SECTION 4

Tools, Measurement, and Safety

What You Will Learn

- Identify tools used to collect and analyze data.
- Explain the importance of the International System of Units.
- Identify the appropriate units to use for particular measurements.
- Identify safety symbols.

Vocabulary

mass
volume
density
temperature

READING STRATEGY

Brainstorming The key idea of this section is scientific tools and measurements. Brainstorm what tools scientists use in their work and what the tools are used for.

Would you use a spoon to dig a hole to plant a tree? You wouldn't if you had a shovel!

To dig a hole, you need the correct tools. A *tool* is anything that helps you do a task. Scientists use many different tools to help them in their experiments.

Tools in Science

One way to collect data is to take measurements. To get the best measurements, you need the proper tools. Stopwatches, metersticks, and balances are some of the tools you can use to make measurements. Thermometers can be used to observe changes in temperature. Some of the uses for these tools are shown in **Figure 1.**

After you collect data, you need to analyze them. Calculators are handy tools to help you do calculations quickly. Or you might show your data in a graph or a figure. A computer that has the correct software can help you display your data. Of course, you can use a pencil and graph paper to graph your data.

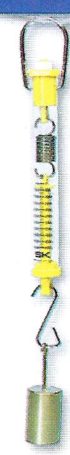
✓ *Reading Check* **Name two ways that scientists use tools.** (*See the Appendix for answers to Reading Checks.*)

Making Measurements

Many years ago, different countries used different systems of measurement. In England, the standard for an inch used to be three grains of barley placed end to end. Other units were originally based on parts of the body, such as the foot.

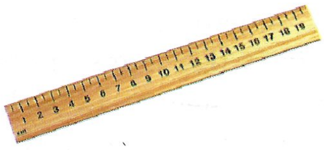
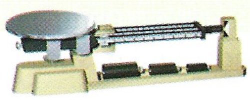
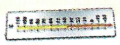
Figure 1 **Measurement Tools**

You can use a stopwatch to measure time.



You can use a spring scale to measure force.

Table 1 Common SI Units

Length 	**meter (m)**	
	kilometer (km)	1 km = 1,000 m
	decimeter (dm)	1 dm = 0.1 m
	centimeter (cm)	1 cm = 0.01 m
	millimeter (mm)	1 mm= 0.001 m
	micrometer (µm)	1 µm = 0.000 001 m
	nanometer (nm)	1 nm = 0.000 000 001 m
Volume 	**cubic meter (m^3)**	
	cubic centimeter (cm^3)	1 cm^3 = 0.000 001 m^3
	liter (L)	1 L = 1 dm^3 = 0.001 m^3
	milliliter (mL)	1 mL = 0.001 L = 1 cm^3
Mass 	**kilogram (kg)**	
	gram (g)	1 g = 0.001 kg
	milligram (mg)	1 mg = 0.000 001 kg
Temperature 	**Kelvin (K)**	0°C = 273 K
	Celsius (°C)	100°C = 373 K

The International System of Units

In the late 1700s, the French Academy of Sciences set out to make a simple and reliable measurement system. Over the next 200 years, the metric system was formed. This system is now the International System of Units (SI). Because all SI units are expressed in multiples of 10, changing from one unit to another is easy. Prefixes are used to express SI units that are larger or smaller than basic units such as meter and gram. For example, *kilo-* means 1,000 times, and *milli-* indicates 1/1,000 times. The prefix used depends on the size of the object being measured. **Table 1** shows common SI units.

MATH PRACTICE

Units of Measure

Pick an object to use as a unit of measure. You can pick a pencil, your hand, or anything else. Find out how many units wide your desk is, and compare your measurement with those of your classmates. What were some of the units used? Now, choose two of the units that were used in your class, and make a conversion factor. For example, 1.5 pencils equal 1 board eraser.

Length

To describe the length of an Olympic-sized swimming pool, a scientist would use meters (m). A *meter* is the basic SI unit of length. Other SI units of length are larger or smaller than the meter by multiples of 10. For example, if you divide 1 m into 1,000 parts, each part equals 1 millimeter (mm). So, 1 mm is one-thousandth of a meter.

Mass

Mass is the amount of matter in an object. The *kilogram* (kg) is the basic SI unit for mass. The kilogram is used to describe the mass of large objects. One kilogram equals 1,000 g. So, the gram is used to describe the mass of small objects. Masses of very large objects are expressed in metric tons. A metric ton equals 1,000 kg.

mass a measure of the amount of matter in an object

Volume

Imagine that you need to move some lenses to a laser laboratory. How many lenses will fit into a crate? The answer depends on the volume of the crate and the volume of each lens. **Volume** is the amount of space that something occupies.

Liquid volume is expressed in *liters* (L). Liters are based on the meter. A cubic meter (1 m^3) is equal to 1,000 L. So, 1,000 L will fit perfectly into a box that is 1 m on each side. A milliliter (mL) will fit perfectly into a box that is 1 cm on each side. So, 1 mL = 1 cm^3. Graduated cylinders are used to measure the volume of liquids.

Volumes of solid objects are usually expressed in cubic meters (m^3). Volumes of smaller objects can be expressed in cubic centimeters (cm^3) or cubic millimeters (mm^3). To find the volume of a crate—or any other rectangular shape—multiply the length by the width by the height.

volume a measure of the size of an object or region in three-dimensional space

density the ratio of the mass of a substance to the volume of the substance

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

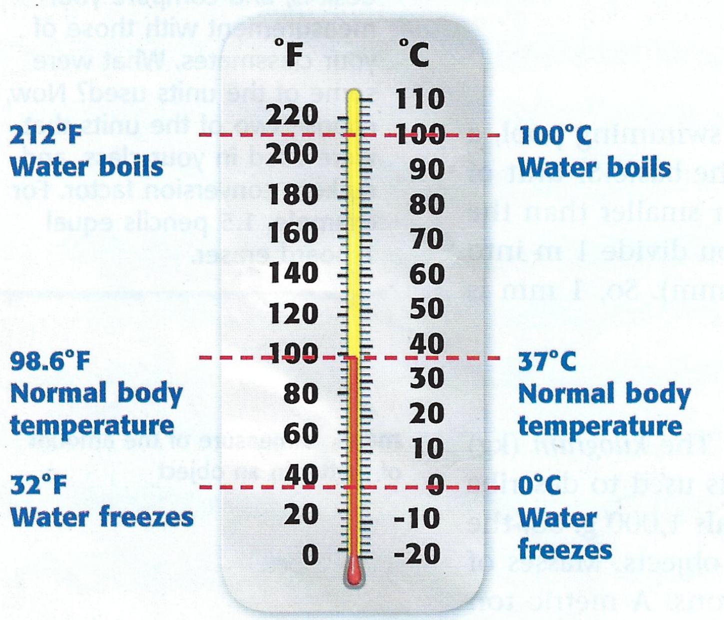
Density

If you measure the mass and the volume of an object, you have the information you need to find the density of the object. **Density** is the amount of matter in a given volume. You cannot measure density directly. But after you measure the mass and the volume, you can calculate density by dividing the mass by the volume, as shown in the following equation:

$$D = \frac{m}{V}$$

Density is called a *derived quantity* because it is found by combining two basic quantities, mass and volume.

Figure 2 *Some common temperature measurements shown in degrees Fahrenheit and degrees Celsius*



Temperature

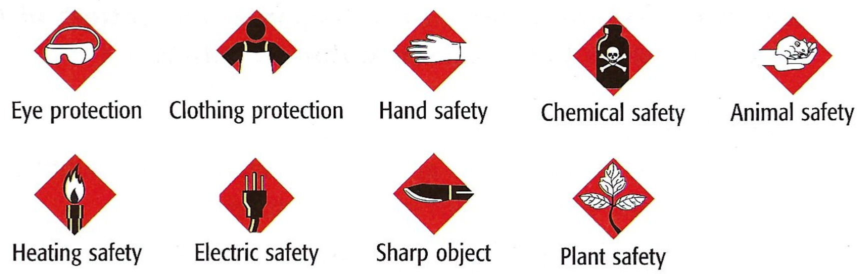
The **temperature** of a substance is a measurement of how hot (or cold) the substance is. Degrees Fahrenheit (°F) and degrees Celsius (°C) are used to describe temperature. However, the *kelvin* (K), the SI unit for temperature, is also used. Notice that the degree sign (°) is not used with the Kelvin scale. The thermometer in **Figure 2** shows how the Celsius and Fahrenheit scales compare.

Reading Check **What is the SI unit for temperature?**

Safety Rules

Science is exciting and fun, but it can also be dangerous. Always follow your teacher's instructions. Don't take shortcuts, even when you think there is no danger. Read lab procedures carefully. Pay special attention to safety information and caution statements. **Figure 3** shows the safety symbols used in this book. Learn these symbols and their meanings by reading the safety information at the start of the book. If you are still not sure about what a safety symbol means, ask your teacher.

Figure 3 Safety Symbols



SECTION Review

Summary

- Tools are used to make observations, take measurements, and analyze data.
- The International System of Units (SI) is the standard system of measurement.
- Length, volume, mass, and temperature are types of measurement.
- Density is the amount of matter in a given volume.
- Safety symbols are for your protection.

Using Key Terms

1. Use each of the following terms in a separate sentence: *volume, density,* and *mass*.

Understanding Key Ideas

2. Which SI unit would you use to express the height of your desk?

a. kilogram　**c.** meter
b. gram　**d.** liter

3. Explain the relationship between mass and density.

4. What is normal body temperature in degrees Fahrenheit and degrees Celsius?

Math Skills

5. A certain bacterial cell has a diameter of 0.50 μm. The tip of a pin is about 1,100 μm in diameter. How many of these bacterial cells would fit on the tip of the pin?

Critical Thinking

6. Analyzing Ideas What safety icons would you expect to see for a lab activity that asks you to pour acid into a beaker? Explain your answer.

7. Applying Concepts To find the area of a rectangle, multiply the length by the width. Why is area called a *derived quantity*?

For a variety of links related to this chapter, go to www.scilinks.org

Topic: SI Units
SciLinks code: HSM1390

Chapter Review

USING KEY TERMS

1. In your own words, write a definition for each of the following terms: *meter, temperature,* and *density*.

For each pair of terms, explain how the meanings of the terms differ.

2. *science* and *scientific methods*

3. *observation* and *hypothesis*

4. *theory* and *law*

5. *model* and *theory*

6. *volume* and *mass*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Physical science is
   - **a.** the study of matter and energy.
   - **b.** the study of physics and chemistry.
   - **c.** important in most sciences.
   - **d.** All of the above

8. The statement "Sheila has a stain on her shirt" is an example of a(n)
   - **a.** law.
   - **b.** hypothesis.
   - **c.** observation.
   - **d.** prediction.

9. A hypothesis
   - **a.** may or may not be testable.
   - **b.** is supported by evidence.
   - **c.** is a possible answer to a question.
   - **d.** All of the above

10. A variable
    - **a.** is found in an uncontrolled experiment.
    - **b.** is the factor that changes in an experiment.
    - **c.** cannot change.
    - **d.** is rarely included in experiments.

11. Organizing data into a graph is an example of
    - **a.** collecting data.
    - **b.** forming a hypothesis.
    - **c.** asking a question.
    - **d.** analyzing data.

12. How many milliliters are in 3.5 kL?
    - **a.** 0.0035
    - **b.** 3,500
    - **c.** 35,000
    - **d.** 3,500,000

13. A map of Seattle is an example of a
    - **a.** physical model.
    - **b.** mathematical model.
    - **c.** conceptual model.
    - **d.** All of the above

14. Ten meters is equal to
    - **a.** 100 cm.
    - **b.** 1,000 cm.
    - **c.** 100,000 mm.
    - **d.** 1,000 μm.

Short Answer

15. Describe three kinds of models used in science. Give an example and explain one limitation of each model.

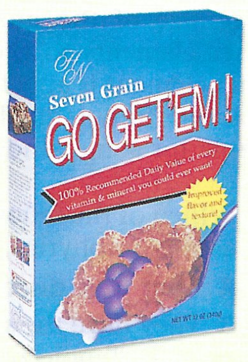
16. Name two SI units that can be used to describe the volume of an object and two SI units that can be used to describe the mass of an object.

17. What are the steps used in scientific methods?

18. If a hypothesis is not testable, is the hypothesis wrong? Explain.

Math Skills

19. The cereal box on the right has a mass of 340 g. Its dimensions are 27 cm × 19 cm × 6 cm. What is the volume of the box? What is its density?



CRITICAL THINKING

20. **Concept Mapping** Use the following terms to create a concept map: *science, scientific methods, hypothesis, problems, questions, experiments,* and *observations*.

21. **Applying Concepts** A tailor is someone who makes or alters items of clothing. Why might a standard system of measurement be helpful to a tailor?

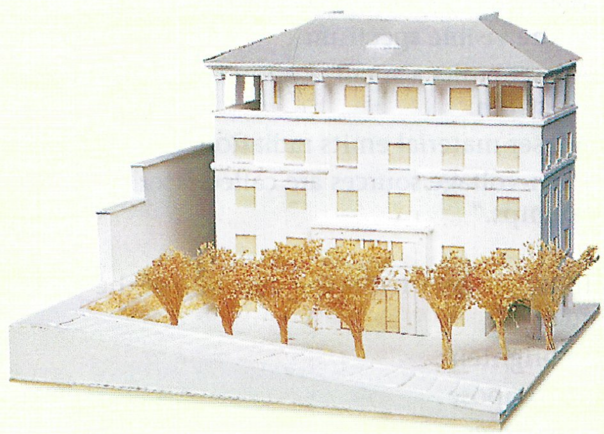
22. **Analyzing Ideas** Imagine that you are conducting an experiment. You are testing the effects of the height of a ramp on the speed at which a toy car goes down the ramp. What is the variable in this experiment? What factors must be controlled?

23. **Evaluating Assumptions** Suppose a classmate says, "I don't need to study science because I'm not going to be a scientist, and scientists are the only people who use science." How would you respond? In your answer, give several examples of careers that use physical science.

24. **Making Inferences** You build a model boat that you predict will float. However, your tests show that the boat sinks. What conclusion would you draw? Suggest some logical next steps.

INTERPRETING GRAPHICS

Use the picture below to answer the questions that follow.



25. How similar is this model to a real object?

26. What are some of the limitations of this model?

27. How might this model be useful?