CHAPTER 2

Data Analysis

What You'll Learn

- You will recognize SI units of measurement.
- You will convert data into scientific notation and from one unit to another.
- You will round off answers to the correct degree of certainty.
- You will use graphs to organize data.

Why It's Important

What do planting a garden, painting a room, and planning a party have in common? For each task, you need to gather and analyze data.

Chemistry Online

Visit the Chemistry Web site at **chemistrymc.com** to find links about data analysis.

Carpenters learn from their mistakes to "measure twice and cut once."

DISCOVERY LAB

Materials

5 mL each in small, plastic containers:
- alcohol
- corn oil
- glycerol
- water

graduated cylinder

Layers of Liquids

How many layers will four different liquids form when you add them to a graduated cylinder?

Safety Precautions

Keep alcohol away from open flames.

Procedure

1. Pour the blue-dyed glycerol from its small container into the graduated cylinder. Allow all of the glycerol to settle to the bottom.
2. Slowly add the water by pouring it down the inside of the cylinder as shown in the photograph.
3. Repeat step 2 with the corn oil.
4. Repeat step 2 with the red-dyed alcohol.

Analysis

How are the liquids arranged in the cylinder? Hypothesize about what property of the liquids is responsible for this arrangement.

Section 2.1 Units of Measurement

Objectives

- **Define** SI base units for time, length, mass, and temperature.
- **Explain** how adding a prefix changes a unit.
- **Compare** the derived units for volume and density.

Vocabulary

base unit
second
meter
kilogram
derived unit
liter
density
kelvin

Suppose you get an e-mail from a friend who lives in Canada. Your friend complains that it has been too hot lately to play soccer or ride a bike. The high temperature each day has been about 35. You think that this figure must be wrong because a temperature of 35 is cold, not hot. Actually, 35 can be either hot or cold depending on which temperature units are used. For a measurement to be useful, it must include both a number and a unit.

SI Units

Measurement is a part of daily activities. Hospitals record the weight and length of each baby. Meters on gasoline pumps measure the volume of gasoline sold. The highway sign in **Figure 2-1** gives the measured distance from the sign's location to two different destinations. In the United States, these distances are shown in both kilometers and miles.

For people born in the United States, the mile is a familiar unit. People in most other countries measure distances in kilometers. Kilometers and miles are units of length in different measurement systems. The system that includes kilometers is the system used by scientists worldwide.

Figure 2-1

How many miles apart are Baker and Barstow? Which is longer, a mile or a kilometer?

Table 2-1

SI Base Units	
Quantity	**Base unit**
Time	second (s)
Length	meter (m)
Mass	kilogram (kg)
Temperature	kelvin (K)
Amount of a substance	mole (mol)
Electric current	ampere (A)
Luminous intensity	candela (cd)

For centuries, units of measurement were fairly inexact. A person might mark off the boundaries of a property by walking and counting the number of steps. The passage of time could be estimated with a sundial or an hourglass filled with sand. Such estimates worked for ordinary tasks. Scientists, however, need to report data that can be reproduced by other scientists. They need standard units of measurement. In 1795, French scientists adopted a system of standard units called the metric system. In 1960, an international committee of scientists met to update the metric system. The revised system is called the Système Internationale d'Unités, which is abbreviated SI.

Base Units

There are seven base units in SI. A **base unit** is a defined unit in a system of measurement that is based on an object or event in the physical world. A base unit is independent of other units. **Table 2-1** lists the seven SI base units, the quantities they measure, and their abbreviations. Some familiar quantities that are expressed in base units are time, length, mass, and temperature.

Time The SI base unit for time is the **second** (s). The frequency of microwave radiation given off by a cesium-133 atom is the physical standard used to establish the length of a second. Cesium clocks are more reliable than the clocks and stopwatches that you use to measure time. For ordinary tasks, a second is a short amount of time. Many chemical reactions take place in less than a second. To better describe the range of possible measurements, scientists add prefixes to the base units. This task is made easier because the metric system is a decimal system. The prefixes in **Table 2-2** are based on multiples, or factors, of ten. These prefixes can be used with all SI units. In Section 2.2, you will learn to express quantities such as 0.000 000 015 s in scientific notation, which also is based on multiples of ten.

Length The SI base unit for length is the **meter** (m). A meter is the distance that light travels through a vacuum in 1/299 792 458 of a second. A vacuum is a space containing no matter. A meter, which is close in length to a yard, is useful for measuring the length and width of a room. For distances between cities, you would use kilometers. The diameter of a drill bit might be reported in millimeters. Use **Table 2-2** to figure out how many millimeters are in a meter and how many meters are in a kilometer.

Try at Home LAB

See page 952 in Appendix E for

SI Measurement Around the Home

Astronomy CONNECTION

A star's temperature and size determine its brightness, or luminous intensity. The SI base unit for luminous intensity is the candela. The more massive a star and the hotter its temperature, the brighter the star will be. How bright a star appears from Earth can be misleading because stars are at different distances from Earth. Light spreads out as it travels from its source. Thus, distant stars will appear less bright than stars of equal intensity that are closer to Earth.

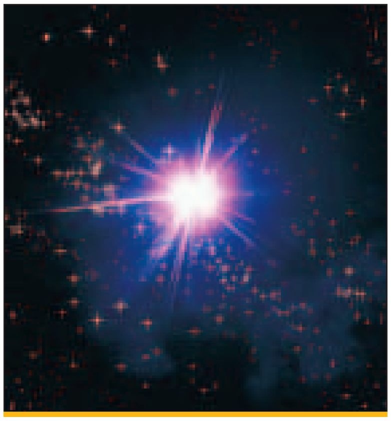


Table 2-2

Prefixes Used with SI Units				
Prefix	**Symbol**	**Factor**	**Scientific notation**	**Example**
giga	G	1 000 000 000	10^9	gigameter (Gm)
mega	M	1 000 000	10^6	megagram (Mg)
kilo	k	1000	10^3	kilometer (km)
deci	d	1/10	10^{-1}	deciliter (dL)
centi	c	1/100	10^{-2}	centimeter (cm)
milli	m	1/1000	10^{-3}	milligram (mg)
micro	μ	1/1 000 000	10^{-6}	microgram (μg)
nano	n	1/1 000 000 000	10^{-9}	nanometer (nm)
pico	p	1/1 000 000 000 000	10^{-12}	picometer (pm)

Mass Recall that mass is a measure of the amount of matter. The SI base unit for mass is the **kilogram** (kg). A kilogram is about 2.2 pounds. The kilogram is defined by the platinum-iridium metal cylinder shown in **Figure 2-2.** The cylinder is stored in a triple bell jar to keep air away from the metal. The masses measured in most laboratories are much smaller than a kilogram. For such masses, scientists use grams (g) or milligrams (mg). There are 1000 grams in a kilogram. How many milligrams are in a gram?

Figure 2-2

The kilogram is the only base unit whose standard is a physical object. The standard kilogram is kept in Sèvres, France. The kilogram in this photo is a copy kept at the National Institute of Standards and Technology in Gaithersburg, Maryland.

Derived Units

Not all quantities can be measured with base units. For example, the SI unit for speed is meters per second (m/s). Notice that meters per second includes two SI base units—the meter and the second. A unit that is defined by a combination of base units is called a **derived unit.** Two other quantities that are measured in derived units are volume and density.

Volume Volume is the space occupied by an object. The derived unit for volume is the cubic meter, which is represented by a cube whose sides are all one meter in length. For measurements that you are likely to make, the more useful derived unit for volume is the cubic centimeter (cm^3). The cubic centimeter works well for solid objects with regular dimensions, but not as well for liquids or for solids with irregular shapes. In the **miniLAB** on the next page, you will learn how to determine the volume of irregular solids.

Figure 2-3 shows the relationship between different SI volume units, including the cubic decimeter (dm^3). The metric unit for volume equal to one cubic decimeter is a **liter** (L). Liters are used to measure the amount of liquid in a container of bottled water or a carbonated beverage. One liter has about the same volume as one quart. For the smaller quantities of liquids that you will work with in the laboratory, volume is measured in milliliters (mL). A milliliter is equal in volume to one cubic centimeter. Recall that *milli* means one-thousandth. Therefore, one liter is equal to 1000 milliliters.

Density Why is it easier to lift a grocery bag full of paper goods than it is to lift a grocery bag full of soup cans? The volumes of the grocery bags are identical. Therefore, the difference in effort must be related to how much mass is packed into the same volume. **Density** is a ratio that compares the mass of an object to its volume. The units for density are often grams per cubic centimeter (g/cm^3).

Figure 2-3

How many cubic centimeters (cm^3) are in one liter?

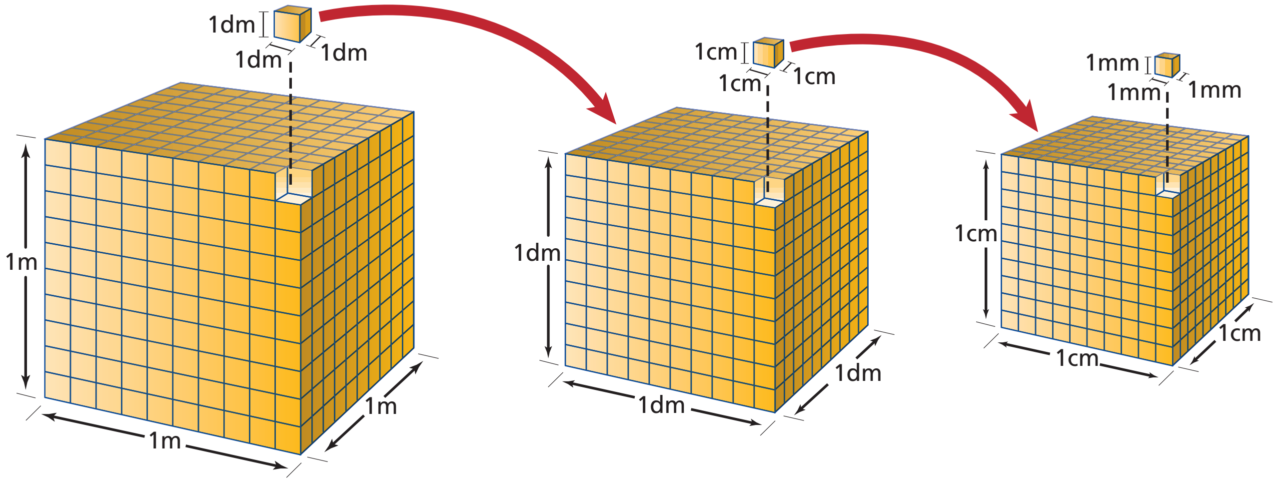


Figure 2-4

The piece of foam has the same mass as the quarter. Compare the densities of the quarter and the foam.

Chemistry Online

Topic: SI
To learn more about SI, visit the Chemistry Web site at **chemistrymc.com**

Activity: Research three SI units not discussed in this section. Share with the class the units you selected and describe what the units measure.

Consider the quarter and the piece of foam in **Figure 2-4.** In this case, the objects have the same mass. Because the density of the quarter is much greater than the density of the foam, the quarter occupies a much smaller space. How does density explain what you observed in the **DISCOVERY LAB?**

You can calculate density using this equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

If a sample of aluminum has a mass of 13.5 g and a volume of 5.0 cm^3, what is its density? Insert the known quantities for mass and volume into the density equation.

$$\text{density} = \frac{13.5\text{ g}}{5.0\text{ cm}^3}$$

The density of aluminum is 2.7 g/cm^3. Density is a property that can be used to identify an unknown sample of matter. Every sample of pure aluminum has the same density. **How It Works** at the end of the chapter explains how ultrasound testing relies on the variation in density among materials.

miniLAB

Density of an Irregular Solid

Measuring To calculate density, you need to know both the mass and volume of an object. You can find the volume of an irregular solid by displacing water.

Materials balance, graduated cylinder, water, washer or other small object

Procedure

1. Find and record the mass of the washer.
2. Add about 15 mL of water to your graduated cylinder. Measure and record the volume. Because the surface of the water in the cylinder is curved, make volume readings at eye level and at the lowest point on the curve. The curved surface is called a *meniscus.*
3. Carefully add the washer to the cylinder. Then measure and record the new volume.

Analysis

1. Use the initial and final volume readings to calculate the volume of the washer.
2. Use the calculated volume and the measured mass to find the density of the washer.
3. Explain why you cannot use displacement of water to find the volume of a sugar cube.
4. The washer is a short cylinder with a hole in the middle. Describe another way to find its volume.

Your textbook includes example problems that explain how to solve word problems related to concepts such as density. Each example problem uses a three-part process for problem solving: analyze, solve, and evaluate. When you analyze a problem, you first separate what is known from what is unknown. Then you decide on a strategy that uses the known data to solve for the unknown. After you solve a problem, you need to evaluate your answer to decide if it makes sense.

EXAMPLE PROBLEM 2-1

Using Density and Volume to Find Mass

Suppose a sample of aluminum is placed in a 25-mL graduated cylinder containing 10.5 mL of water. The level of the water rises to 13.5 mL. What is the mass of the aluminum sample?

1. Analyze the Problem

The unknown is the mass of aluminum. You know that mass, volume, and density are related. The volume of aluminum equals the volume of water displaced in the graduated cylinder. You know that the density of aluminum is 2.7 g/cm^3, or 2.7 g/mL, because 1 cm^3 equals 1 mL.

Known	Unknown
density = 2.7 g/mL	mass = ? g
volume = 13.5 mL – 10.5 mL = 3.0 mL	

2. Solve for the Unknown

Rearrange the density equation to solve for mass.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{mass} = \text{volume} \times \text{density}$$

Substitute the known values for volume and density into the equation.

$$\text{mass} = 3.0 \text{ mL} \times 2.7 \text{ g/mL}$$

Multiply the values and the units. The mL units will cancel out.

$$\text{mass} = 3.0 \cancel{\text{mL}} \times \frac{2.7 \text{ g}}{\cancel{\text{mL}}} = 8.1 \text{ g}$$

3. Evaluate the Answer

You can check your answer by using it with the known data in the equation for density. The two sides of the equation should be equal.

density = mass/volume

2.7 g/mL = 8.1 g/3.0 mL

If you divide 8.1 g by 3.0 mL, you get 2.7 g/mL.

Problem-Solving Process

THE PROBLEM
1. Read the problem carefully.
2. Be sure that you understand what it is asking you.

ANALYZE THE PROBLEM
1. Read the problem again.
2. Identify what you are given and list the known data.
3. Identify and list the unknowns.
4. Gather information you need from graphs, tables, or figures.
5. Plan the steps you will follow to find the answer.

SOLVE FOR THE UNKNOWN
1. Determine whether you need a sketch to solve the problem.
2. If the solution is mathematical, write the equation and isolate the unknown factor.
3. Substitute the known quantities into the equation.
4. Solve the equation.
5. Continue the solution process until you solve the problem.

EVALUATE THE ANSWER
1. Re-read the problem. Is the answer reasonable?
2. Check your math. Are the units and the significant figures correct? (See Section 2.3.)

PRACTICE PROBLEMS

1. A piece of metal with a mass of 147 g is placed in a 50-mL graduated cylinder. The water level rises from 20 mL to 41 mL. What is the density of the metal?
2. What is the volume of a sample that has a mass of 20 g and a density of 4 g/mL?
3. A metal cube has a mass of 20 g and a volume of 5 cm^3. Is the cube made of pure aluminum? Explain your answer.

Practice!

For more practice with density problems, go to **Supplemental Practice Problems** in Appendix A.

Temperature

Suppose you run water into a bathtub. You control the temperature of the water by adjusting the flow from the hot and cold water pipes. When the streams mix, heat flows from the hot water to the cold water. You classify an object as hot or cold by whether heat flows from you to the object or from the object to you. The temperature of an object is a measure of how hot or cold the object is relative to other objects.

Temperature scales Hot and cold are qualitative terms. For quantitative descriptions of temperature, you need measuring devices such as thermometers. In a thermometer, a liquid expands when heated and contracts when cooled. The tube that contains the liquid is narrow so that small changes in temperature can be detected. Scientists use two temperature scales. The Celsius scale was devised by Anders Celsius, a Swedish astronomer. He used the temperatures at which water freezes and boils to establish his scale because these temperatures are easy to reproduce. He defined the freezing point as 0 and the boiling point as 100. Then he divided the distance between these points into 100 equal units, or degrees Celsius.

The Kelvin scale was devised by a Scottish physicist and mathematician, William Thomson, who was known as Lord Kelvin. A **kelvin** (K) is the SI base unit of temperature. On the Kelvin scale, water freezes at about 273 K and boils at about 373 K. **Figure 2-5** compares the two scales. You will use the Celsius scale for your experiments. In Chapter 14, you will learn why scientists use the Kelvin scale to describe the behavior of gases.

It is easy to convert from the Celsius scale to the Kelvin scale. For example, the element mercury melts at −39°C and boils at 357°C. To convert temperatures reported in degrees Celsius into kelvins, you just add 273.

$$-39°C + 273 = 234 \text{ K}$$

$$357°C + 273 = 630 \text{ K}$$

It is equally easy to convert from the Kelvin scale to the Celsius scale. For example, the element bromine melts at 266 K and boils at 332 K. To convert temperatures reported in kelvins into degrees Celsius, you subtract 273.

$$266 \text{ K} - 273 = -7°C$$

$$332 \text{ K} - 273 = 59°C$$

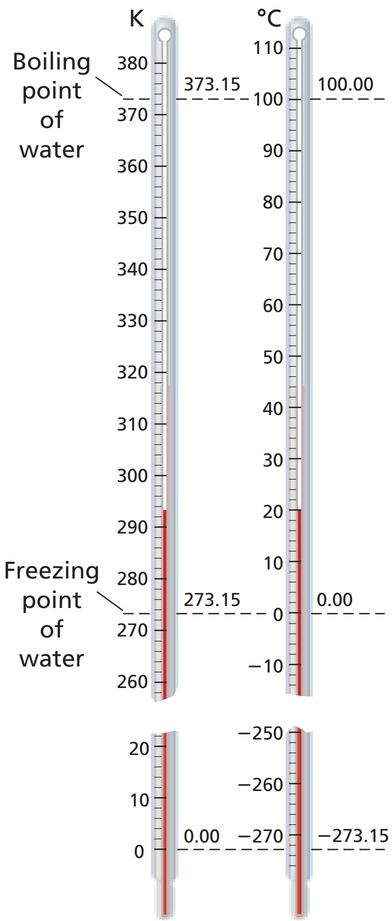


Figure 2-5

One kelvin is equal in size to one degree on the Celsius scale. The degree sign ° is not used with temperatures on the Kelvin scale.

Section 2.1 Assessment

4. List SI units of measurement for length, mass, time, and temperature.

5. Describe the relationship between the mass, volume, and density of a material.

6. Which of these samples have the same density?

Density Data		
Sample	**Mass**	**Volume**
A	80 g	20 mL
B	12 g	4 cm^3
C	33 g	11 mL

7. What is the difference between a base unit and a derived unit?

8. How does adding the prefix *mega-* to a unit affect the quantity being described?

9. How many milliseconds are in a second? How many centigrams are in a gram?

10. Thinking Critically Why does oil float on water?

11. Using Numbers You measure a piece of wood with a meterstick and it is exactly one meter long. How many centimeters long is it?

Section 2.2

Scientific Notation and Dimensional Analysis

A proton's mass is 0.000 000 000 000 000 000 000 000 001 672 62 kg. An electron's mass is 0.000 000 000 000 000 000 000 000 000 000 910 939 kg. If you try to compare the mass of a proton with the mass of an electron, the zeros get in the way. Numbers that are extremely small or large are hard to handle. You can convert such numbers into a form called scientific notation.

Objectives

- **Express** numbers in scientific notation.
- **Use** dimensional analysis to **convert** between units.

Vocabulary

scientific notation
conversion factor
dimensional analysis

Scientific Notation

Scientific notation expresses numbers as a multiple of two factors: a number between 1 and 10; and ten raised to a power, or exponent. The exponent tells you how many times the first factor must be multiplied by ten. The mass of a proton is $1.627\ 62 \times 10^{-27}$ kg in scientific notation. The mass of an electron is $9.109\ 39 \times 10^{-31}$ kg. When numbers larger than 1 are expressed in scientific notation, the power of ten is positive. When numbers smaller than 1 are expressed in scientific notation, the power of ten is negative.

EXAMPLE PROBLEM 2-2

Convert Data into Scientific Notation

Change the following data into scientific notation.

a. The diameter of the Sun is 1 392 000 km.

b. The density of the Sun's lower atmosphere is 0.000 000 028 g/cm^3.

1. Analyze the Problem

You are given two measurements. One measurement is much larger than 10. The other is much smaller than 10. In both cases, the answers will be factors between 1 and 10 that are multiplied by a power of ten.

2. Solve for the Unknown

Move the decimal point to produce a factor between 1 and 10. Count the number of places the decimal point moved and the direction.

1 392 000.	0.000 000 028
The decimal point moved 6 places to the left.	The decimal point moved 8 places to the right.

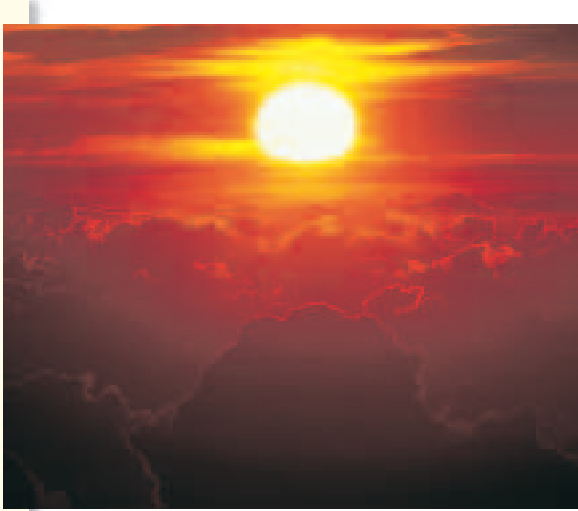
Remove the extra zeros at the end or beginning of the factor. Multiply the result by 10^n where n equals the number of places moved. When the decimal point moves to the *left*, n is a *positive* number. When the decimal point moves to the *right*, n is a *negative* number. Remember to add units to the answers.

a. $1\ 392\ 000 = 1.392 \times 10^6$ km

b. $0.000\ 000\ 028 = 2.8 \times 10^{-8}$ g/cm^3

3. Evaluate the Answer

The answers have two factors. The first factor is a number between 1 and 10. Because the diameter of the Sun is a large number, 10 has a positive exponent. Because the density of the Sun's lower atmosphere is a small number, 10 has a negative exponent.



The density of the Sun's lower atmosphere is similar to the density of Earth's outermost atmosphere.

PRACTICE PROBLEMS

12. Express the following quantities in scientific notation.

a. 700 m
b. 38 000 m
c. 4 500 000 m
d. 685 000 000 000 m
e. 0.0054 kg
f. 0.000 006 87 kg
g. 0.000 000 076 kg
h. 0.000 000 000 8 kg

13. Express the following quantities in scientific notation.

a. 360 000 s
b. 0.000 054 s
c. 5060 s
d. 89 000 000 000 s

Practice!

For more practice converting to scientific notation, go to **Supplemental Practice Problems** in Appendix A.

Adding and subtracting using scientific notation When adding or subtracting numbers written in scientific notation, you must be sure that the exponents are the same before doing the arithmetic. Suppose you need to add 7.35×10^2 m + 2.43×10^2 m. You note that the quantities are expressed to the same power of ten. You can add 7.35 and 2.43 to get 9.78×10^2 m. What can you do if the quantities are not expressed to the same power of ten?

As shown in **Figure 2-6,** some of the world's cities are extremely crowded. In 1995, the population figures for three of the four largest cities in the world were: 2.70×10^7 for Tokyo, Japan; 15.6×10^6 for Mexico City, Mexico; and 0.165×10^8 for São Paulo, Brazil. To find the total population for these three cities in 1995, you first need to change the data so that all three quantities are expressed to the same power of ten. Because the first factor in the data for Tokyo is a number between 1 and 10, leave that quantity as is: 2.70×10^7. Change the other two quantities so that the exponent is 7. For the Mexico City data, you need to increase the power of ten from 10^6 to 10^7. You must move the decimal point one place to the left.

$$15.6 \times 10^6 = 1.56 \times 10^7$$

For the São Paulo data, you need to decrease the power of ten from 10^8 to 10^7. You must move the decimal point one place to the right.

$$0.165 \times 10^8 = 1.65 \times 10^7$$

Now you can add the quantities.

$$2.70 \times 10^7 + 1.56 \times 10^7 + 1.65 \times 10^7 = 5.91 \times 10^7$$

You can test this procedure by writing the original data in ordinary notation. When you add 27 000 000 + 15 600 000 + 16 500 000, you get 59 100 000. When you convert the answer back to scientific notation, you get 5.91×10^7.

Figure 2-6

Population density is high in a city such as São Paulo, Brazil.

PRACTICE PROBLEMS

Solve the following addition and subtraction problems. Express your answers in scientific notation.

14. a. 5×10^{-5} m + 2×10^{-5} m
b. 7×10^{8} m – 4×10^{8} m
c. 9×10^{2} m – 7×10^{2} m
d. 4×10^{-12} m + 1×10^{-12} m
e. 1.26×10^{4} kg + 2.5×10^{3} kg
f. 7.06×10^{-3} kg + 1.2×10^{-4} kg
g. 4.39×10^{5} kg – 2.8×10^{4} kg
h. 5.36×10^{-1} kg – 7.40×10^{-2} kg

Multiplying and dividing using scientific notation Multiplying and dividing also involve two steps, but in these cases the quantities being multiplied or divided do not have to have the same exponent. For multiplication, you multiply the first factors. Then, you add the exponents. For division, you divide the first factors. Then, you subtract the exponent of the divisor from the exponent of the dividend.

Take care when determining the sign of the exponent in an answer. Adding $+3$ to $+4$ yields $+7$, but adding $+3$ to -4 yields -1. Subtracting -6 from -4 yields $+2$, but subtracting -4 from -6 yields -2.

EXAMPLE PROBLEM 2-3

Multiplying and Dividing Numbers in Scientific Notation

Suppose you are asked to solve the following problems.

a. $(2 \times 10^3) \times (3 \times 10^2)$

b. $(9 \times 10^8) \div (3 \times 10^{-4})$

1. Analyze the Problem

You are given values to multiply and divide. For the multiplication problem, you multiply the first factors. Then you add the exponents. For the division problem, you divide the first factors. Then you subtract the exponent of the divisor from the exponent of the dividend.

$$\text{Quotient} = \frac{9 \times 10^8}{3 \times 10^{-4}} \quad \begin{array}{l}\leftarrow \text{Dividend} \\ \leftarrow \text{Divisor}\end{array}$$

2. Solve for the Unknown

a. $(2 \times 10^3) \times (3 \times 10^2)$

Multiply the first factors.

$2 \times 3 = 6$

Add the exponents.

$3 + 2 = 5$

Combine the factors.

6×10^5

b. $(9 \times 10^8) \div (3 \times 10^{-4})$

Divide the first factors.

$9 \div 3 = 3$

Subtract the exponents.

$8 - (-4) = 8 + 4 = 12$

Combine the factors.

3×10^{12}

3. Evaluate the Answer

You can test these procedures by writing the original data in ordinary notation. For example, problem **a** becomes 2000×300. An answer of 600 000 seems reasonable.

PRACTICE PROBLEMS

Solve the following multiplication and division problems. Express your answers in scientific notation.

15. Calculate the following areas. Report the answers in square centimeters, cm^2.

a. $(4 \times 10^2\ cm) \times (1 \times 10^8\ cm)$

b. $(2 \times 10^{-4}\ cm) \times (3 \times 10^2\ cm)$

c. $(3 \times 10^1\ cm) \times (3 \times 10^{-2}\ cm)$

d. $(1 \times 10^3\ cm) \times (5 \times 10^{-1}\ cm)$

16. Calculate the following densities. Report the answers in g/cm^3.

a. $(6 \times 10^2\ g) \div (2 \times 10^1\ cm^3)$

b. $(8 \times 10^4\ g) \div (4 \times 10^1\ cm^3)$

c. $(9 \times 10^5\ g) \div (3 \times 10^{-1}\ cm^3)$

d. $(4 \times 10^{-3}\ g) \div (2 \times 10^{-2}\ cm^3)$

Math Handbook

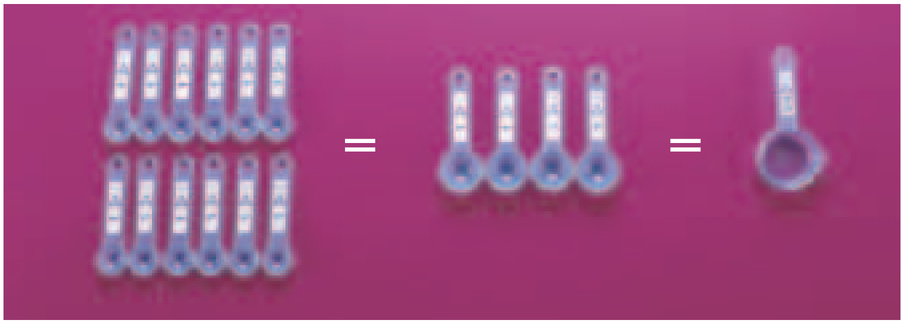
Review arithmetic operations with positive and negative numbers in the **Math Handbook** on pages 887 to 889 of this text.

Practice!

For more practice doing arithmetic operations using scientific notation, go to Supplemental Practice Problems in Appendix A.

Figure 2-7

Twelve teaspoons equal four tablespoons; four tablespoons equal 1/4 of a cup. How many teaspoons are equivalent to two 1/4 measuring cups?



Dimensional Analysis

Suppose you have a salad dressing recipe that calls for 2 teaspoons of vinegar. You plan to make 6 times as much salad dressing for a party. That means you need 12 teaspoons of vinegar. You could measure out 12 teaspoons or you could use a larger unit. According to **Figure 2-7,** 3 teaspoons are equivalent to 1 tablespoon and 4 tablespoons are equivalent to 1/4 of a cup. The relationship between teaspoons and tablespoons can be expressed as a pair of ratios. These ratios are conversion factors.

$$\frac{3 \text{ teaspoons}}{1 \text{ tablespoon}} = \frac{1 \text{ tablespoon}}{3 \text{ teaspoons}} = 1$$

A **conversion factor** is a ratio of equivalent values used to express the same quantity in different units. A conversion factor is always equal to 1. Because a quantity does not change when it is multiplied or divided by 1, conversion factors change the units of a quantity without changing its value. If you measure out 12 teaspoons of vinegar, 4 tablespoons of vinegar, or 1/4 of a cup of vinegar, you will get the same volume of vinegar.

Dimensional analysis is a method of problem-solving that focuses on the units used to describe matter. For example, if you want to convert a temperature in degrees Celsius to a temperature in kelvins, you focus on the relationship between the units in the two temperature scales. Scale drawings such as maps and the blueprint in **Figure 2-8** are based on the relationship between different units of length.

Figure 2-8

Blueprints are scale drawings. On a blueprint, objects and distances appear smaller than their actual sizes but the relative sizes of objects remain the same. How can conversion factors be used to make a scale drawing?

Dimensional analysis often uses conversion factors. Suppose you want to know how many meters are in 48 km. You need a conversion factor that relates kilometers to meters. You know that 1 km is equal to 1000 m. Because you are going to multiply 48 km by the conversion factor, you want to set up the conversion factor so the kilometer units will cancel out.

$$48 \cancel{\text{km}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = 48\,000 \text{ m}$$

When you convert from a large unit to a small unit, the number of units must increase. A meter is a much smaller unit than a kilometer, one one-thousandth smaller to be exact. Thus, it is reasonable to find that there are 48 000 meters in 48 kilometers.

PRACTICE PROBLEMS

Refer to Table 2-2 to figure out the relationship between units.

17. a. Convert 360 s to ms.
b. Convert 4800 g to kg.
c. Convert 5600 dm to m.
d. Convert 72 g to mg.

18. a. Convert 245 ms to s.
b. Convert 5 m to cm.
c. Convert 6800 cm to m.
d. Convert 25 kg to Mg.

EXAMPLE PROBLEM 2-4

Using Multiple Conversion Factors

What is a speed of 550 meters per second in kilometers per minute?

1. Analyze the Problem

You are given a speed in meters per second. You want to know the equivalent speed in kilometers per minute. You need conversion factors that relate kilometers to meters and seconds to minutes.

2. Solve for the Unknown

First convert meters to kilometers. Set up the conversion factor so that the meter units will cancel out.

$$\frac{550\ \cancel{m}}{s} \times \frac{1\ km}{1000\ \cancel{m}} = \frac{0.55\ km}{s}$$

Next convert seconds to minutes. Set up the conversion factor so that the seconds cancel out.

$$\frac{0.55\ km}{\cancel{s}} \times \frac{60\ \cancel{s}}{1\ min} = \frac{33\ km}{min}$$

3. Evaluate the Answer

To check your answer, you can do the steps in reverse order.

$$\frac{550\ m}{\cancel{s}} \times \frac{60\ \cancel{s}}{1\ min} = \frac{33\ 000\ \cancel{m}}{min} \times \frac{1\ km}{1000\ \cancel{m}} = \frac{33\ km}{min}$$

PRACTICE PROBLEMS

19. How many seconds are there in 24 hours?

20. The density of gold is 19.3 g/mL. What is gold's density in decigrams per liter?

21. A car is traveling 90.0 kilometers per hour. What is its speed in miles per minute? One kilometer = 0.62 miles.

Using the wrong units to solve a problem can be a costly error. In 1999, the Mars Climate Orbiter crashed into the atmosphere of Mars instead of flying closely by as planned. The probe was destroyed before it could collect any data. Two teams of engineers working on the probe had used different sets of units—English and metric—and no one had caught the error in time.

Math Handbook

Review dimensional analysis and unit conversions in the **Math Handbook** on pages 900 and 901 of this text.

Practice!

For more practice using conversion factors, go to **Supplemental Practice Problems** in Appendix A.

Section 2.2 Assessment

22. Is the number 5×10^{-4} greater or less than 1.0? Explain your answer.

23. When multiplying numbers in scientific notation, what do you do with the exponents?

24. Write the quantities 3×10^{-4} cm and 3×10^{4} km in ordinary notation.

25. Write a conversion factor for cubic centimeters and milliliters.

26. What is dimensional analysis?

27. **Thinking Critically** When subtracting or adding two numbers in scientific notation, why do the exponents need to be the same?

28. **Applying Concepts** You are converting 68 km to meters. Your answer is 0.068 m. Explain why this answer is incorrect and the likely source of the error.

Section 2.3 How reliable are measurements?

Objectives

- **Define** and **compare** accuracy and precision.
- **Use** significant figures and rounding to reflect the certainty of data.
- **Use** percent error to **describe** the accuracy of experimental data.

Vocabulary

accuracy
precision
percent error
significant figure

Suppose someone is planning a bicycle trip from Baltimore, Maryland to Washington D.C. The actual mileage will be determined by where the rider starts and ends the trip, and the route taken. While planning the trip, the rider does not need to know the actual mileage. All the rider needs is an estimate, which in this case would be about 39 miles. People need to know when an estimate is acceptable and when it is not. For example, you could use an estimate when buying material to sew curtains for a window. You would need more exact measurements when ordering custom shades for the same window.

Accuracy and Precision

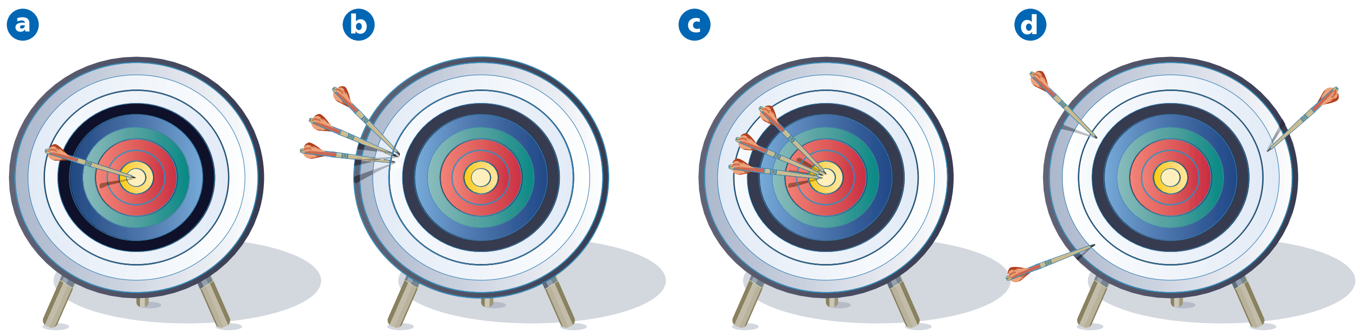
When scientists make measurements, they evaluate both the accuracy and the precision of the measurements. **Accuracy** refers to how close a measured value is to an accepted value. **Precision** refers to how close a series of measurements are to one another. The archery target in **Figure 2-9** illustrates the difference between accuracy and precision. For this example, the center of the target is the accepted value.

In **Figure 2-9a,** the location of the arrow is accurate because the arrow is in the center. In **Figure 2-9b,** the arrows are close together but not near the center. They have a precise location but not an accurate one. In **Figure 2-9c,** the arrows are closely grouped in the center. Their locations are both accurate and precise. In **Figure 2-9d,** the arrows are scattered at a distance from the center. Their locations are neither accurate nor precise. Why does it make no sense to discuss the precision of the arrow location in **Figure 2-9a?**

Consider the data in **Table 2-3.** Students were asked to find the density of an unknown white powder. Each student measured the volume and mass of three separate samples. They reported calculated densities for each trial and an average of the three calculations. The powder was sucrose, also called table sugar, which has a density of 1.59 g/cm^3. Who collected the most accurate data? Student A's measurements are the most accurate because they are closest to the accepted value of 1.59 g/cm^3. Which student collected the most precise data? Student C's measurements are the most precise because they are the closest to one another.

Figure 2-9

An archery target illustrates the difference between accuracy and precision.



a: Arrow in the center = high accuracy

b: Arrows far from center = low accuracy; Arrows close together = high precision

c: Arrows in center = high accuracy; Arrows close together = high precision

d: Arrows far from center = low accuracy; Arrows far apart = low precision

Table 2-3

Density Data Collected by Three Different Students			
	Student A	**Student B**	**Student C**
Trial 1	1.54 g/cm^3	1.40 g/cm^3	1.70 g/cm^3
Trial 2	1.60 g/cm^3	1.68 g/cm^3	1.69 g/cm^3
Trial 3	1.57 g/cm^3	1.45 g/cm^3	1.71 g/cm^3
Average	1.57 g/cm^3	1.51 g/cm^3	1.70 g/cm^3

Recall that precise measurements may not be accurate. Looking at just the average of the densities can be misleading. Based solely on the average, Student B appears to have collected fairly reliable data. However, on closer inspection, Student B's data are neither accurate nor precise. The data are not close to the accepted value and they are not close to one another.

What factors could account for inaccurate or imprecise data? Perhaps Student A did not follow the procedure with consistency. He or she might not have read the graduated cylinder at eye level for each trial. Student C may have made the same slight error with each trial. Perhaps he or she included the mass of the filter paper used to protect the balance pan. Student B may have recorded the wrong data or made a mistake when dividing the mass by the volume. External conditions such as temperature and humidity also can affect the collection of data.

Percent error The density values reported in **Table 2-3** are experimental values, which are values measured during an experiment. The density of sucrose is an accepted value, which is a value that is considered true. To evaluate the accuracy of experimental data, you can calculate the difference between an experimental value and an accepted value. The difference is called an error. The errors for the data in **Table 2-3** are listed in **Table 2-4.**

Scientists want to know what percent of the accepted value an error represents. **Percent error** is the ratio of an error to an accepted value.

$$\text{Percent error} = \frac{\text{error}}{\text{accepted value}} \times 100$$

For this calculation, it does not matter whether the experimental value is larger or smaller than the accepted value. Only the size of the error matters. When you calculate percent error, you ignore plus and minus signs. Percent error is an important concept for the person assembling bicycle gears in **Figure 2-10.** The dimensions of a part may vary within narrow ranges of error called tolerances. Some of the manufactured parts are tested to see if they meet engineering standards. If one dimension of a part exceeds its tolerance, the item will be discarded or, if possible, retooled.

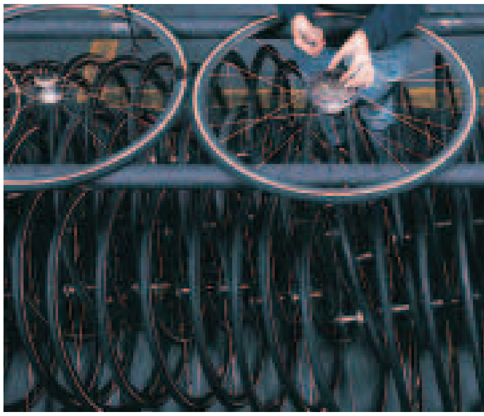


Figure 2-10

The dimensions for each part used to build a bicycle gear have accepted values.

Table 2-4

Errors for Data in Table 2-3			
	Student A	**Student B**	**Student C**
Trial 1	–0.05 g/cm^3	–0.19 g/cm^3	+0.11 g/cm^3
Trial 2	+0.01 g/cm^3	+0.09 g/cm^3	+0.10 g/cm^3
Trial 3	–0.02 g/cm^3	–0.14 g/cm^3	+0.12 g/cm^3

Table 2-5

Student A's Data		
Trial	**Density (g/cm^3)**	**Error (g/cm^3)**
1	1.54	−0.05
2	1.60	+0.01
3	1.57	−0.02

EXAMPLE PROBLEM 2-5

Calculating Percent Error

Calculate the percent errors. Report your answers to two places after the decimal point. **Table 2-5** summarizes Student A's data.

1. Analyze the Problem

You are given the errors for a set of density measurements. To calculate percent error, you need to know the accepted value for density, the errors, and the equation for percent error.

Known

accepted value for density = 1.59 g/cm^3

errors: –0.05 g/cm^3; 0.01 g/cm^3; –0.02 g/cm^3

Unknown

percent errors = ?

2. Solve for the Unknown

Substitute each error into the percent error equation. Ignore the plus and minus signs. Note that the units for density cancel out.

$$\text{percent error} = \frac{\text{error}}{\text{accepted value}} \times 100$$

$$\text{percent error} = \frac{0.05\ \cancel{g/cm^3}}{1.59\ \cancel{g/cm^3}} \times 100 = 3.14\%$$

$$\text{percent error} = \frac{0.01\ \cancel{g/cm^3}}{1.59\ \cancel{g/cm^3}} \times 100 = 0.63\%$$

$$\text{percent error} = \frac{0.02\ \cancel{g/cm^3}}{1.59\ \cancel{g/cm^3}} \times 100 = 1.26\%$$

3. Evaluate the Answer

The percent error is greatest for trial 1, which had the largest error, and smallest for trial 2, which was closest to the accepted value.

For more practice with percent error, go to **Supplemental Practice Problems** in Appendix A.

PRACTICE PROBLEMS

Use data from Table 2-4. Remember to ignore plus and minus signs.

29. Calculate the percent errors for Students B's trials.

30. Calculate the percent errors for Student C's trials.

Significant Figures

Often, precision is limited by the available tools. If you have a digital clock that displays the time as 12:47 or 12:48, you can record the time only to the nearest minute. If you have a clock with a sweep hand, you can record the time to the nearest second. With a stopwatch, you might record time elapsed to the nearest hundredth of a second. As scientists have developed better measuring devices, they have been able to make more precise measurements. Of course, the measuring devices must be in good working order. For example, a balance must read zero when no object is resting on it. The process for assuring the accuracy of a measuring device is called calibration. The person using the instrument must be trained and use accepted techniques.

Scientists indicate the precision of measurements by the number of digits they report. A value of 3.52 g is more precise than a value of 3.5 g. The digits that are reported are called significant figures. **Significant figures**

CONTENTS

include all known digits plus one estimated digit. Consider the rod in **Figure 2-11.** The end of the rod falls somewhere between 5 and 6 cm. Counting over from the 5-cm mark, you can count 2 millimeter tick marks. Thus, the rod's length is between 5.2 cm and 5.3 cm. The 5 and 2 are known digits that correspond to marks on the ruler. You can add one estimated digit to reflect the rod's location relative to the 2 and 3 millimeter marks. The third digit is an estimate because the person reading the ruler must make a judgment call. One person may report the answer as 5.23 cm. Another may report it as 5.22 cm. Either way, the answer has three significant figures—two known and one estimated.

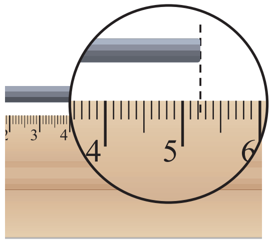


Figure 2-11

What determines whether a figure is known or estimated?

Rules for recognizing significant figures

1. *Non-zero numbers are always significant.*	72.3 g has three
2. *Zeros between non-zero numbers are always significant.*	60.5 g has three
3. *All final zeros to the right of the decimal place are significant.*	6.20 g has three
4. *Zeros that act as placeholders are not significant. Convert quantities to scientific notation to remove the placeholder zeros.*	0.0253 g and 4320 g each have three
5. *Counting numbers and defined constants have an infinite number of significant figures.*	6 molecules 60 s = 1 min

EXAMPLE PROBLEM 2-6

Applying Significant Figure Rules

Determine the number of significant figures in the following masses.

a. 0.000 402 30 g

b. 405 000 kg

1. Analyze the Problem

You are given two measurements of mass. Choose the rules that are appropriate to the problem.

2. Solve for the Unknown

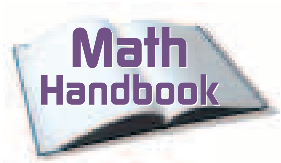
Count all non-zero numbers (rule 1), zeros between non-zero numbers (rule 2), and final zeros to the right of the decimal place (rule 3). Ignore zeros that act as placeholders (rule 4).

a. 0.000 402 30 g has five significant figures.

b. 405 000 kg has three significant figures.

3. Evaluate the Answer

Write the data in scientific notation: 4.0230×10^{-4} g and 4.05×10^{5} kg. Without the placeholder zeros, it is clear that 0.000 402 30 g has five significant figures and 405 000 kg has three significant figures.



Review significant figures in the **Math Handbook** on page 893 of this text.

PRACTICE PROBLEMS

Determine the number of significant figures in each measurement.

31. a. 508.0 L
b. 820 400.0 L
c. 1.0200×10^{5} kg
d. 807 000 kg

32. a. 0.049 450 s
b. 0.000 482 mL
c. 3.1587×10^{-8} g
d. 0.0084 mL

Practice!

For more practice with significant figures, go to **Supplemental Practice Problems** in Appendix A.

Figure 2-12

The calculator often provides more significant figures than are appropriate for a given calculation.

Rounding Off Numbers

Suppose you are asked to find the density of an object whose mass is 22.44 g and whose volume is 14.2 cm^3. When you use your calculator, you get a density of 1.580 281 7 g/cm^3, as shown in **Figure 2-12.** A calculated density with eight significant figures is not appropriate if the mass has only four significant figures and the volume has only three. The answer should have no more significant figures than the data with the fewest significant figures. The density must be rounded off to three significant figures, or 1.58 g/cm^3.

Rules for rounding numbers

In the example for each rule, there are three significant figures.

1. *If the digit to the immediate right of the last significant figure is less than five, do not change the last significant figure.* 2.532 $\rightarrow$ 2.53
2. *If the digit to the immediate right of the last significant figure is greater than five, round up the last significant figure.* 2.536 $\rightarrow$ 2.54
3. *If the digit to the immediate right of the last significant figure is equal to five and is followed by a nonzero digit, round up the last significant figure.* 2.5351 $\rightarrow$ 2.54
4. *If the digit to the immediate right of the last significant figure is equal to five and is not followed by a nonzero digit, look at the last significant figure. If it is an odd digit, round it up. If it is an even digit, do not round up.* 2.5350 $\rightarrow$ 2.54 but 2.5250 $\rightarrow$ 2.52

EXAMPLE PROBLEM 2-7

Applying the Rounding Rules

Round 3.515 014 to (a) five significant figures, then to (b) three significant figures, and finally to (c) one significant figure.

1. Analyze the Problem

You are given a number that has seven significant figures. You will remove two figures with each step. You will need to choose the rule that is appropriate for each step.

2. Solve for the Unknown

a. Round 3.515 014 to five significant figures.

Rule 1 applies. The last significant digit is 0. The number to its immediate right is 1, which is less than 5. The zero does not change. The answer is 3.5150.

b. Round 3.5150 to three significant figures.

Rule 4 applies. The last significant digit is 1. The number to its immediate right is a 5 that is not followed by a nonzero digit. Because the 1 is an odd number it is rounded up to 2.
The answer is 3.52.

c. Round 3.52 to one significant figure.

Rule 3 applies. The last significant digit is 3. The number to its immediate right is a 5 that is followed by a nonzero digit. Thus, the 3 is rounded up to 4.
The answer is 4.

3. Evaluate the Answer

The final answer, 4, makes sense because 3.515 013 7 is greater than the halfway point between 3 and 4, which is 3.5.

PRACTICE PROBLEMS

Round all numbers to four significant figures. Write the answers to problem 34 in scientific notation.

33. a. 84 791 kg
b. 38.5432 g
c. 256.75 cm
d. 4.9356 m

34. a. 0.000 548 18 g
b. 136 758 kg
c. 308 659 000 mm
d. 2.0145 mL

Addition and subtraction When you add or subtract measurements, your answer must have the same number of digits to the right of the decimal point as the value with the fewest digits to the right of the decimal point. For example, the measurement 1.24 mL has two digits to the right of the decimal point. The measurement 12.4 mL has one digit to the right of the decimal point. The measurement 124 mL has zero digits to the right of the decimal point, which is understood to be to the right of the 4. The easiest way to solve addition and subtraction problems is to arrange the values so that the decimal points line up. Then do the sum or subtraction. Identify the value with the fewest places after the decimal point. Round the answer to the same number of places.

EXAMPLE PROBLEM 2-8

Applying Rounding Rules to Addition

Add the following measurements: 28.0 cm, 23.538 cm, and 25.68 cm.

1. Analyze the Problem

There are three measurements that need to be aligned on their decimal points and added. The measurement with the fewest digits after the decimal point is 28.0 cm, with one digit. Thus, the answer must be rounded to only one digit after the decimal point.

2. Solve for the Unknown

Line up the measurements.

$$\begin{array}{rl} & 28.0\text{ cm} \\ & 23.538\text{ cm} \\ + & 25.68\text{ cm} \\ \hline & 77.218\text{ cm} \end{array}$$

Because the digit immediately to the right of the last significant digit is less than 5, rule 1 applies. The answer is 77.2 cm.

3. Evaluate the Answer

The answer, 77.2 cm, has the same precision as the least precise measurement, 28.0 cm.

PRACTICE PROBLEMS

Complete the following addition and subtraction problems. Round off the answers when necessary.

35. a. 43.2 cm + 51.0 cm + 48.7 cm
b. 258.3 kg + 257.11 kg + 253 kg
c. 0.0487 mg + 0.058 34 mg + 0.004 83 mg

36. a. 93.26 cm – 81.14 cm
b. 5.236 cm – 3.14 cm
c. 4.32×10^3 cm – 1.6×10^3 cm

Careers Using Chemistry

Scientific Illustrator

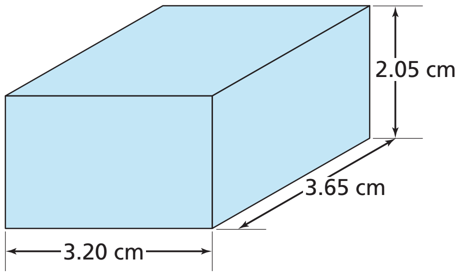
Imagine the expertise that went into illustrating this book. You can combine a science background with your artistic ability in the technically demanding career of scientific illustrator.

Scientific illustrations are a form of art required for textbooks, museum exhibits, Web sites, and publications of scientific research. These figures often show what photographs cannot—the reconstruction of an object from fragments, comparisons among objects, or the demonstration of a process or idea. Scientific illustrators use everything from paper and pencil to computer software to provide this vital link in the scientific process.

Practice!

For more practice with rounding after addition or subtraction, go to **Supplemental Practice Problems** in Appendix A.

Multiplication and division When you multiply or divide numbers, your answer must have the same number of significant figures as the measurement with the fewest significant figures.



To find the volume of a rectangular object, multiply the length of the base times the width times the height.

EXAMPLE PROBLEM 2-9

Applying Rounding Rules to Multiplication

Calculate the volume of a rectangular object with the following dimensions: length = 3.65 cm; width = 3.20 cm; height = 2.05 cm.

1. Analyze the Problem

You are given measurements for the length, width, and height of a rectangular object. Because all three measurements have three significant figures, the answer will have three significant figures. Note that the units must be multiplied too.

2. Solve for the Unknown

To find the volume of a rectangular object, multiply the length times the width times the height.

$3.20 \text{ cm} \times 3.65 \text{ cm} \times 2.05 \text{ cm} = 23.944 \text{ cm}^3$

Because the data have only three significant figures, the answer can have only three significant figures.

The answer is 23.9 cm^3.

3. Evaluate the Answer

To test if your answer is reasonable, round the data to one significant figure. Multiply $3 \text{ cm} \times 4 \text{ cm} \times 2 \text{ cm}$ to get 24 cm^3. Your answer, 23.9 cm^3, has the same number of significant figures as the data. All three measurements should have the same number of significant figures because the same ruler or tape measure was used to collect the data.

PRACTICE PROBLEMS

Complete the following calculations. Round off the answers to the correct number of significant figures.

37. **a.** 24 m × 3.26 m
b. 120 m × 0.10 m
c. 1.23 m × 2.0 m
d. 53.0 m × 1.53 m

38. **a.** 4.84 m/2.4 s
b. 60.2 m/20.1 s
c. 102.4 m/51.2 s
d. 168 m/58 s

Practice!

For more practice with rounding after multiplication, go to **Supplemental Practice Problems** in Appendix A.

Section 2.3 Assessment

39. A piece of wood has a labeled length value of 76.49 cm. You measure its length three times and record the following data: 76.48 cm, 76.47 cm, and 76.59 cm. How many significant figures do these measurements have?

40. Are the measurements in problem 39 accurate? Are they precise? Explain your answers.

41. Calculate the percent error for each measurement in problem 39.

42. Round 76.51 cm to two significant figures. Then round your answer to one significant figure.

43. **Thinking Critically** Which of these measurements was made with the most precise measuring device: 8.1956 m, 8.20 m, or 8.196 m? Explain your answer.

44. **Using Numbers** Write an expression for the quantity 506 000 cm in which it is clear that all the zeros are significant.

Section 2.4 Representing Data

When you analyze data, you may set up an equation and solve for an unknown, but this is not the only method scientists have for analyzing data. A goal of many experiments is to discover whether a pattern exists in a certain situation. Does raising the temperature change the rate of a reaction? Does a change in diet affect a rat's ability to solve a maze? When data are listed in a table such as **Table 2-6,** a pattern may not be obvious.

Objectives

- **Create** graphs to reveal patterns in data.
- **Interpret** graphs.

Vocabulary

graph

Graphing

Using data to create a graph can help to reveal a pattern if one exists. A **graph** is a visual display of data. Have you ever heard the saying, "A picture is worth a thousand words?"

Circle graphs If you read a paper or a news magazine, you will find many graphs. The circle graph in **Figure 2-13a** is sometimes called a pie chart because it is divided into wedges like a pie or pizza. A circle graph is useful for showing parts of a fixed whole. The parts are usually labeled as percents with the circle as a whole representing 100%. The graph in **Figure 2-13a** is based on the data in **Table 2-6.** What percent of the chlorine sources are natural? What percent are manufactured compounds? Which source supplies the most chlorine to the stratosphere?

Bar graph A bar graph often is used to show how a quantity varies with factors such as time, location, or temperature. In those cases, the quantity being measured appears on the vertical axis (y-axis). The independent variable appears on the horizontal axis (x-axis). The relative heights of the bars show how the quantity varies. A bar graph can be used to compare population figures for a country by decade. It can compare annual precipitation for different cities or average monthly precipitation for a single location, as in **Figure 2-13b.** The precipitation data was collected over a 30-year period (1961–1990). During which four months does Jacksonville receive about half of its annual precipitation?

Table 2-6

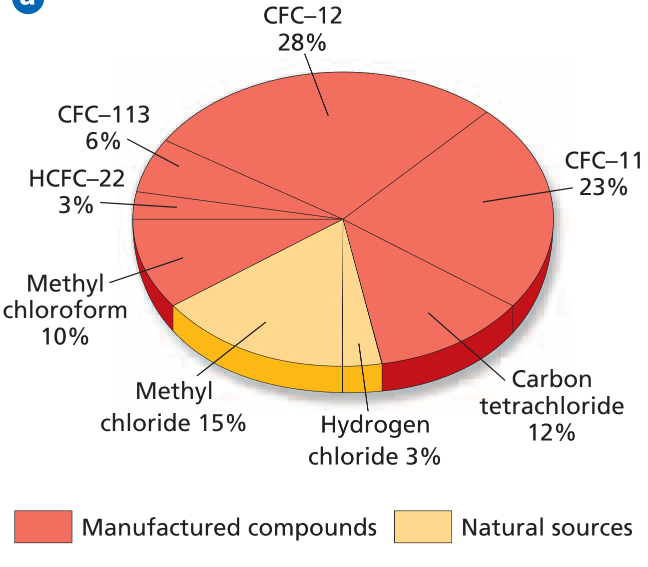
Sources of Chlorine in the Stratosphere

Source	Percent
Hydrogen chloride	3
Methyl chloride	15
Carbon tetrachloride	12
Methyl chloroform	10
CFC-11	23
CFC-12	28
CFC-113	6
HCFC-22	3

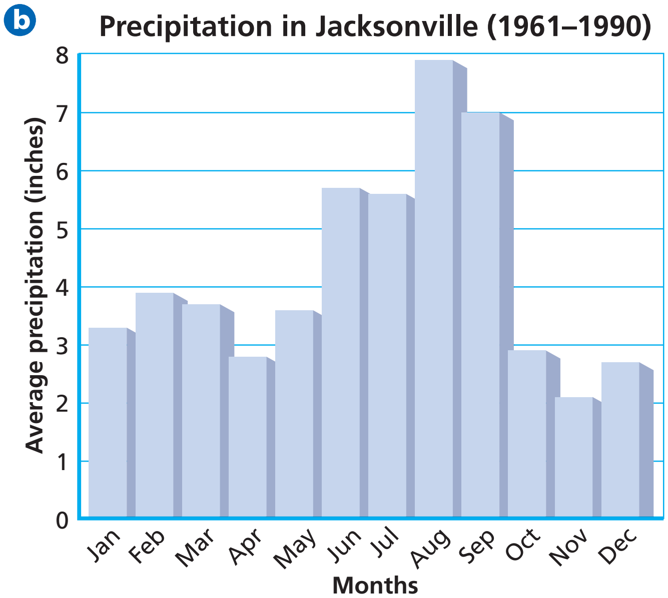
Figure 2-13

What do circle graphs and bar graphs have in common?

a



b



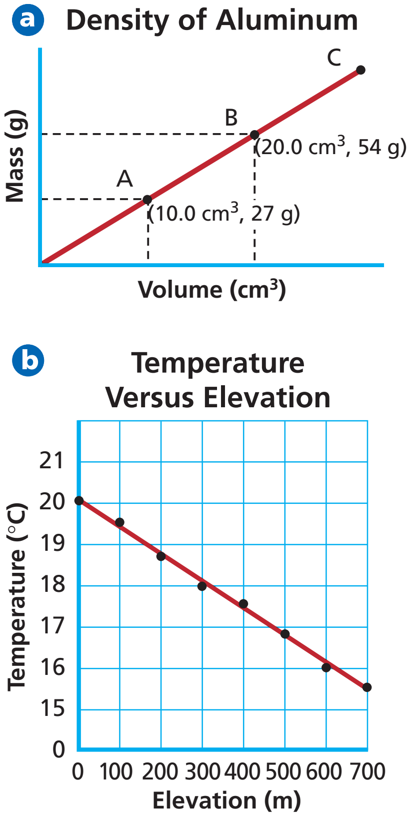


Figure 2-14

Compare the slopes of these two graphs.

Line Graphs

In chemistry, most graphs that you create and interpret will be line graphs. The points on a line graph represent the intersection of data for two variables. The independent variable is plotted on the *x*-axis. The dependent variable is plotted on the *y*-axis. Remember that the independent variable is the variable that a scientist deliberately changes during an experiment. In **Figure 2-14a,** the independent variable is volume and the dependent variable is mass. What are the values for the independent variable and the dependent variable at point B? **Figure 2-14b** is a graph of elevation versus temperature. Because the points are scattered, the line cannot pass through all the data points. The line must be drawn so that about as many points fall above the line as fall below it. This line is called a best fit line.

If the best fit line is straight, there is a linear relationship between the variables and the variables are *directly* related. This relationship can be further described by the steepness, or slope, of the line. If the line rises to the right, the slope is *positive*. A positive slope indicates that the dependent variable *increases* as the independent variable increases. If the line sinks to the right, the slope is *negative*. A negative slope indicates that the dependent variable *decreases* as the independent variable increases. Either way, the slope of the graph is constant. You can use the data points to calculate the slope of the line. The slope is the change in *y* divided by the change in *x*.

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta y}{\Delta x}$$

Calculate the slope for the line in **Figure 2-14a** using data points A and B.

$$\text{slope} = \frac{54\text{ g} - 27\text{ g}}{20.0\text{ cm}^3 - 10.0\text{ cm}^3} = \frac{27\text{ g}}{10.0\text{ cm}^3} = 2.7\text{ g/cm}^3$$

When the mass of a material is plotted against volume, the slope of the line is the density of the material. Do the **CHEMLAB** at the end of the chapter to learn more about using a graph to find density.

problem-solving LAB

How does speed affect stopping distance?

Making and Using Graphs Use the steps below and the data to make a line graph.

Speed (m/s)	11	16	20	25	29
Stopping distance (m)	18	32	49	68	92

1. Identify the independent and dependent variables.
2. Determine the range of data that needs to be plotted for each axis. Choose intervals for the axes that spread out the data. Make each square on the graph a multiple of 1, 2, or 5.
3. Number and label each axis.
4. Plot the data points.
5. Draw a best fit line for the data. The line may be straight or it may be curved. Not all points may fall on the line.
6. Give the graph a title.

Analysis

What does the graph tell you about the relationship between speed and stopping distance?

Thinking Critically

There are two components to stopping distance: reaction distance (distance traveled before the driver applies the brake) and braking distance (distance traveled after the brake is applied). Predict which component will increase more rapidly as the speed increases. Explain your choice.

When the best fit line is curved, the relationship between the variables is nonlinear. In chemistry, you will study nonlinear relationships called inverse relationships. See pages 903–907 in the **Math Handbook** for more discussion of graphs. Do the **problem-solving LAB** to practice making line graphs.

Interpreting Graphs

An organized approach can help you understand the information on a graph. First, identify the independent and dependent variables. Look at the ranges of the data and consider what measurements were taken. Decide if the relationship between the variables is linear or nonlinear. If the relationship is linear, is the slope positive or negative? If a graph has multiple lines or regions, study one area at a time.

When points on a line graph are connected, the data is considered continuous. You can read data from a graph that falls between measured points. This process is called interpolation. You can extend the line beyond the plotted points and estimate values for the variables. This process is called extrapolation. Why might extrapolation be less reliable than interpolation?

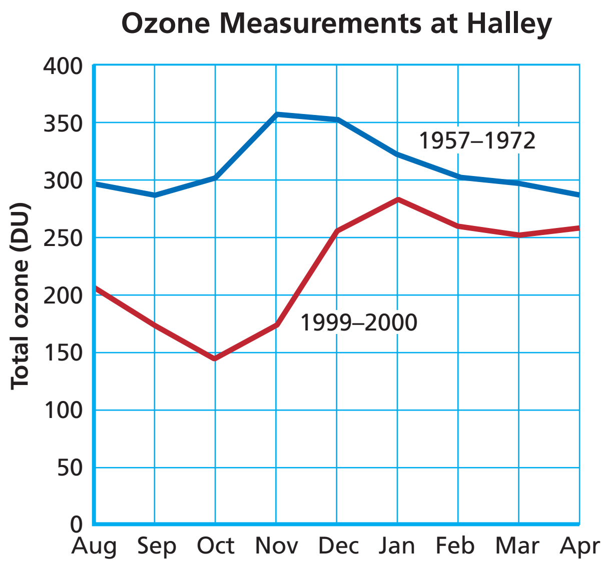


Figure 2-15

In Antarctica, spring begins in October and winter begins in April. Why are there no measurements from May to July?

Interpreting ozone data **Figure 2-15** is a graph of ozone measurements taken at a scientific settlement in Antarctica called Halley. The independent variable is months of the year. The dependent variable is total ozone measured in Dobson units (DU). The graph shows how ozone levels vary from August to April. There are two lines on the graph. Multiple lines allow scientists to introduce a third variable, in this case different periods of time. Having two lines on the same graph allows scientists to compare data gathered before the ozone hole developed with data from a recent season. They can identify a significant trend in ozone levels and verify the depletion in ozone levels over time.

The top line represents average ozone levels for the period 1957–1972. Follow the line from left to right. Ozone levels were about 300 DU in early October. By November, they rose to about 360 DU. Ozone levels slowly dropped back to around 290 DU by April. The bottom line shows the ozone levels from the 1999–2000 survey. The ozone levels were around 200 DU in August, dipped to about 150 DU during October, and slowly rose to a maximum of about 280 DU in January. At no point during this 9-month period were the ozone levels as high as they were at the corresponding points during 1957–1972. The "ozone hole" is represented by the dip in the bottom line. Based on the graph, was there an ozone hole in the 1957–1972 era?

Section 2.4 Assessment

45. Explain why graphing can be an important tool for analyzing data.

46. What type of data can be displayed on a circle graph? On a bar graph?

47. If a linear graph has a negative slope, what can you say about the dependent variable?

48. When can the slope of a graph represent density?

49. **Thinking Critically** Why does it make sense for the line in **Figure 2-14a** to extend to 0, 0 even though this point was not measured?

50. **Interpreting Graphs** Using **Figure 2-15,** determine how many months the ozone hole lasts.

Using Density to Find the Thickness of a Wire

The thickness of wire often is measured using a system called the American Wire Gauge (AWG) standard. The smaller the gauge number, the larger the diameter of the wire. For example, 18-gauge copper wire has a diameter of about 0.102 cm; 12-gauge copper wire has a diameter of about 0.205 cm. Such small diameters are difficult to measure accurately with a metric ruler. In this experiment, you will plot measurements of mass and volume to find the density of copper. Then, you will use the density of copper to confirm the gauge of copper wire.

Problem

How can density be used to verify the diameter of copper wire?

Objectives

- **Collect** and **graph** mass and volume data to find the density of copper.
- **Measure** the length and volume of a copper wire, and **calculate** its diameter.
- **Calculate** percent errors for the results.

Materials

tap water
100-mL graduated cylinder
small cup, plastic
balance
copper shot
copper wire (12-gauge, 18-gauge)
metric ruler
pencil
graph paper
graphing calculator (optional)

Safety Precautions

- **Always wear safety goggles and a lab apron.**

Pre-Lab

1. Read the entire **CHEMLAB.**
2. What is the equation used to calculate density?
3. How can you find the volume of a solid that has an irregular shape?
4. What is a meniscus and how does it affect volume readings?
5. If you plot mass versus volume, what property of matter will the slope of the graph represent?
6. How do you find the slope of a graph?
7. A piece of copper wire is a narrow cylinder. The equation for the volume of a cylinder is
$$V = \pi r^2 h$$
where V is the volume, r is the radius, h is the height, and π (pi) is a constant with a value of 3.14. Rearrange the equation to solve for r.
8. What is the relationship between the diameter and the radius of a cylinder?
9. Prepare two data tables.

Density of Copper

Trial	Mass of copper added	Total mass of copper	Total volume of water displaced
1			
2			
3			
4			

Diameter of Copper Wire

	12-gauge	18-gauge
Length		
Mass		
Measured diameter		
Calculated diameter		

Procedure

Record all measurements in your data tables.

1. Pour about 20 mL of water into a 100-mL graduated cylinder. Read the actual volume.
2. Find the mass of the plastic cup.
3. Add about 10 g of copper shot to the cup and find the mass again.
4. Pour the copper shot into the graduated cylinder and read the new volume.
5. Repeat steps 3 and 4 three times. By the end of the four trials, you will have about 40 g of copper in the graduated cylinder.
6. Obtain a piece of 12-gauge copper wire and a piece of 18-gauge copper wire. Use a metric ruler to measure the length and diameter of each wire.
7. Wrap each wire around a pencil to form a coil. Remove the coils from the pencil. Find the mass of each coil.

Cleanup and Disposal

1. Carefully drain off most of the water from the graduated cylinder. Make sure all of the copper shot remains in the cylinder.
2. Pour the copper shot onto a paper towel to dry. Both the copper shot and wire can be reused.

Analyze and Conclude

1. **Using Numbers** Complete the table for the density of copper by calculating the total mass of copper and the total water displaced for each trial.
2. **Making and Using Graphs** Graph total mass versus total volume of copper. Draw a line that best fits the points. Then use two points on your line to find the slope of your graph. Because density equals mass divided by volume, the slope will give you the density of copper.

   If you are using a graphing calculator, select the 5:FIT CURVE option from the MAIN MENU of the ChemBio program. Choose 1:LINEAR L1,L2 from the REGRESSION/LIST to help you plot and calculate the slope of the graph.
3. **Using Numbers** Calculate the percent error for your value of density.
4. **Using Numbers** To complete the second data table, you must calculate the diameter for each wire. Use the accepted value for the density of copper and the mass of each wire to calculate volume. Then use the equation for the volume of a cylinder to solve for the radius. Double the radius to find the diameter.
5. **Comparing and Contrasting** How do your calculated values for the diameter compare to your measured values and to the AWG values listed in the introduction?
6. **Error Analysis** How could you change the procedure to reduce the percent error for density?

Real-World Chemistry

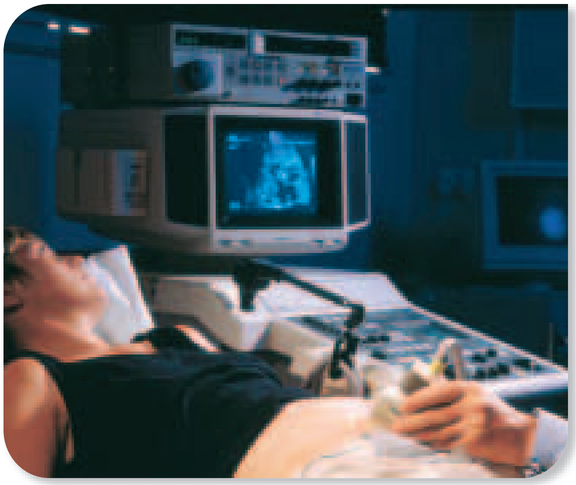
1. There is a standard called the British Imperial Standard Wire Gauge (SWG) that is used in England and Canada. Research the SWG standard to find out how it differs from the AWG standard. Are they the only standards used for wire gauge?
2. Interview an electrician or a building inspector who reviews the wiring in new or remodeled buildings. Ask what the codes are for the wires used and how the diameter of a wire affects its ability to safely conduct electricity. Ask to see a wiring diagram.

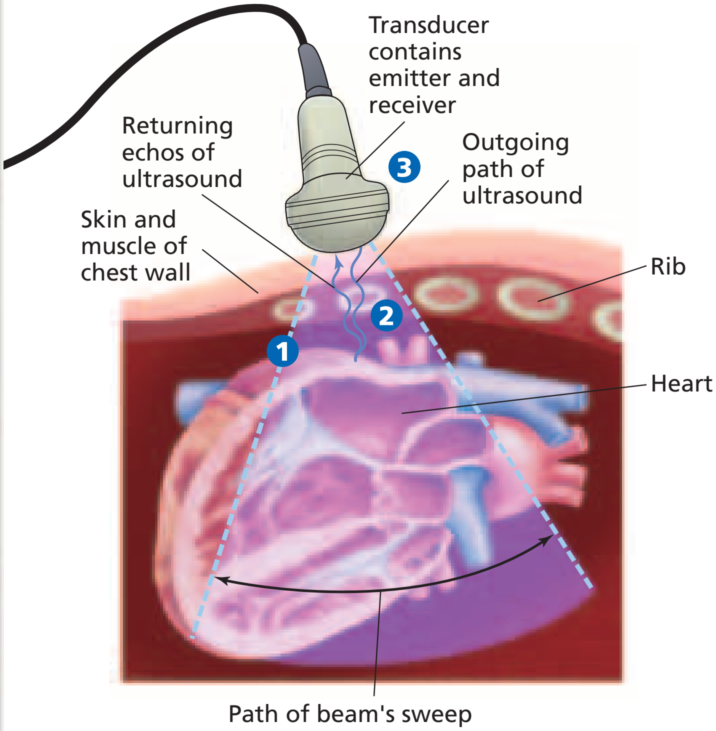
How It Works

Ultrasound Devices

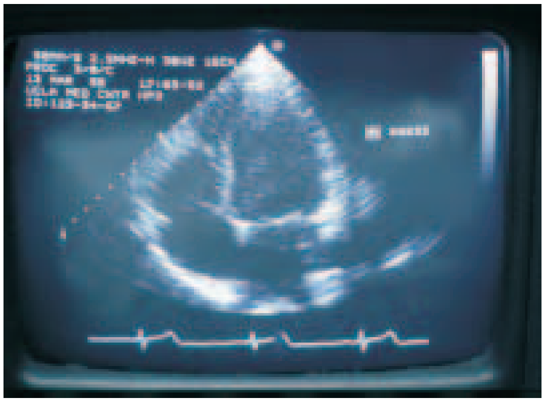
An ultrasound device is a diagnostic tool that allows doctors to see inside the human body without having to perform surgery. With an ultrasound device, doctors can detect abnormal growths, follow the development of a fetus in the uterus, or study the action of heart valves.

An ultrasound device emits high-frequency sound waves that can pass through a material, be absorbed, or reflect off the surface of a material. Waves are reflected at the border between tissues with different densities, such as an organ and a tumor. The larger the difference in density, the greater the reflection.





1. In the transducer, electrical pulses are changed into sound waves, which are aimed at a specific part of the body.
2. As the transducer is moved across the body, some sound is reflected back as echoes.
3. A receiver detects the reflected waves and converts the sound back into electrical pulses.
4. A computer analyzes the data and creates an image of an internal organ, such as the heart.



4

Thinking Critically

1. **Predicting** If all parts of the heart had the same density, would doctors be able to use ultrasound to detect heart defects? Explain.
2. **Inferring** Why is it considered safe to use ultrasound but not X rays during pregnancy?

Summary

2.1 Units of Measurement

- SI measurement units allow scientists to report data that can be reproduced by other scientists.
- Adding prefixes to SI units extends the range of possible measurements.
- SI base units include the meter for length, the second for time, the kilogram for mass, and the kelvin for temperature.
- Volume and density have derived units. Density is the ratio of mass to volume. Density can be used to identify a sample of matter.

2.2 Scientific Notation and Dimensional Analysis

- Scientific notation makes it easier to handle extremely large or small measurements.
- Numbers expressed in scientific notation are a product of two factors: (1) a number between 1 and 10 and (2) ten raised to a power.
- Numbers added or subtracted in scientific notation must be expressed to the same power of ten.
- When measurements are multiplied or divided in scientific notation, their exponents are added or subtracted, respectively.
- Dimensional analysis often uses conversion factors to solve problems that involve units. A conversion factor is a ratio of equivalent values.

2.3 How reliable are measurements?

- An accurate measurement is close to the accepted value. Precise measurements show little variation over a series of trials.
- The type of measurement instrument determines the degree of precision possible.
- Percent error compares the size of an error in experimental data to the size of the accepted value.
- The number of significant figures reflects the precision of reported data. Answers to calculations are rounded off to maintain the correct number of significant figures.

2.4 Representing Data

- Graphs are visual representations of data. Graphs can reveal patterns in data.
- Circle graphs show parts of a whole. Bar graphs can show how a factor varies with time, location, or temperature.
- The relationship between the independent and dependent variables on a line graph can be linear or nonlinear.
- Because the data on a line graph are considered continuous, you can interpolate or extrapolate data from a line graph.

Key Equations and Relationships

- density: (p. 28) $\text{density} = \dfrac{\text{mass}}{\text{volume}}$
- conversion between temperature scales: (p. 30) $°C + 273 = K$; $K - 273 = °C$
- percent error: (p. 37) $\text{percent error} = \dfrac{\text{error}}{\text{accepted value}} \times 100$
- slope of graph: (p. 44) $\text{slope} = \dfrac{y_2 - y_1}{x_2 - x_1} = \dfrac{\Delta y}{\Delta x}$

Vocabulary

- accuracy (p. 36)
- base unit (p. 26)
- conversion factor (p. 34)
- density (p. 27)
- derived unit (p. 27)
- dimensional analysis (p. 34)
- graph (p. 43)
- kelvin (p. 30)
- kilogram (p. 27)
- liter (p. 27)
- meter (p. 26)
- percent error (p. 37)
- precision (p. 36)
- scientific notation (p. 31)
- second (p. 26)
- significant figure (p. 38)

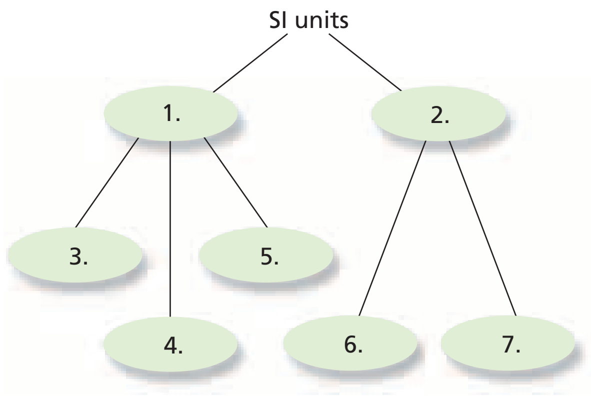
chemistrymc.com/vocabulary_puzzlemaker

CHAPTER 2 ASSESSMENT

Go to the Chemistry Web site at **chemistrymc.com** *for additional Chapter 2 Assessment.*

Concept Mapping

51. Use the following terms to complete the concept map: volume, derived unit, mass, density, base unit, time, length.



Mastering Concepts

52. Why must a measurement include both a number and a unit? (2.1)

53. Explain why scientists, in particular, need standard units of measurement. (2.1)

54. What role do prefixes play in the metric system? (2.1)

55. How many meters are there in one kilometer? In one decimeter? (2.1)

56. What is the relationship between the SI unit for volume and the SI unit for length? (2.1)

57. Explain how temperatures on the Celsius and Kelvin scales are related. (2.1)

58. How does scientific notation differ from ordinary notation? (2.2)

59. If you move the decimal place to the left to convert a number into scientific notation, will the power of ten be positive or negative? (2.2)

60. When dividing numbers in scientific notation, what must you do with the exponents? (2.2)

61. When you convert from a small unit to a large unit, what happens to the number of units? (2.2)

62. If you report two measurements of mass, 7.42 g and 7.56 g, are the measurements accurate? Are they precise? Explain your answers. (2.3)

63. When converting from meters to centimeters, how do you decide which values to place in the numerator and denominator of the conversion factor? (2.2)

64. Why are plus and minus signs ignored in percent error calculations? (2.3)

65. In 50 540, which zero is significant? What is the other zero called? (2.3)

66. Which of the following three numbers will produce the same number when rounded to three significant figures: 3.456, 3.450, or 3.448? (2.3)

67. When subtracting 61.45 g from 242.6 g, which factor determines the number of significant figures in the answer? Explain. (2.3)

68. When multiplying 602.4 m by 3.72 m, which factor determines the number of significant figures in the answer? Explain. (2.3)

69. Which type of graph would you choose to depict data on how many households heat with gas, oil, or electricity? Explain. (2.4)

70. Which type of graph would you choose to depict changes in gasoline consumption over a period of ten years? Explain. (2.4)

71. How can you find the slope of a line graph? (2.4)

Mastering Problems

Density (2.1)

72. A 5-mL sample of water has a mass of 5 g. What is the density of water?

73. An object with a mass of 7.5 g raises the level of water in a graduated cylinder from 25.1 mL to 30.1 mL. What is the density of the object?

74. The density of aluminum is 2.7 g/mL. What is the volume of 8.1 g?

Scientific Notation (2.2)

75. Write the following numbers in scientific notation.

a. 0.004 583 4 mm
b. 0.03054 g
c. 438 904 s
d. 7 004 300 000 g

76. Write the following numbers in ordinary notation.

a. 8.348×10^6 km
b. 3.402×10^3 g
c. 7.6352×10^{-3} kg
d. 3.02×10^{-5} s

77. Complete the following addition and subtraction problems in scientific notation.

a. 6.23×10^6 kL + 5.34×10^6 kL
b. 3.1×10^4 mm + 4.87×10^5 mm
c. 7.21×10^3 mg + 43.8×10^2 mg
d. 9.15×10^{-4} cm + 3.48×10^{-4} cm
e. 4.68×10^{-5} cg + 3.5×10^{-6} cg
f. 3.57×10^2 mL − 1.43×10^2 mL
g. 9.87×10^4 g − 6.2×10^3 g
h. 7.52×10^5 kg − 5.43×10^5 kg
i. 6.48×10^{-3} mm − 2.81×10^{-3} mm
j. 5.72×10^{-4} dg − 2.3×10^{-5} dg

78. Complete the following multiplication and division problems in scientific notation.

a. $(4.8 \times 10^5$ km$) \times (2.0 \times 10^3$ km$)$
b. $(3.33 \times 10^{-4}$ m$) \times (3.00 \times 10^{-5}$ m$)$
c. $(1.2 \times 10^6$ m$) \times (1.5 \times 10^{-7}$ m$)$
d. $(8.42 \times 10^8$ kL$) \div (4.21 \times 10^3$ kL$)$
e. $(8.4 \times 10^6$ L$) \div (2.4 \times 10^{-3}$ L$)$
f. $(3.3 \times 10^{-4}$ mL$) \div (1.1 \times 10^{-6}$ mL$)$

Conversion Factors (2.2)

79. Write the conversion factor that converts

a. grams to kilograms
b. kilograms to grams
c. millimeters to meters
d. meters to millimeters
e. milliliters to liters
f. centimeters to meters

80. Convert the following measurements.

a. 5.70 g to milligrams
b. 4.37 cm to meters
c. 783 kg to grams
d. 45.3 mm to meters
e. 10 m to centimeters
f. 37.5 g/mL to kg/L

Percent Error (2.3)

81. The accepted length of a steel pipe is 5.5 m. Calculate the percent error for each of these measurements.

a. 5.2 m
b. 5.5 m
c. 5.7 m
d. 5.1 m

82. The accepted density for copper is 8.96 g/mL. Calculate the percent error for each of these measurements.

a. 8.86 g/mL
b. 8.92 g/mL
c. 9.00 g/mL
d. 8.98 g/mL

Significant Figures (2.3)

83. Round each number to four significant figures.

a. 431 801 kg
b. 10 235.0 mg
c. 1.0348 m
d. 0.004 384 010 cm
e. 0.000 781 00 mL
f. 0.009 864 1 cg

84. Round each figure to three significant figures.

a. 0.003 210 g
b. 3.8754 kg
c. 219 034 m
d. 25.38 L
e. 0.087 63 cm
f. 0.003 109 mg

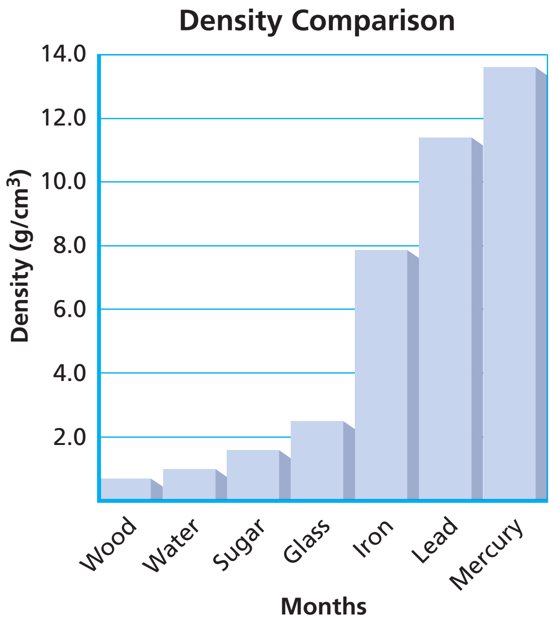
85. Round the answers to each of the following problems to the correct number of significant figures.

a. $7.31 \times 10^4 + 3.23 \times 10^3$
b. $8.54 \times 10^{-3} - 3.41 \times 10^{-4}$
c. 4.35 dm × 2.34 dm × 7.35 dm
d. 4.78 cm + 3.218 cm + 5.82 cm
e. 3.40 mg + 7.34 mg + 6.45 mg
f. 45 m × 72 m × 132 m
g. 38736 km/4784 km

Representing Data (2.4)

86. Use the accompanying bar graph to answer the following questions.

a. Which substance has the greatest density?
b. Which substance has the least density?
c. Which substance has a density of 7.87 g/cm^3?
d. Which substance has a density of 11.4 g/ cm^3?



87. Graph the following data with the volume on the *x*-axis and the mass on the *y*-axis. Then calculate the slope of the line.

Table 2-7

Density Data	
Volume (mL)	**Mass (g)**
2.0 mL	5.4
4.0 mL	10.8
6.0 mL	16.2
8.0 mL	21. 6
10.0 mL	27.0

Mixed Review

Sharpen your problem-solving skills by answering the following.

88. You have a 23-g sample of ethanol with a density of 0.7893 g/mL. What volume of ethanol do you have?

89. Complete the following problems in scientific notation. Round off to the correct number of significant figures.

a. $(5.31 \times 10^{-2}\ \text{cm}) \times (2.46 \times 10^{5}\ \text{cm})$
b. $(3.78 \times 10^{3}\ \text{m}) \times (7.21 \times 10^{2}\ \text{m})$
c. $(8.12 \times 10^{-3}\ \text{m}) \times (1.14 \times 10^{-5}\ \text{m})$
d. $(5.53 \times 10^{-6}\ \text{km}) \times (7.64 \times 10^{3}\ \text{km})$
e. $(9.33 \times 10^{4}\ \text{mm}) \div (3.0 \times 10^{2}\ \text{mm})$
f. $(4.42 \times 10^{-3}\ \text{kg}) \div (2.0 \times 10^{2}\ \text{kg})$
g. $(6.42 \times 10^{-2}\ \text{g}) \div (3.21 \times 10^{-3}\ \text{g})$

90. Evaluate the following conversion. Will the answer be correct? Explain.

$$\text{rate} = \frac{75\ \text{m}}{1\ \text{s}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{1\ \text{h}}{60\ \text{min}}$$

91. What mass of lead (density 11.4 g/cm^3) would have an identical volume to 15.0 g of mercury (density 13.6 g/cm^3)?

92. Three students use a meterstick to measure a length of wire. One student records a measurement of 3 cm. The second records 3.3 cm. The third records 2.87 cm. Explain which answer was recorded correctly.

93. Express each quantity in the unit listed to its right.

a. 3.01 g	cg	**d.** 0.2 L	dm^3
b. 6200 m	km	**e.** 0.13 cal/g	kcal/g
c. 6.24×10^{-7} g	µg	**f.** 3.21 mL	L

94. The black hole in the galaxy M82 has a mass about 500 times the mass of our Sun. It has about the same volume as Earth's moon. What is the density of this black hole?

$\text{mass}_{\text{sun}} = 1.9891 \times 10^{30}\ \text{kg}$

$\text{volume}_{\text{moon}} = 2.1968 \times 10^{10}\ \text{km}^3$

95. The density of water is 1 g/cm^3. Use your answer to question 94 to compare the densities of water and a black hole.

Thinking Critically

96. Comparing and Contrasting What advantages do SI units have over the units in common use in the United States? Is there any disadvantage to using SI units?

97. Forming a Hypothesis Why do you think the SI standard for time was based on the distance light travels through a vacuum?

98. Inferring Explain why the mass of an object cannot help you identify what material the object is made from.

99. Drawing Conclusions Why might property owners hire a surveyor to determine property boundaries rather than measure the boundaries themselves?

Writing in Chemistry

100. Although the standard kilogram is stored at constant temperature and humidity, unwanted matter can build up on its surface. Scientists have been looking for a more reliable standard for mass. Research and describe alternate standards that have been proposed. Find out why no alternate standard has been chosen.

101. Research and report on some unusual units of measurement such as bushels, pecks, firkins, and frails.

102. Research the range of volumes used for packaging liquids sold in supermarkets.

103. Find out what the acceptable limits of error are for some manufactured products or for the doses of medicine given at a hospital.

Cumulative Review

Refresh your understanding of previous chapters by answering the following.

104. You record the following in your lab book: A liquid is thick and has a density of 4.58 g/mL. Which data is qualitative? Which is quantitative? (Chapter 1)

Use the questions and the test-taking tip to prepare for your standardized test.

1. Which of the following is *not* an SI base unit?

a. second (s)
b. kilogram (kg)
c. degrees Celsius (°C)
d. meter (m)

2. Which of the following values is NOT equivalent to the others?

a. 500 meters
b. 0.5 kilometers
c. 5000 centimeters
d. 5×10^{11} nanometers

3. What is the correct representation of 702.0 g using scientific notation?

a. 7.02×10^{3} g
b. 70.20×10^{1} g
c. 7.020×10^{2} g
d. 70.20×10^{2} g

4. Three students measured the length of a stamp whose accepted length is 2.71 cm. Based on the table, which statement is true?

a. Student 2 is both precise and accurate.
b. Student 1 is more accurate than Student 3.
c. Student 2 is less precise than Student 1.
d. Student 3 is both precise and accurate.

Measured Values for a Stamp's Length

	Student 1	Student 2	Student 3
Trial 1	2.60 cm	2.70 cm	2.75 cm
Trial 2	2.72 cm	2.69 cm	2.74 cm
Trial 3	2.65 cm	2.71 cm	2.64 cm
Average	2.66 cm	2.70 cm	2.71 cm

5. Chemists found that a complex reaction occurred in three steps. The first step takes 2.5731×10^{2} s to complete, the second step takes 3.60×10^{-1} s, and the third step takes 7.482×10^{1} s. What is the total amount of time elapsed during the reaction?

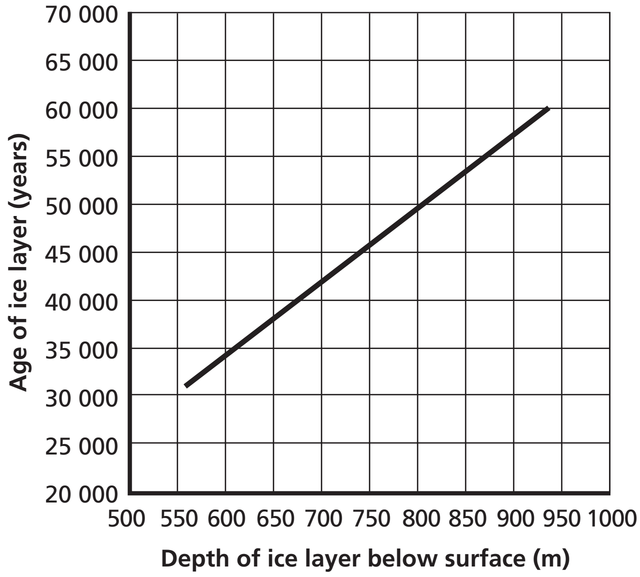
a. 3.68×10^{1} s
b. 7.78×10^{1} s
c. 1.37×10^{1} s
d. 3.3249×10^{2} s

6. How many significant figures are there in a distance measurement of 20.070 km?

a. 2
b. 3
c. 4
d. 5

Interpreting Graphs Use the graph to answer the following questions.

Age of Ice Layers in Vostok Ice Sheet



7. Using the graph, a student reported the age of an ice layer at 705 m as 4.250×10^{4} years. The accepted value for the age of this ice layer is 4.268×10^{4} years. What is the percent error of the student's value?

a. 0.4217%
b. 99.58%
c. 0.4235%
d. 1.800%

8. The slope of the graph is about ______ .

a. 80 years/m
b. 80 m/year
c. 0.015 years/m
d. 1500 m/year

9. What age is an ice layer found at a depth of 1000 m?

a. 6.75×10^{4} years
b. 7.00×10^{4} years
c. 6.25×10^{4} years
d. 6.5×10^{4} years

TEST-TAKING TIP

Practice Under Test-Like Conditions

Ask your teacher to set a time limit. Then do all of the questions in the time provided without referring to your book. Did you complete the test? Could you have made better use of your time? What topics do you need to review? Show your test to your teacher for an objective assessment of your performance.