINK

Visit the Harcourt Learning Site for related links, activities, and resources.
www.harcourtschool.com