Section 1

Four States of Matter

Terms to Learn

states of matter	pressure
solid	Boyle's law
liquid	Charles's law
gas	plasma

What You'll Do

- Describe the properties shared by particles of all matter.
- Describe the four states of matter discussed here.
- Describe the differences between the states of matter.
- Predict how a change in pressure or temperature will affect the volume of a gas.

Figure 1 shows a model of the earliest known steam engine, invented about A.D. 60 by Hero, a scientist who lived in Alexandria, Egypt. This model also demonstrates the four most familiar states of matter: solid, liquid, gas, and plasma. The **states of matter** are the physical forms in which a substance can exist. For example, water commonly exists in three different states of matter: solid (ice), liquid (water), and gas (steam).

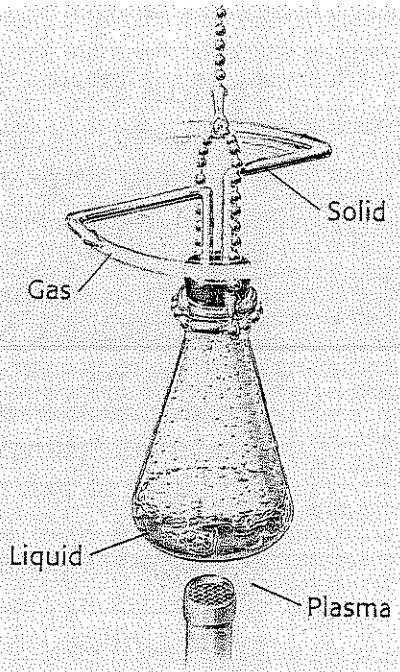
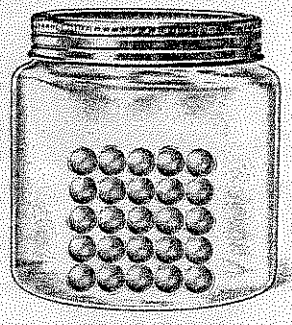


Figure 1 *This model of Hero's steam engine spins as steam escapes through the nozzles.*

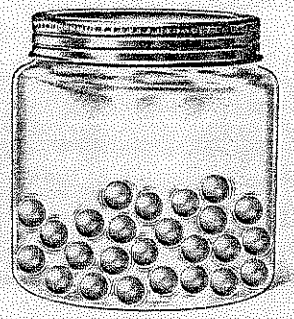
Moving Particles Make Up All Matter

Matter consists of tiny particles called atoms and molecules (MAHL i KYOOLZ) that are too small to see without an amazingly powerful microscope. These atoms and molecules are always in motion and are constantly bumping into one another. The state of matter of a substance is determined by how fast the particles move and how strongly the particles are attracted to one another. **Figure 2** illustrates three of the states of matter—solid, liquid, and gas—in terms of the speed and attraction of the particles.

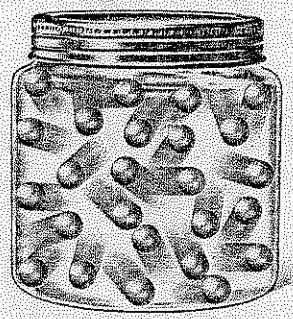
Figure 2 Models of a Solid, a Liquid, and a Gas



Particles of a solid do not move fast enough to overcome the strong attraction between them, so they are held tightly in place. The particles vibrate in place.



Particles of a liquid move fast enough to overcome some of the attraction between them. The particles are able to slide past one another.



Particles of a gas move fast enough to overcome nearly all of the attraction between them. The particles move independently of one another.

4

Solids Have Definite Shape and Volume

Look at the ship in **Figure 3.** Even in a bottle, it keeps its original shape and volume. If you moved the ship to a larger bottle, the ship's shape and volume would not change. Scientifically, the state in which matter has a definite shape and volume is **solid.** The particles of a substance in a solid are very close together. The attraction between them is stronger than the attraction between the particles of the same substance in the liquid or gaseous state. The atoms or molecules in a solid move, but not fast enough to overcome the attraction between them. Each particle vibrates in place because it is locked in position by the particles around it.

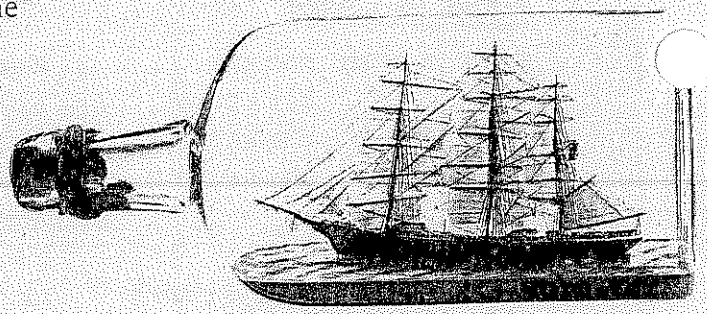


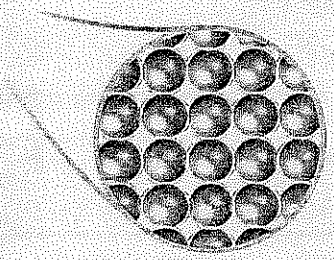
Figure 3 *Because this ship is a solid, it does not take the shape of the bottle.*

Two Types of Solids Solids are often divided into two categories—*crystalline* and *amorphous* (uh MOHR fuhs). Crystalline solids have a very orderly, three-dimensional arrangement of atoms or molecules. That is, the particles are arranged in a repeating pattern of rows. Examples of crystalline solids include iron, diamond, and ice. Amorphous solids are composed of atoms or molecules that are in no particular order. That is, each particle is in a particular spot, but the particles are in no organized pattern. Examples of amorphous solids include rubber and wax. **Figure 4** illustrates the differences in the arrangement of particles in these two solids.

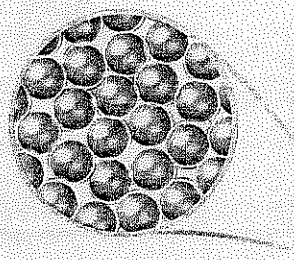
Activity

Imagine that you are a particle in a solid. Your position in the solid is your chair. In your ScienceLog, describe the different types of motion that are possible even though you cannot leave your chair.

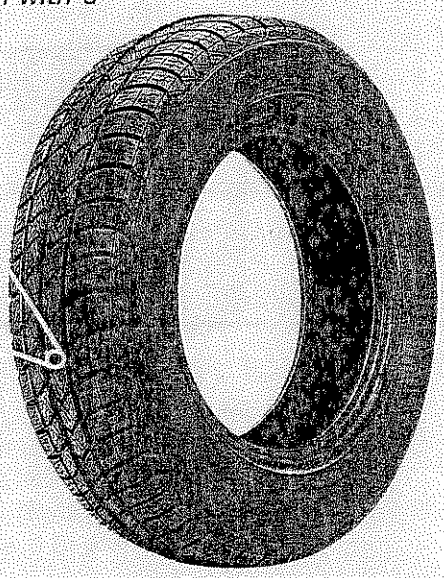
Figure 4 *Differing arrangements of particles in crystalline solids and amorphous solids lead to different properties. Imagine trying to hit a home run with a rubber bat!*



The particles in a **crystalline solid** have a very orderly arrangement.



The particles in an **amorphous solid** do not have an orderly arrangement.



Liquids Change Shape but Not Volume

A liquid will take the shape of whatever container it is put in. You are reminded of this every time you pour yourself a glass of juice. The state in which matter takes the shape of its container and has a definite volume is **liquid.** The atoms or molecules in liquids move fast enough to overcome some of the attractions between them. The particles slide past each other until the liquid takes the shape of its container. **Figure 5** shows how the particles in juice might look if they were large enough to see.

Even though liquids change shape, they do not readily change volume. You know that a can of soda contains a certain volume of liquid regardless of whether you pour it into a large container or a small one. **Figure 6** illustrates this point using a beaker and a graduated cylinder.

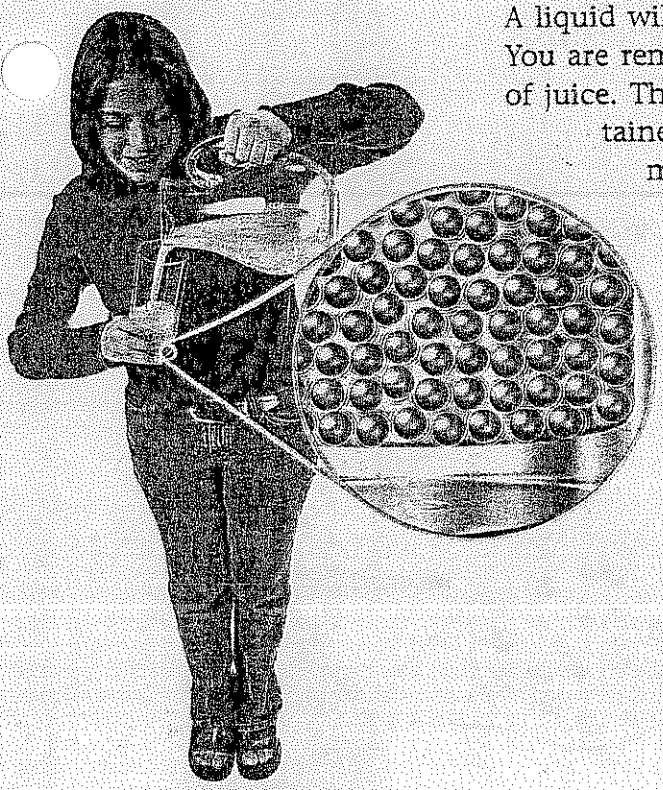
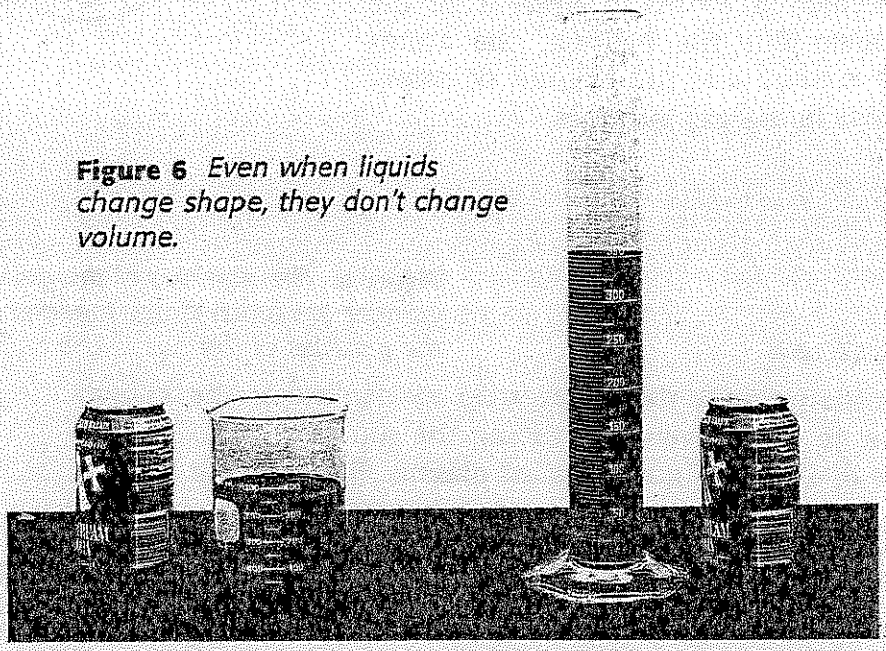


Figure 5 *Particles in a liquid slide past one another until the liquid conforms to the shape of its container.*

Figure 6 *Even when liquids change shape, they don't change volume.*



Gases Change Both Shape and Volume

How many balloons can be filled from a single metal cylinder of helium? The number may surprise you. One cylinder can fill approximately 700 balloons. How is this possible? After all, the volume of the metal cylinder is equal to the volume of only about five inflated balloons.

It's a Gas! Helium is a gas. **Gas** is the state in which matter changes in both shape and volume. The atoms or molecules in a gas move fast enough to break away completely from one another. Therefore, the particles of a substance in the gaseous state have less attraction between them than particles of the same substance in the solid or liquid state. In a gas, there is empty space between particles.

The amount of empty space in a gas can change. For example, the helium in the metal cylinder consists of atoms that have been forced very close together, as shown in **Figure 8.** As the helium fills the balloon, the atoms spread out, and the amount of empty space in the gas increases.

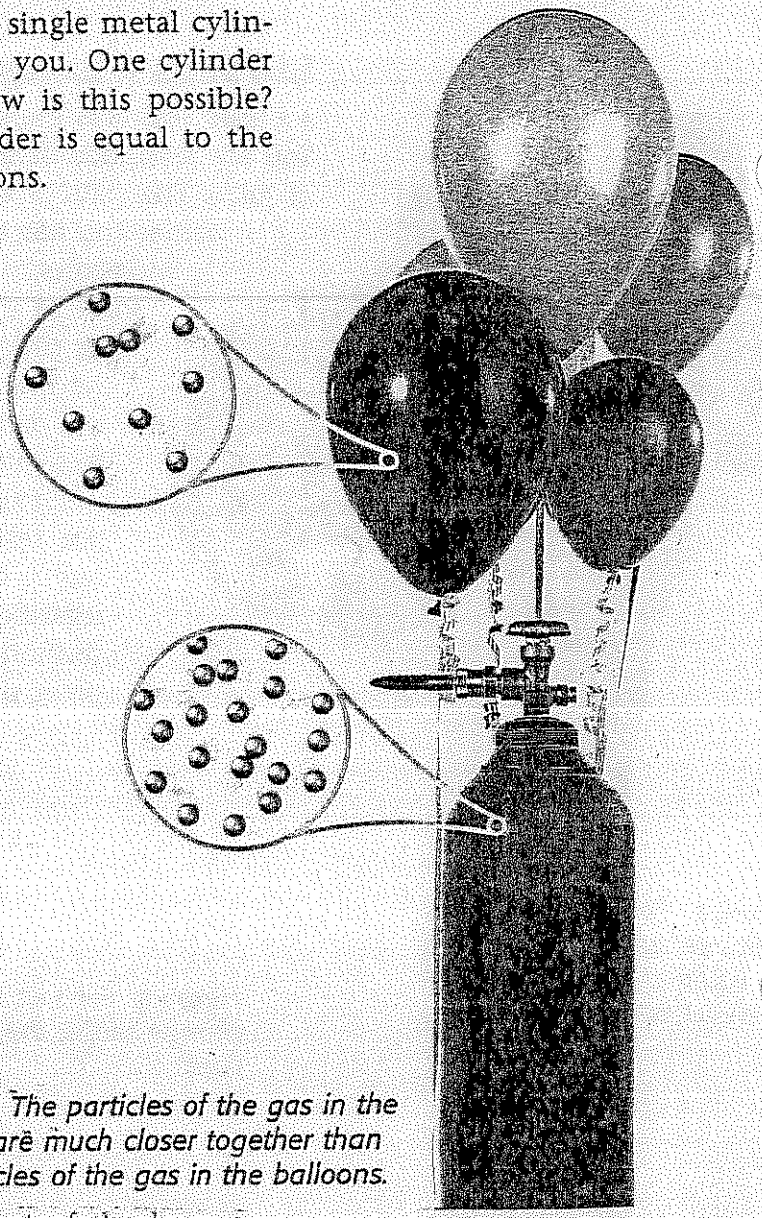


Figure 8 *The particles of the gas in the cylinder are much closer together than the particles of the gas in the balloons.*

Plasmas

Scientists estimate that more than 99 percent of the known matter in the universe, including the sun and other stars, is made of a state of matter called plasma. **Plasma** is the state of matter that does not have a definite shape or volume and whose particles have broken apart.

Plasmas have some properties that are quite different from the properties of gases. Plasmas conduct electric current, while gases do not. Electric and magnetic fields affect plasmas but do not affect gases. In fact, strong magnetic fields are used to contain very hot plasmas that would destroy any other container.

Natural plasmas are found in lightning, fire, and the incredible light show in **Figure 12,** called the aurora borealis (ah ROHR uh BOHR ee AL is). Artificial plasmas, found in fluorescent lights and plasma balls, are created by passing electric charges through gases.

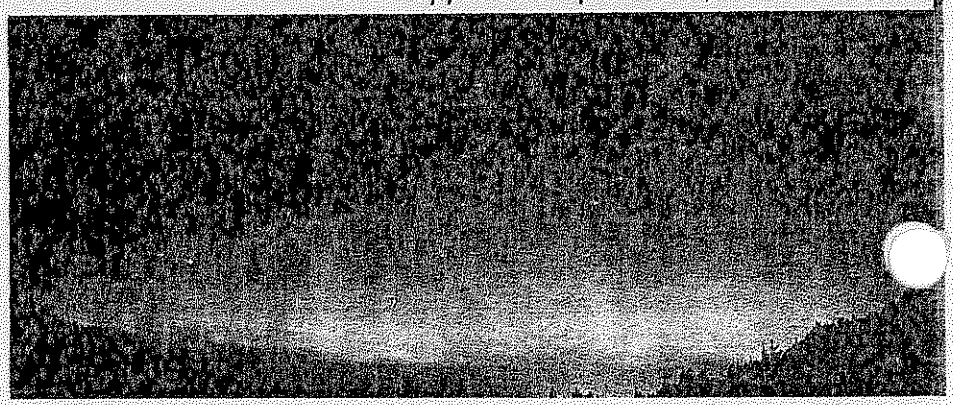


Figure 12 *Auroras, like the aurora borealis seen here, form when high-energy plasma collides with gas particles in the upper atmosphere.*