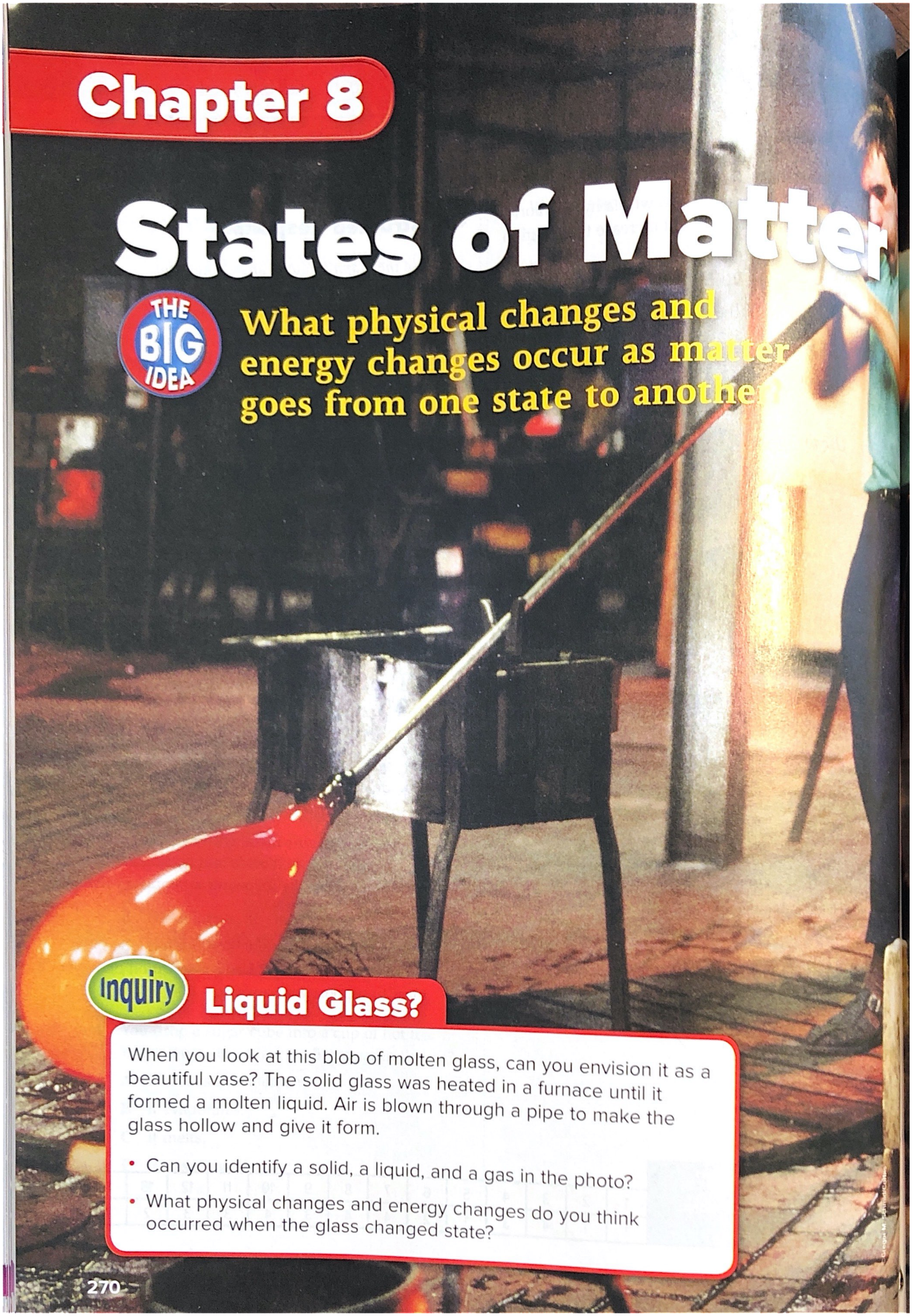
Chapter 8

States of Matter



THE BIG IDEA What physical changes and energy changes occur as matter goes from one state to another?

Inquiry Liquid Glass?

When you look at this blob of molten glass, can you envision it as a beautiful vase? The solid glass was heated in a furnace until it formed a molten liquid. Air is blown through a pipe to make the glass hollow and give it form.

- Can you identify a solid, a liquid, and a gas in the photo?
- What physical changes and energy changes do you think occurred when the glass changed state?

Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Particles moving at the same speed make up all matter.
2. The particles in a solid do not move.
3. Particles of matter have both potential energy and kinetic energy.
4. When a solid melts, thermal energy is removed from the solid.
5. Changes in temperature and pressure affect gas behavior.
6. If the pressure on a gas increases, the volume of the gas also increases.

Lesson 1

Reading Guide

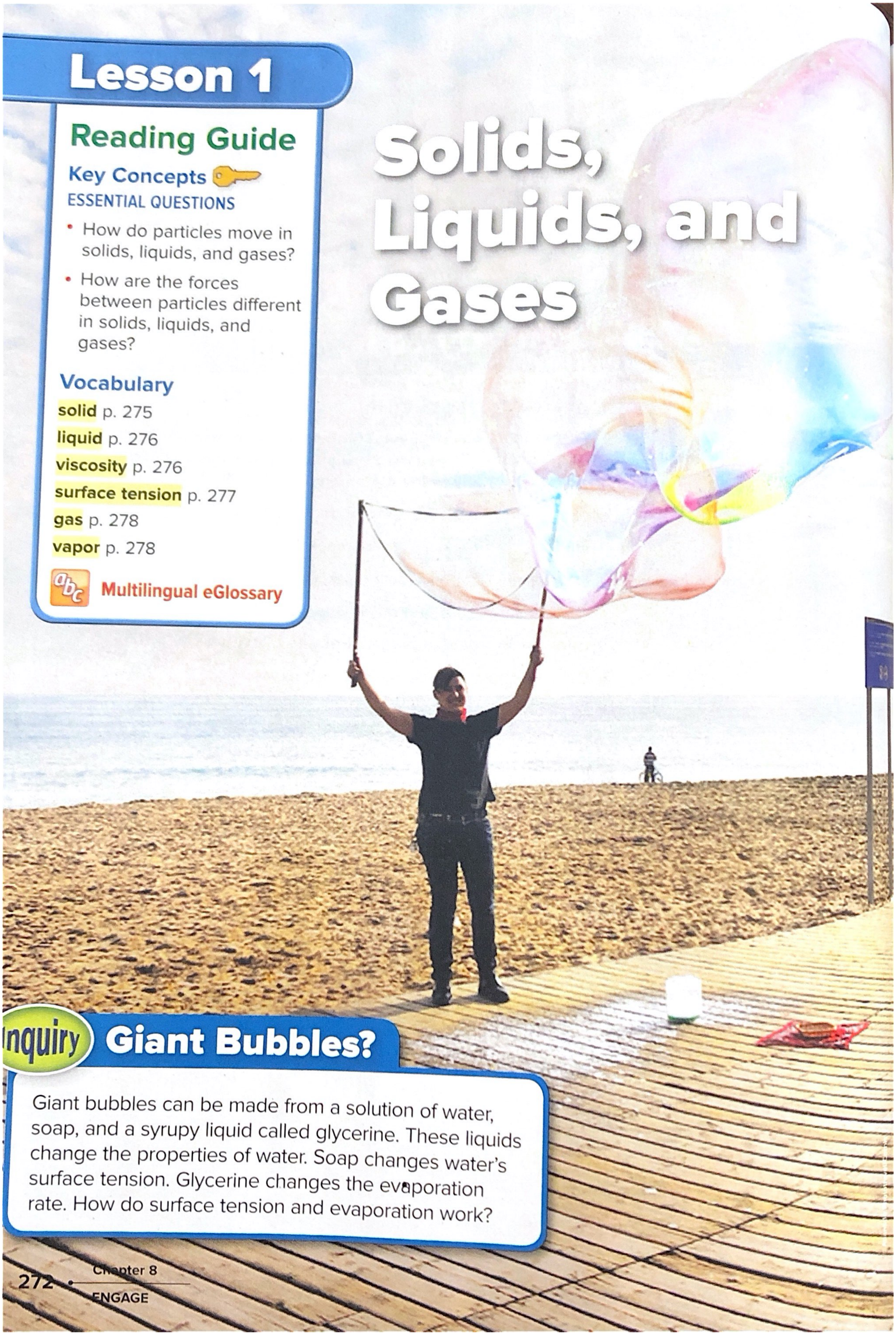
Key Concepts
ESSENTIAL QUESTIONS

- How do particles move in solids, liquids, and gases?
- How are the forces between particles different in solids, liquids, and gases?

Vocabulary
solid p. 275
liquid p. 276
viscosity p. 276
surface tension p. 277
gas p. 278
vapor p. 278

Multilingual eGlossary

Solids, Liquids, and Gases



Inquiry Giant Bubbles?

Giant bubbles can be made from a solution of water, soap, and a syrupy liquid called glycerine. These liquids change the properties of water. Soap changes water's surface tension. Glycerine changes the evaporation rate. How do surface tension and evaporation work?

Launch Lab

10 minutes

How can you see particles in matter?

It's sometimes difficult to picture how tiny objects, such as the particles that make up matter, move. However, you can use other objects to model the movement of these particles.

1. Read and complete a lab safety form.
2. Place about 50 **copper pellets** into a **plastic petri dish.** Place the cover on the dish, and secure it with **tape.**
3. Hold the dish by the edges. Gently vibrate the dish from side to side no more than 1–2 mm. Observe the pellets. Record your observations in your Science Journal.
4. Repeat step 3, vibrating the dish less than 1 cm from side to side.
5. Repeat step 3, vibrating the dish 3–4 cm from side to side.

Think About This

1. If the pellets represent particles in matter, what do you think the shaking represents?
2. In which part of the experiment do you think the pellets were like a liquid? Explain.
3. **Key Concept** If the pellets represent molecules of water, what do you think are the main differences among molecules of ice, water, and vapor?

Describing Matter

Take a closer look at the photo on the previous page. Do you see **matter?** The three most common forms, or states, of matter on Earth are solids, liquids, and gases. The giant bubble contains air, which is a mixture of gases. The ocean water and the soap mixture used to make the bubble are liquids. The sand, sign, and walkway are a few of the solids in the photo.

Review Vocabulary

matter
anything that takes up space and has mass

There is a fourth state of matter, plasma, that is not shown in this photo. Plasma is high-energy matter consisting of positively and negatively charged particles. Plasma is the most common state of matter in space. It also is in lightning flashes, fluorescent lighting, and stars, such as the Sun.

There are many ways to describe matter. You can describe the state, the color, the texture, and the odor of matter using your senses. You also can describe matter using measurements, such as mass, volume, and density. Mass is the amount of matter in an object. The units for mass are often grams (g) or kilograms (kg). Volume is the amount of space that a sample of matter occupies. The units for liquid volume are usually liters (L) or milliliters (mL). The units for solid volume are usually cubic centimeters (cm^3) or cubic meters (m^3). Density is the mass per unit volume of a substance. The units are usually g/cm^3 or g/mL. Density of a given substance remains constant, regardless of the size of the sample.

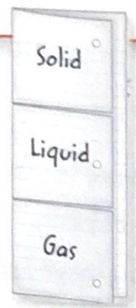
Particles in Motion

Have you ever wondered what makes something a solid, a liquid, or a gas? Two main factors that determine the state of matter are particle motion and particle forces.

Particles, such as atoms, ions, or molecules, moving in different ways make up all matter. The particles that make up some matter are close together and vibrate back and forth. In other types of matter, the particles are farther apart, move freely, and can spread out. Regardless of how close particles are to each other, they all move in random motion–movement in all directions and at different speeds. However, particles will move in straight lines until they collide with something. Collisions change the speed and direction of the particles' movements.

FOLDABLES®

Use a sheet of notebook paper to make a three-tab Foldable as shown. Record information about each state of matter under the tabs.



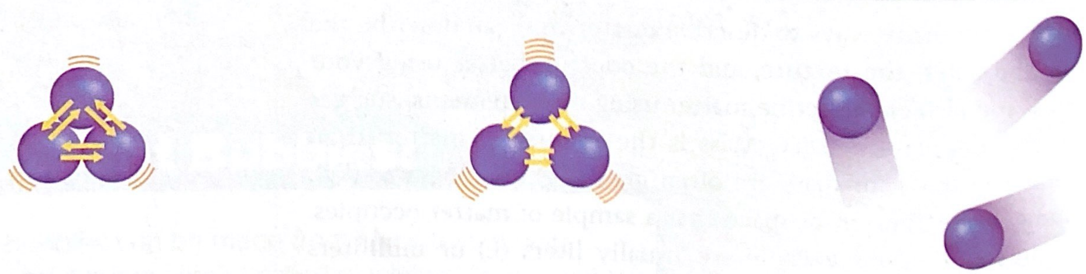
Forces Between Particles

Recall that atoms that make up matter contain positively charged protons and negatively charged electrons. There is a force of attractions between these oppositely charged particles, as shown in **Figure 1**.

You just read that the particles that make up matter move at all speeds and in all directions. If the motion of particles slows, the particles move closer together. This is because the attraction between them pulls them toward each other. Strong attractive forces hold particles close together. As the motion of particles increases, particles move farther apart. The attractive forces between particles get weaker. The spaces between them increase and the particles can slip past one another. As the motion of particles continues to increase, they move even farther apart. Eventually, the distance between particles is so great that there are little or no attractive forces between the particles. The particles move randomly and spread out. As you continue to read, you will learn how particle motion and particle forces determine whether matter is a solid, a liquid, or a gas.

Figure 1 The forces between particles of matter and the movement of particles determine the physical state of matter.

Animation



Particles move slowly and can only vibrate in place. Therefore, the attractive forces between particles are strong.

Particles move faster and slip past each other. The distance between particles increases. Therefore, the attractive forces between particles are weaker.

Particles move fast. The distance between the particles is great, and therefore, the attractive forces between particles are very weak.

Solids

If you had to describe a solid, what would you say? You might say, a **solid** *is matter that has a definite shape and a definite volume.* For example, if the skateboard in **Figure 2** moves from one location to another, the shape and volume of it do not change.

Particles in a Solid

Why doesn't a solid change its shape and volume? Notice in **Figure 2** how the particles in a solid are close together. The particles are very close to their neighboring particles. That's because the attractive forces between the particles are strong and hold them close together. The strong attractive forces and slow motion of the particles keep them tightly held in their positions. The particles simply vibrate back and forth in place. This arrangement gives solids a definite shape and volume.

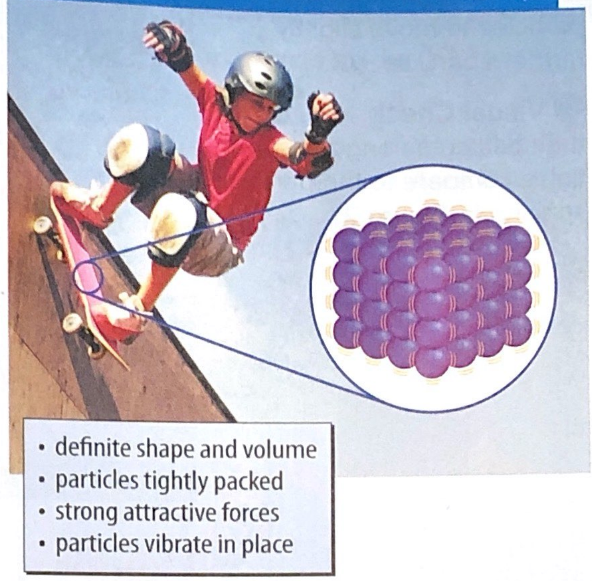
Key Concept Check Describe the movement of particles in a solid and the forces between them.

Types of Solids

All solids are not the same. For example, a diamond and a piece of charcoal don't look alike. However, they are both solids made of only carbon atoms. A diamond and a lump of charcoal both contain particles that strongly attract each other and vibrate in place. What makes them different is the arrangement of their particles. Notice in **Figure 3** that the arrangement of particles in a diamond is different from that in charcoal. A diamond is a crystalline solid. It has particles arranged in a specific, repeating order. Charcoal is an amorphous solid. It has particles arranged randomly. Different particle arrangements give these materials different properties. For example, a diamond is a hard material, and charcoal is a brittle material.

Reading Check What is the difference between crystalline and amorphous solids?

Solid Particle Movement



▲ **Figure 2** The particles in a solid have strong attractive forces and vibrate in place.

Figure 3 Carbon is a solid that can have different particle arrangements. ▼

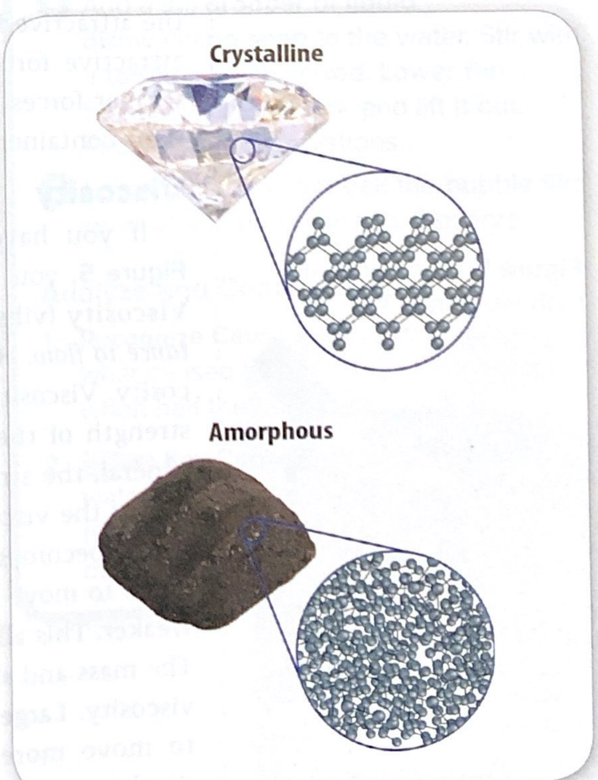
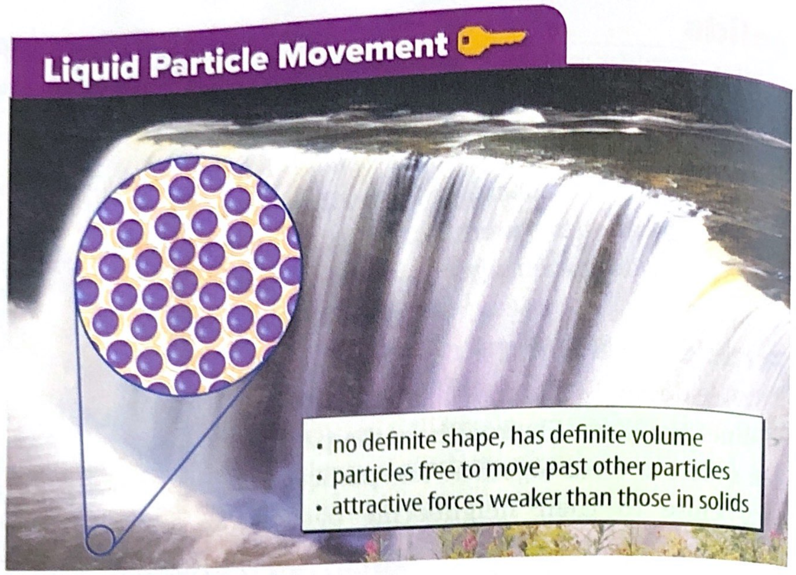


Figure 4 The motion of particles in a liquid causes the particles to move slightly farther apart. ▶

Visual Check How does the spacing among these particles compare to the particle spacing in **Figure 2?**



Liquids

You have probably seen a waterfall, such as the one in **Figure 4.** Water is a liquid. A **liquid** *is matter with a definite volume but no definite shape.* Liquids flow and can take the shape of their containers. The container for this water is the riverbed.

Particles in a Liquid

How can liquids change their shape? The particle motion in the liquid state of a material is faster than the particle motion in the solid state. This increased particle motion causes the particles to move slightly farther apart. As the particles move farther apart, the attractive forces between the particles decrease. The weaker attractive forces allow particles to slip past one another. The weaker forces also enable liquids to flow and take the shape of their containers.

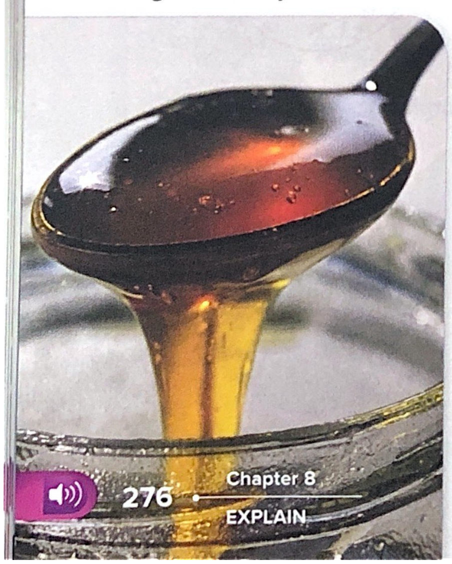
WORD ORIGIN

viscosity
from Latin *viscum,* means "sticky"

Viscosity

If you have ever poured or dipped honey, as shown in **Figure 5,** you have experienced a liquid with a high viscosity. **Viscosity** (vihs KAW sih tee) *is a measurement of a liquid's resistance to flow.* Honey has high viscosity, while water has low viscosity. Viscosity is due to particle mass, particle shape, and the strength of the attraction between the particles of a liquid. In general, the stronger the attractive forces between particles, the higher the viscosity. For many liquids, viscosity decreases as the liquid becomes warmer. As a liquid becomes warmer, particles begin to move faster and the attractive forces between them get weaker. This allows particles to more easily slip past one another. The mass and shape of particles that make up a liquid also affect viscosity. Large particles or particles with complex shapes tend to move more slowly and have difficulty slipping past one another.

Figure 5 Honey has a high viscosity. ▼



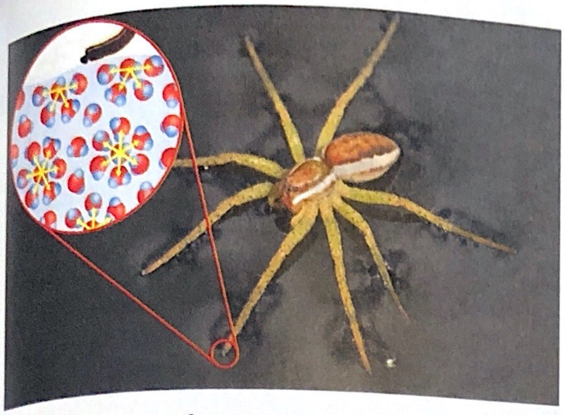


Figure 6 The surface tension of water enables this spider to walk on the surface of a lake.

Surface Tension

How can the nursery web spider in Figure 6 walk on water? Believe it or not, it is because of the interactions between molecules.

The blowout in Figure 6 shows the attractive forces between water molecules. Water molecules below the surface are surrounded on all sides by other water molecules. Therefore, they have attractive forces, or pulls, in all directions. The attraction between similar molecules, such as water molecules, is called cohesion.

Water molecules at the surface of a liquid do not have liquid water molecules above them. As a result, they experience a greater downward pull, and the surface particles become tightly stretched like the head of a drum. Molecules at the surface of a liquid have **surface tension,** *the uneven forces acting on the particles on the surface of a liquid.* Surface tension allows a spider to walk on water. In general, the stronger the attractive forces between particles, the greater the surface tension of the liquid.

Recall the giant bubbles at the beginning of the chapter. The thin water-soap film surrounding the bubbles forms because of surface tension between the particles.

Key Concept Check Describe the movement of particles in a liquid and the forces between them.

MiniLab

20 minutes

How can you make bubble films?

Have you ever observed surface tension? Which liquids have greater surface tension?

1. Read and complete a lab safety form.
2. Place about 100 mL of cool water in a **small bowl.** Lower a **wire bubble frame** into the bowl, and gently lift it. Use a **magnifying lens** to observe the edges of the frame. Write your observations in your Science Journal.
3. Add a full **dropper** of **liquid dishwashing soap** to the water. Stir with a **toothpick** until mixed. Lower the frame into the mixture and lift it out. Record your observations.
4. Use a toothpick to break the bubble film on one side of the thread. Observe.

Analyze and Conclude

1. **Recognize Cause and Effect** Explain what caused the thread to form an arc when half the bubble film broke.
2. **Key Concept** Explain why pure water doesn't form bubbles. What happens to the forces between water molecules when you add soap?

Gas Particle Movement

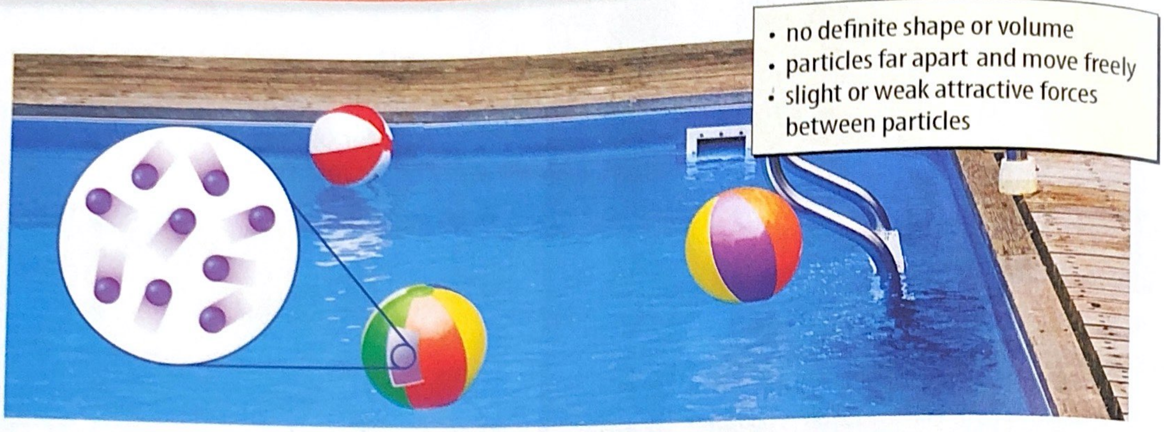


Figure 7 The particles in a gas are far apart, and there are little or no attractive forces between particles.

Visual Check What are gas particles likely to hit as they move?

Gases

Look at the photograph in **Figure 7**. Where is the gas? *A* **gas** *is matter that has no definite volume and no definite shape.* It is not easy to identify the gas because you cannot see it. However, gas particles are inside and outside the inflatable balls. Air is a mixture of gases, including nitrogen, oxygen, argon, and carbon dioxide.

Reading Check What is a gas, and what is another object that contains a gas?

Particles in a Gas

Why don't gases have definite volumes or definite shapes like solids and liquids? Compare the particles in **Figures 2, 4,** and **7.** Notice how the distance between particles differs. As the particles move faster, such as when matter goes from the solid state to the liquid state, the particles move farther apart. When the particles in matter move even faster, such as when matter goes from the liquid state to the gas state, the particles move even farther apart. When the distances between particles change, the attractive forces between the particles also change.

Forces Between Particles

As a type of matter goes from the solid state to the liquid state, the distance between the particles increases and the attractive forces between the particles decrease. When the same matter goes from the liquid state to the gas state, the particles are even farther apart and the attractive forces between the particles are weak or absent. As a result, the particles spread out to fill their container. Because gas particles lack attractive forces between particles, they have no definite shape or definite volume.

Vapor

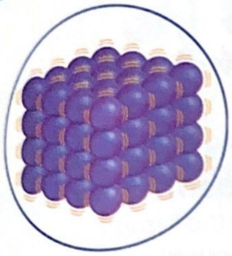
Have you ever heard the term *vapor*? *The gas state of a substance that is normally a solid or a liquid at room temperature is called* **vapor**. For example, water is normally a liquid at room temperature. When it is in a gas state, such as in air, it is called water vapor. Other substances that can form a vapor are rubbing alcohol, iodine, mercury, and gasoline.

Key Concept Check How do particles move and interact in a gas?

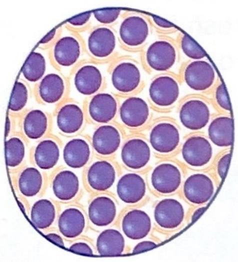
Lesson 1 Review

Online Quiz

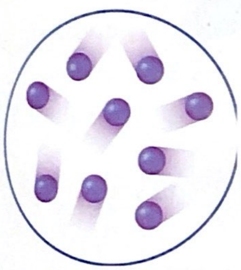
Visual Summary



The particles that make up a solid can only vibrate in place. The particles are close together, and there are strong forces among them.



The particles that make up a liquid are far enough apart that particles can flow past other particles. The forces among these particles are weaker than those in a solid.



The particles that make up a gas are far apart. There is little or no attraction between the particles.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Particles moving at the same speed make up all matter.
2. The particles in a solid do not move.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

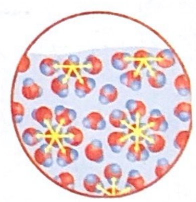
1. A measurement of how strongly particles attract one another at the surface of a liquid is ________.
2. **Define** *solid, liquid,* and *gas* in your own words.
3. A measurement of a liquid's resistance to flow is known as ________.

Understand Key Concepts

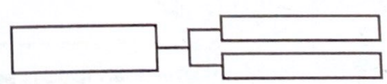
4. Which state of matter rarely is found on Earth?
   - **A.** gas
   - **B.** liquid
   - **C.** plasma
   - **D.** solid
5. **Compare** particle movement in solids, liquids, and gases.
6. **Compare** the forces between particles in a liquid and in a gas.

Interpret Graphics

7. **Explain** why the particles at the surface in the image below have surface tension while the particles below the surface do not.



8. **Summarize** Copy and fill in the graphic organizer to compare two types of solids.



Critical Thinking

9. **Hypothesize** how you could change the viscosity of a cold liquid, and explain why your idea would work.
10. **Summarize** the relationship between the motion of particles and attractive forces between particles.

HOW IT WORKS

Freeze-Drying Foods

Have you noticed that the berries you find in some breakfast cereals are lightweight and dry—much different from the berries you get from the market or the garden?

Fresh fruit would spoil quickly if it were packaged in breakfast cereal, so fruits in cereals are often freeze-dried. When liquid is returned to the freeze-dried fruit, its physical properties more closely resemble fresh fruit. Freeze-drying, or lyophilization (lie ah fuh luh ZAY shun), is the process in which a solvent (usually water) is removed from a solid. During this process, a frozen solvent changes to a gas without going through the liquid state. Freeze-dried foods are lightweight and long-lasting. Astronauts have been using freeze-dried food during space travel since the 1960s.

How Freeze-Drying Works

1 Machines called freeze-dryers are used to freeze-dry foods and other products. Fresh or cooked food is flash-frozen, changing moisture in the food to a solid.

2 The frozen food is placed in a large vacuum chamber, where moisture is removed. Heat is applied to accelerate moisture removal. Condenser plates remove vaporized solvent from the chamber and convert the frozen food to a freeze-dried solid.

3 Freeze-dried food is sealed in oxygen- and moisture-proof packages to ensure stability and freshness. When the food is rehydrated, it returns to its near-normal state of weight, color, and texture.

It's Your Turn

PREDICT/DISCOVER What kinds of products besides food are freeze-dried? Use library or internet resources to learn about other products that undergo the freeze-drying process. Discuss the benefits or drawbacks of freeze-drying.