Recall that matter is anything that has mass and there are properties to consider when selecting a sample, not the amount of matter.

**Intensive Properties**

Extensive Properties

Recall that matter is anything that has mass and takes up space. The **mass** of an object is a measure of the amount of matter the object contains. The mass of a bowling ball with finger holes is five or six times greater than the mass of the bowling ball shown in Figure 2.1, which is used to play a game called candlepins. There is also a difference in the volume of the balls. The **volume** of an object is a measure of the space occupied by the object. Mass and volume are examples of extensive properties. An **extensive property** is a property that depends on the amount of matter in a sample.

Intensive Properties

There are properties to consider when selecting a bowling ball other than mass. Beginning bowlers want a bowling ball that is likely to maintain a straight path. They use bowling balls with a hard surface made from polyester. Experienced bowlers want a bowling ball they can curve, or hook, toward the pins. Often, they use a polyurethane ball, which has a softer surface. Hardness is an example of an intensive property. An **intensive property** is a property that depends on the type of matter in a sample, not the amount of matter.

**Figure 2.1** This bowling ball and candlepin are used in a game played mainly in New England.

Understanding matter begins with observation and what you observe in a sample, not the amount of matter. An **intensive property** is a property that depends on the type of matter in a sample, not the amount of matter. An **extensive property** is a property that depends on the amount of matter in a sample.

Properties used to describe matter can be classified as extensive or intensive.

**Describing Matter**

The more than 1200 species of bamboo belong to a family of grasses that includes wheat and corn. In tropical regions, bamboo plants grow rapidly to great heights. The tender shoots of some bamboo plants are a favorite food of pandas. People use the woody stems of mature plants to make furniture, fishing rods, and flooring. Because bamboo is inexpensive and abundant, disposable chopsticks are usually made from bamboo. Bamboo has properties that make it a good choice for use in chopsticks. It has no noticeable odor or taste. It is hard, yet easy to split, and it is heat resistant. In this section, you will learn how properties can be used to classify and identify matter.

**Connecting to Your World**

Imagine a Picture  Before students read this section, have them visualize the structure of solids, liquids, and gases at the microscopic level. Then have them compare their mental pictures with the drawings in Figure 2.3.

Active Comprehension  Read the first paragraph of Describing Matter. Ask students what they would like to know about extensive and intensive properties. Students can look for answers as they read the rest of Describing Matter.

**Guide for Reading**

**Key Concepts**

- How can properties used to describe matter be classified?
- Why do all samples of a substance have the same intensive properties?
- What are three states of matter?
- How can physical changes be classified?

**Vocabulary**

- mass
- volume
- extensive property
- intensive property
- substance
- physical property
- solid
- liquid
- gas
- vapor
- physical change

**Reading Strategy**

**Using Prior Knowledge**  Before you read, write a definition for the term **liquid**. After you read this section, compare and contrast the definition of liquid in the text with your original definition.

Tell students that the characters on the chopsticks translate as good fortune, prosperity, longevity, and good health. **Why are bamboo chopsticks usually disposable?** (Bamboo is inexpensive and abundant.) **What characteristic makes bamboo useful for cooking tools?** (It is heat resistant.)

**Section Resources**

**Print**

- **Guided Reading and Study Workbook, Section 2.1**
- **Core Teaching Resources, Section 2.1 Review**
- **Transparencies, T10-T11**

**Technology**

- **Interactive Textbook with ChemASAP, Animation 1, Assessment 2.1**
- **Go Online, Section 2.1**
Volume and Mass

**Purpose** Students observe that air takes up space and has mass.

**Materials** plastic syringe (50 mL or larger), balance that reads to 0.01 g, Erlenmeyer flask with tightly fitting 1-hole rubber stopper, funnel, water

**Procedure** Ask students whether or not air takes up space and has mass. Determine the mass of the empty syringe. Then determine the mass when the syringe is full of air. Subtract the two masses to find the mass of air in the syringe. Fit a stopper and funnel into an Erlenmeyer flask. The equipment must be airtight. Quickly pour water through the funnel.

**Expected Outcome** The mass of the air will be about 0.06 g. Some water will run into the flask (air can be compressed), but not very much, because air takes up the space in the flask.

### Identifying Substances

**(Use Visuals)**

**Table 2.1** Ask, What is the relationship between the state of a substance at room temperature and its boiling point? (Substances that are gases at room temperature have boiling points below 20°C; liquids and solids have boiling points above 20°C.) Are the properties listed in the table intensive or extensive? (intensive)

**FYI**

Some texts use *substance* to describe all materials and *pure substance* to describe elements and compounds. In this text, *substance* and *pure substance* are synonyms. A sample of matter can be described as pure if the amount of impurities in the sample is negligible.

**Table 2.1**

<table>
<thead>
<tr>
<th>Substance</th>
<th>State</th>
<th>Color</th>
<th>Melting point (°C)</th>
<th>Boiling point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neon</td>
<td>gas</td>
<td>colorless</td>
<td>−249</td>
<td>−246</td>
</tr>
<tr>
<td>Oxygen</td>
<td>gas</td>
<td>colorless</td>
<td>−218</td>
<td>−183</td>
</tr>
<tr>
<td>Chlorine</td>
<td>gas</td>
<td>greenish-yellow</td>
<td>−101</td>
<td>−34</td>
</tr>
<tr>
<td>Ethanol</td>
<td>liquid</td>
<td>colorless</td>
<td>−117</td>
<td>72</td>
</tr>
<tr>
<td>Mercury</td>
<td>liquid</td>
<td>silvery-white</td>
<td>−39</td>
<td>357</td>
</tr>
<tr>
<td>Bromine</td>
<td>liquid</td>
<td>reddish-brown</td>
<td>−7</td>
<td>59</td>
</tr>
<tr>
<td>Water</td>
<td>liquid</td>
<td>colorless</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Sulfur</td>
<td>solid</td>
<td>yellow</td>
<td>115</td>
<td>445</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>solid</td>
<td>white</td>
<td>801</td>
<td>1413</td>
</tr>
<tr>
<td>Gold</td>
<td>solid</td>
<td>yellow</td>
<td>1064</td>
<td>2856</td>
</tr>
<tr>
<td>Copper</td>
<td>solid</td>
<td>reddish-yellow</td>
<td>1084</td>
<td>2562</td>
</tr>
</tbody>
</table>

**Identifying Substances**

Each object in Figure 2.2 has a different chemical makeup, or composition. The sculpture of a falcon is mainly gold. The kettles are mainly copper. Matter that has a uniform and definite composition is called a *substance*. Gold and copper are examples of substances, which are also referred to as pure substances. Every sample of a given substance has identical intensive properties because every sample has the same composition.

Gold and copper have some properties in common, but there are differences besides their distinctive colors. Pure copper can scratch the surface of pure gold because copper is harder than gold. Copper is better than gold as a conductor of heat or electric current. Both gold and copper are malleable, which means they can be hammered into sheets without breaking. But gold is more malleable than copper. Hardness, color, conductivity, and malleability are examples of physical properties. A *physical property* is a quality or condition of a substance that can be observed or measured without changing the substance’s composition.

Table 2.1 lists physical properties for some substances. The states of the substances are given at room temperature. (Although scientists use room temperature to refer to a range of temperatures, in this book it will be used to refer to a specific temperature, 20°C.) Physical properties can help chemists identify substances. For example, a colorless substance that was found to boil at 100°C and melt at 0°C would likely be water. A colorless substance that boiled at 78°C and melted at −117°C would most certainly not be water. Based on Table 2.1, it would likely be ethanol.

Which is a better conductor of electric current—gold or copper?

<table>
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</tr>
</tbody>
</table>

**Differentiated Instruction**

**Gifted and Talented**

Ask students to identify two states of matter other than solid, liquid, and gas. Have students prepare an oral or written report describing the general characteristics of these states and the conditions under which matter is likely to exist in these states.

(Plasmas are likely at extremely high temperatures; Bose-Einstein condensates are possible at extremely low temperatures.) Students should explain why these states of matter are not common on Earth.
States of Matter

Depending on the circumstances, you use three different words to refer to water—water, ice, and steam. Water, which is a common substance, exists in three different physical states. So can most other substances. Three states of matter are solid, liquid, and gas. Certain characteristics that can distinguish these three states of matter are summarized in Figure 2.3.

Solids A solid is a form of matter that has a definite shape and volume. The shape of a solid doesn’t depend on the shape of its container. The particles in a solid are packed tightly together, often in an orderly arrangement, as shown in Figure 2.3a. As a result, solids are almost incompressible; that is, it is difficult to squeeze a solid into a smaller volume. In addition, solids expand only slightly when heated.

Liquids Look at Figure 2.3b. The particles in a liquid are in close contact with one another, but the arrangement of particles in a liquid is not rigid or orderly. Because the particles in a liquid are free to flow from one location to another, a liquid takes the shape of the container in which it is placed. However, the volume of the liquid doesn’t change as its shape changes. The volume of a liquid is fixed or constant. Thus, a liquid is a form of matter that has an indefinite shape, flows, yet has a fixed volume. Liquids are almost incompressible, but they tend to expand slightly when heated.

Gases Look at Figure 2.3c. The particles in a gas are far apart and can move freely. Gases are neither incompressible, nor do they have a fixed volume. Thus, a gas is a form of matter that has no definite shape or volume.

Figure 2.3 The arrangement of particles is different in solids, liquids, and gases. a In a solid, the particles are packed closely together in a rigid arrangement. b In a liquid, the particles are close together, but they are free to flow past one another. c In a gas, the particles are relatively far apart and can move freely.

Relating Cause and Effect Use the arrangements of their particles to explain the general shape and volume of solids and gases.

Thixotropic Materials
Changes of state are typically associated with changes in temperature. However, the state of matter can also be affected by other variables. Thixotropic materials are solidlike materials that liquefy when subjected to shearing forces. For example, many paints are thixotropic; they thin out when brushed on a surface and thicken when the brush strokes stop, thus keeping the paint from sliding off the wall! A shearing force has an opposite effect on quicksand. Quick movements “thicken” the quicksand and make it much more difficult for a person or animal trapped in it to move. (A shearing force causes two layers to slide in opposite directions along a plane of contact.)
Physical Changes

Use Visuals

Figure 2.4 Have students study the photograph. Refer them to page R14 of the Elements Handbook for data on the properties of gallium. Ask, Is the melting of gallium a reversible or irreversible change? (reversible) What is the physical state of gallium at room temperature? (solid)

ASSESS

Evaluate Understanding

To assess students’ knowledge of states of matter, ask, How are three states of matter involved when a candle burns? Tell students to include the definitions for each state. (Solid wax has a definite shape and volume; the melted liquid wax is shapeless and runs down the side of the candle; the vapor that forms above the wick has no shape.)

Re-teach

If possible, bring samples of some of the substances listed in Table 2.1 to class. Describe the physical properties of selected samples and have students practice identifying them by referring to Table 2.1.

Elements Handbook

The melting point of indium is 157°C. Both indium and gallium (30°C) have relatively low melting points compared with gold (1064°C).

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 2.1.

Section 2.1 (continued)

Gases

Like a liquid, a gas takes the shape of its container. But unlike a liquid, a gas can expand to fill any volume. A gas is a form of matter that takes both the shape and volume of its container. Look back at Figure 2.3c. As shown in the model, the particles in a gas are usually much farther apart than the particles in a liquid. Because of the space between particles, gases are easily compressed into a smaller volume.

The words vapor and gas are sometimes used interchangeably. But there is a difference. The term gas is used for substances, like oxygen, that exist in the gaseous state at room temperature. (Gaseous is the adjective form of gas.) Vapor describes the gaseous state of a substance that is generally a liquid or solid at room temperature, as in water vapor.

When should the term vapor be used instead of gas?

Physical Changes

The melting point of gallium metal is 30°C. Figure 2.4 shows how heat from a person’s hand can melt a sample of gallium. The shape of the sample changes during melting as the liquid begins to flow, but the composition of the sample does not change. Melting is an example of a physical change. During a physical change, some properties of a material change, but the composition of the material does not change.

Words such as boil, freeze, melt, and condense are used to describe physical changes. So are words such as break, split, grind, cut, and crush. However, there is a difference between these two sets of words. Each set describes a different type of physical change. Physical changes can be classified as reversible or irreversible. Melting is an example of a reversible physical change. If a sample of liquid gallium is cooled below its melting point, the liquid will become a solid. All physical changes that involve a change from one state to another are reversible. Cutting hair, filing nails, and cracking an egg are examples of irreversible physical changes.

2.1 Section Assessment

1. Key Concept Name two categories used to classify properties of matter.
2. Key Concept Explain why all samples of a given substance have the same intensive properties.
3. Key Concept Name three states of matter.
4. Key Concept Describe the two categories used to classify physical changes.
5. Which property in Table 2.1 can most easily distinguish sodium chloride from the other solids?
6. In what way are liquids and gases alike? In what way are liquids and solids different?
7. Is the freezing of mercury a reversible or irreversible physical change? Explain your answer.
8. Explain why samples of gold and copper can have the same extensive properties, but not the same intensive properties.

Elements Handbook

Read about the metal indium on page R16. What is the melting point of indium? Which other metal has a similar melting point—gallium or gold? Provide data to support your answer.

Section 2.1 Assessment

1. intensive and extensive properties
2. Every sample of a given substance has the same chemical composition.
3. solid, liquid, gas
4. Physical changes are either reversible or irreversible. Reversible changes can be “undone,” or reversed. Irreversible changes cannot be undone.
5. Color; sodium chloride is the only white solid listed.
6. Liquids and gases have an indefinite shape. The shape of a solid is definite; the shape of a liquid is indefinite.
7. The freezing of mercury is reversible because solid mercury can be melted.
8. Samples of gold and copper can have the same mass and volume (extensive properties). They cannot have the same set of intensive properties because they have different chemical compositions.
Hanging by a Thread

Strands in a spider web are about one tenth the diameter of a human hair. Yet a golden orb spider web can withstand the impact of an insect, or even a small bird, flying at high speed because the silk in the web’s frame and spokes is stronger than steel, more elastic than nylon, and tougher than rubber. Scientists are always looking for lightweight materials with these properties, but they cannot set up farms to harvest spider silk because a spider will fight to defend its territory. Instead, scientists use biotechnology to produce spider silk. **Interpreting Diagrams** Where are the silk glands located in a spider?

*Female Golden Orb Spider* 
*Nephila clavipes*  
Body length: 24 mm to 40 mm

**Spider anatomy** A spider releases its silk through spinnerets at the tip of its abdomen. Inside each spinneret are tens or hundreds of spigots. Silk travels from a silk gland through a duct to a spigot. As the silk is released from a spigot, it changes from a liquid to a solid.

**Spider from goat’s milk** Scientists have identified the spider genes that contain the instructions for producing silk. When these genes are transferred to goats, the goats produce milk containing spider silk. Scientists separate the silk from the milk, purify it, and spin it into fibers.

**Background**

- Only about one-third of spider species spin webs, but all spiders produce silk. Different types of silk glands produce silk used for wrapping prey, silk used for wrapping eggs, non-sticky silk used for draglines, and sticky strands or droplets used for trapping prey.
- Silk is a composite of proteins, which explains why the silk can be strong, tough, and elastic.
- Semi-permanent webs of golden orb spiders are large (40–80 cm diameter). A cable of golden orb dragline silk that is slightly thicker than a garden hose would be strong enough to support two jet planes full of passengers and cargo without breaking.
- Historically, people have collected spider silk to catch fish or birds and to use as bandages to stop blood flow from wounds. Possible commercial applications of recombinant spider silk are for sutures, biodegradable fishing lines, soft body armor, and in composites.

**Answers to...**

**Interpreting Diagrams** The silk glands are in the spider’s abdomen.  
**Figure 2.4** Because gallium is shown in the liquid state, the temperature of the hand must be greater than 30°C.

**Checkpoint** The term vapor is used to refer to the gaseous state of a substance that is usually a liquid or solid at room temperature.