Analyzing Data

BIG Idea Chemists collect and analyze data to determine how matter interacts.

2.1 Units and Measurements
MAIN Idea Chemists use an internationally recognized system of units to communicate their findings.

2.2 Scientific Notation and Dimensional Analysis
MAIN Idea Scientists often express numbers in scientific notation and solve problems using dimensional analysis.

2.3 Uncertainty in Data
MAIN Idea Measurements contain uncertainties that affect how a calculated result is presented.

2.4 Representing Data
MAIN Idea Graphs visually depict data, making it easier to see patterns and trends.

Parachute opens

Begins free fall

ChemFacts

- Most skydivers jump from an altitude of about 4000 m.

- A skydiver's maximum speed is about 190 km/h, but speeds as high as 483 km/h have been achieved.

- The freefall portion of a dive usually lasts more than a minute, while the parachute portion lasts 5–9 minutes.

- Critical altitudes for skydivers include the minimum altitude at which the main parachute can be safely deployed and the minimum altitude for cutting away the main chute and deploying the reserve.

- High-quality altimeters are accurate to ±1%.

LAUNCH Lab

How can you form layers of liquids?

You know that ice floats in water, whereas a rock sinks. Not surprisingly, water and other liquids sometimes form distinct layers when poured together.

Procedure 🥽 🧤 🚫 🧤

1. Read and complete the lab safety form.
2. Observe **5-mL samples of alcohol** (dyed red), **glycerol** (dyed blue), **corn oil,** and **water.** Plan the order in which to add the liquids to a **graduated cylinder** to form four layers.
   WARNING: *Keep alcohol away from open flames.*
3. Test your plan by adding the liquids, one at a time, to the graduated cylinder. When adding each liquid, tilt the graduated cylinder, and slowly pour the liquid so it runs down the inside. When adding the glycerol, allow it to settle before adding the next liquid.
4. Did the liquids form four distinct layers? If not, rinse out the graduated cylinder and repeat Steps 2 and 3 using a different order.

Analysis

1. **Identify** the order, from top to bottom, of the layers in the graduated cylinder.
2. **Hypothesize** what property of the liquids is responsible for the arrangement of the layers.

Inquiry What do you think would happen if small pieces of metal, plastic, and wood were added to the layers of liquids in the graduated cylinder?
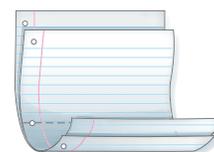

FOLDABLES™
Study Organizer

**Types of Graphs** Make the following Foldable to organize information about types of graphs.

▶ **STEP 1** Collect two sheets of paper, and layer them about 2 cm apart vertically. Keep the left and right edges even.

▶ **STEP 2** Fold up the bottom edges of the paper to form three equal tabs. Crease the fold to hold the tabs in place.

▶ **STEP 3** Staple along the fold. Label as follows: *Types of Graphs, Circle Graphs, Bar Graphs,* and *Line Graphs.*

> *Line Graphs*
> *Bar Graphs*
> *Circle Graphs*
> *Types of Graphs*
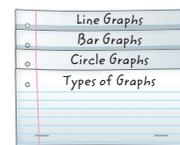
FOLDABLES **Use this Foldable with Section 2.4** As you read this section, summarize what you learn about the three types of graphs. Include the types of information that can be graphed on each. Be sure to include examples.

Chemistry Online

Visit glencoe.com to:
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Review Vocabulary

mass: a measurement that reflects the amount of matter an object contains

New Vocabulary

base unit
second
meter
kilogram
kelvin
derived unit
liter
density

Units and Measurements

MAIN ◁Idea **Chemists use an internationally recognized system of units to communicate their findings.**

Real-World Reading Link Have you ever noticed that a large drink varies in volume depending on where it is purchased? Wouldn't it be better if you always knew how much drink you would get when you ordered the large size? Chemists use standard units to ensure the consistent measurement of a given quantity.

Units

You use measurements almost every day. For example, reading the bottled water label in **Figure 2.1** helps you decide what size bottle to buy. Notice that the label uses a number and a unit, such as 500 mL, to give the volume. The label also gives the volume as 16.9 fluid ounces. Fluid ounces, pints, and milliliters are units used to measure volume.

Système Internationale d'Unités For centuries, units of measurement were not exact. A person might measure distance by counting steps, or measure time using a sundial or an hourglass filled with sand. Such estimates worked for ordinary tasks. Because scientists need to report data that can be reproduced by other scientists, they need standard units of measurement. In 1960, an international committee of scientists met to update the existing metric system. The revised international unit system is called the Système Internationale d'Unités, which is abbreviated SI.

■ **Figure 2.1** The label gives the volume of water in the bottle in three different units: fluid ounces, pints, and milliliters. Notice that each volume includes a number and a unit.

Infer *Which is the larger unit of volume: a fluid ounce or a milliliter?*

Base Units and SI Prefixes

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.

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—a system based on units of 10. The prefixes in **Table 2.2** are based on factors of ten and can be used with all SI units. For example, the prefix *kilo-* means one thousand; therefore, 1 km equals 1000 m. Similarly, the prefix *milli-* means one-thousandth; therfore, 1 mm equals 0.001 m. Many mechanical pencils use lead that is 0.5 mm in diameter. How much of a meter is 0.5 mm?

Time The SI base unit for time is the **second** (s). The physical standard used to define the second is the frequency of the radiation given off by a cesium-133 atom. Cesium-based clocks are used when highly accurate timekeeping is required. For everyday tasks, a second seems like a short amount of time. In chemistry, however, many chemical reactions take place within a fraction of a second.

Length The SI base unit for length is the **meter** (m). A meter is the distance that light travels in a vacuum in 1/299,792,458 of a second. A vacuum exists where space contains no matter.

A meter is close in length to a yard and is useful for measuring the length and width of a small area, such as a room. For larger distances, such as between cities, you would use kilometers. Smaller lengths, such as the diameter of a pencil, are likely to be given in millimeters. Use **Table 2.2** to determine how many centimeters are in a meter and how many centimeters are in 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)

VOCABULARY ....

SCIENCE USAGE V. COMMON USAGE

Meter
Science usage: the SI base unit of length
*The metal rod was 1 m in length.*

Common usage: a device used to measure
The time ran out on the parking meter. ....

Concepts In Motion

Interactive Table Explore SI prefixes at **glencoe.com**.

CLICK HERE

Table 2.2	SI Prefixes		
Prefix	**Symbol**	**Numerical Value in Base Units**	**Power of 10 Equivalent**
Giga	G	1,000,000,000	10^9
Mega	M	1,000,000	10^6
Kilo	K	1000	10^3
--	--	1	10^0
Deci	d	0.1	10^{-1}
Centi	c	0.01	10^{-2}
Milli	m	0.001	10^{-3}
Micro	μ	0.000001	10^{-6}
Nano	n	0.000000001	10^{-9}
Pico	p	0.000000000001	10^{-12}
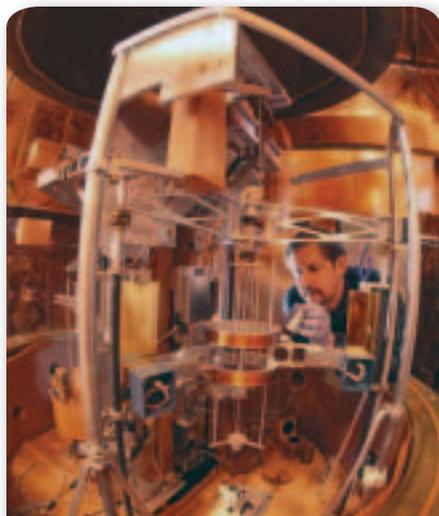
■ **Figure 2.2** Scientists at the National Institute of Standards and Technology are experimenting with redefining the kilogram using an apparatus known as a watt balance. The watt balance uses electric current and a magnetic field to measure the force required to balance a one-kilogram mass against the force of gravity. Other scientists are counting the number of atoms in a one-kilogram mass to redefine the kilogram.

Mass Recall that mass is a measure of the amount of matter an object contains. The SI base unit for mass is the **kilogram** (kg). Currently, a platinum and iridium cylinder kept in France defines the kilogram. The cylinder is stored in a vacuum under a triple bell jar to prevent the cylinder from oxidizing. As shown in **Figure 2.2,** scientists are working to redefine the kilogram using basic properties of nature.

A kilogram is equal to about 2.2 pounds. Because the masses measured in most laboratories are much smaller than a kilogram, scientists often measure quantities in grams (g) or milligrams (mg). For example, a laboratory experiment might ask you to add 35 mg of an unknown substance to 350 g of water. When working with mass values, it is helpful to remember that there are 1000 g in a kilogram. How many milligrams are in a gram?

Temperature People often use qualitative descriptions, such as hot and cold, when describing the weather or the water in a swimming pool. Temperature, however, is a quantitative measurement of the average kinetic energy of the particles that make up an object. As the particle motion in an object increases, so does the temperature of the object.

Measuring temperature requires a thermometer or a temperature probe. A thermometer consists of a narrow tube that contains a liquid. The height of the liquid indicates the temperature. A change in temperature causes a change in the volume of the liquid, which results in a change in the height of the liquid in the tube. Electronic temperature probes make use of thermocouples. A thermocouple produces an electric current that can be calibrated to indicate temperature.

Several different temperature scales have been developed. Three temperature scales—Kelvin, Celsius, and Fahrenheit—are commonly used to describe how hot or cold an object is.

Fahrenheit In the United States, the Fahrenheit scale is used to measure temperature. German scientist Gabriel Daniel Fahrenheit devised the scale in 1724. On the Fahrenheit scale, water freezes at 32°F and boils at 212°F.

Celsius Another temperature scale, the Celsius scale, is used throughout much of the rest of the world. Anders Celsius, a Swedish astronomer, devised the Celsius scale. The scale is based on the freezing and boiling points of water. He defined the freezing point of water as 0 and the boiling point of water as 100. He then divided the distance between these two fixed points into 100 equal units, or degrees. To convert from degrees Celsius (°C) to degrees Fahrenheit (°F), you can use the following equation.

$$°F = 1.8(°C) + 32$$

Imagine a friend from Canada calls you and says that it is 35°C outside. What is the temperature in degrees Fahrenheit? To convert to degrees Fahrenheit, substitute 35°C into the above equation and solve.

$$1.8(35) + 32 = 95°F$$

If it is 35°F outside, what is the temperature in degrees Celsius?

$$\frac{35°F - 32}{1.8} = 1.7\,°C$$

✓ **Reading Check** **Infer** Which is warmer, 25°F or 25°C?

Kelvin The SI base unit for temperature is the **kelvin** (K). The Kelvin scale was devised by a Scottish physicist and mathematician, William Thomson, who was known as Lord Kelvin. Zero kelvin is a point where all particles are at their lowest possible energy state. On the Kelvin scale, water freezes at 273.15 K and boils at 373.15 K. In Chapter 13, you will learn why scientists use the Kelvin scale to describe properties of a gas.

Figure 2.3 compares the Celsius and Kelvin scales. It is easy to convert between the Celsius scale and the Kelvin scale using the following equation.

> ### Kelvin-Celsius Conversion Equation
>
> $$K = °C + 273$$
>
> **K represents temperature in kelvins.**
> **°C represents temperature in degrees Celsius.**
>
> Temperature in kelvins is equal to temperature in degrees Celsius plus 273.

As shown by the equation above, to convert temperatures reported in degrees Celsius to kelvins, you simply add 273. For example, consider the element mercury, which melts at −39°C. What is this temperature in kelvins?

$$-39°C + 273 = 234 \text{ K}$$

To convert from kelvins to degrees Celsius, just subtract 273. For example, consider the element bromine, which melts at 266 K. What is this temperature in degrees Celsius?

$$266 \text{ K} - 273 = -7°C$$

You will use these conversions frequently throughout chemistry, especially when you study how gases behave. The gas laws you will learn are based on kelvin temperatures.

Derived Units

Not all quantities can be measured with SI 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 (cm^3) and density (g/cm^3).

Volume Volume is the space occupied by an object. The volume of an object with a cubic or rectangular shape can be determined by multiplying its length, width, and height dimensions. When each dimension is given in meters, the calculated volume has units of cubic meters (m^3). In fact, the derived SI unit for volume is the cubic meter. It is easy to visualize a cubic meter; imagine a large cube whose sides are each 1 m in length. The volume of an irregularly shaped solid can be determined using the water displacement method, a method used in the MiniLab in this section.

The cubic meter is a large volume that is difficult to work with. For everyday use, a more useful unit of volume is the liter. A **liter** (L) is equal to one cubic decimeter (dm^3), that is, 1 L equals 1 dm^3. Liters are commonly used to measure the volume of water and beverage containers. One liter has about the same volume as one quart.
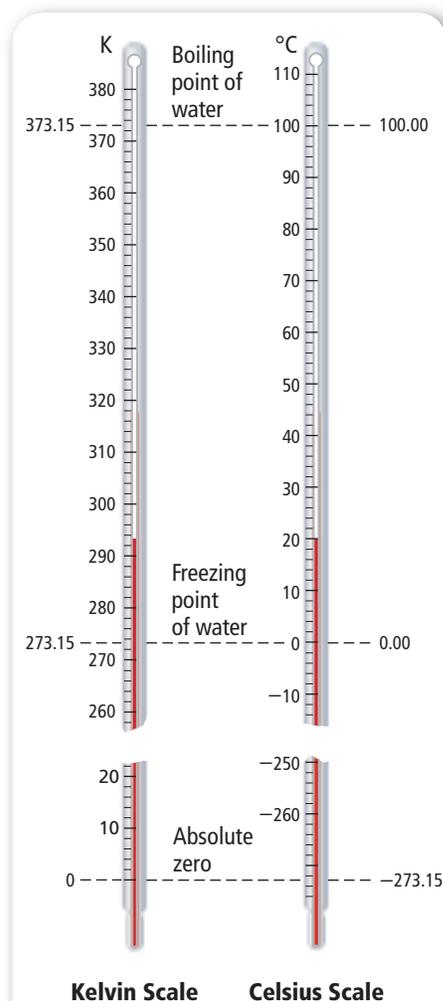
■ **Figure 2.3** A change of 1 K on the Kelvin scale is equal in size to a change of 1°C on the Celsius scale. Notice also that the degree sign (°) is not used with the Kelvin scale.

■ Illustration not to scale.

$1 m^3 = 1000 dm^3$

$1 dm^3 = 1000 cm^3 = 1 L$

$1 cm^3 = 1000 mm^3$
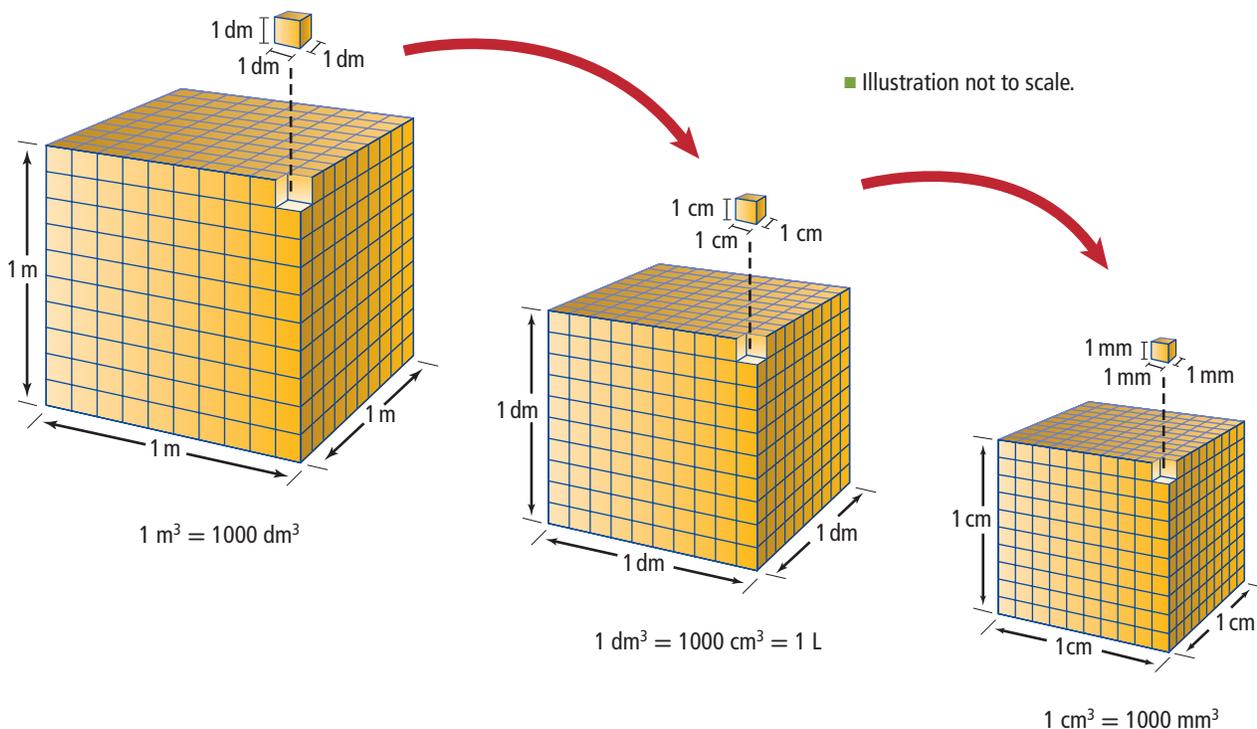
■ **Figure 2.4** The three cubes show volume relationships between cubic meters (m³), cubic decimeters (dm³), cubic centimeters (cm³), and cubic millimeters (mm³). As you move from left to right, the volume of each cube gets 10 × 10 × 10, or 1000 times, smaller.

Interpret *How many cubic centimeters (cm³) are in 1 L?*

For smaller quantities of liquids in the laboratory, volume is often measured in cubic centimeters (cm^3) or milliliters (mL). A milliliter and a cubic centimeter are equal in size.

$$1 \text{ mL} = 1 \text{ cm}^3$$

Recall that the prefix *milli-* means one-thousandth. Therefore, one milliliter is equal to one-thousandth of a liter. In other words, there are 1000 ml in 1 L.

$$1 \text{ L} = 1000 \text{ mL}$$

Figure 2.4 shows the relationships among several different SI units of volume.

Density Why is it easier to lift a backpack filled with gym clothes than the same backpack filled with books? The answer can be thought of in terms of density—the book-filled backpack contains more mass in the same volume. **Density** is a physical property of matter and is defined as the amount of mass per unit volume. Common units of density are grams per cubic centimeter (g/cm^3) for solids and grams per milliliter (g/mL) for liquids and gases.

Consider the grape and the piece of foam in **Figure 2.5.** Although both have the same mass, they clearly occupy different amounts of space. Because the grape occupies less volume for the same amount of mass, its density must be greater than that of the foam.

The density of a substance usually cannot be measured directly. Rather, it is calculated using mass and volume measurements. You can calculate density using the following equation.

Density Equation

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

The density of an object or a sample of matter is equal to its mass divided by its volume.

Because density is a physical property of matter, it can sometimes be used to identify an unknown element. For example, imagine you are given the following data for a piece of an unknown metallic element.

$$\text{volume} = 5.0 \text{ cm}^3$$
$$\text{mass} = 13.5 \text{ g}$$

Substituting these values into the equation for density yields:

$$\text{density} = \frac{13.5 \text{ g}}{5.0 \text{ cm}^3} = 2.7 \text{ g/cm}^3$$

Now turn to **Table R–7** on page 971, and scan through the given density values until you find one that closely matches the calculated value of 2.7 g/cm^3. What is the identity of the unknown element?

Connection 🌼 **to** **Earth Science** As air at the equator is warmed, the particles in the air move farther apart and the air density decreases. At the poles, the air cools and its density increases as the particles move closer together. When a cooler, denser air mass sinks beneath a rising warm air mass, winds are produced. Weather patterns are created by moving air masses of different densities.

✓ **Reading Check** **State** the quantities that must be known in order to calculate density.

Real-World Chemistry
Liquid Density Measurement
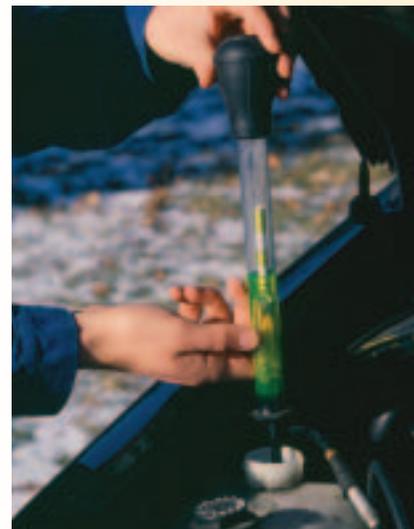
Hydrometers A hydrometer is a device that measures the specific gravity (the ratio of the fluid's density to that of water) of a fluid. Fluids of different densities result in different readings. Hydrometers are often used at service stations to diagnose problems with an automobile's battery.

Your textbook includes many Example Problems, each of which is solved using a three-step process. Read Example Problem 2.1 and follow the steps to calculate the mass of an object using density and volume.

EXAMPLE Problem 2.1

Using Density and Volume to Find Mass When a piece of aluminum is placed in a 25-mL graduated cylinder that contains 10.5 mL of water, the water level rises to 13.5 mL. What is the mass of the aluminum?

1 Analyze the Problem

The mass of aluminum is unknown. The known values include the initial and final volumes and the density of aluminum. The volume of the sample equals the volume of water displaced in the graduated cylinder. The density of aluminum is 2.7 g/mL. Use the density equation to solve for the mass of the aluminum sample.

Known

density = 2.7 g/mL

initial volume = 10.5 mL

final volume = 13.5 mL

Unknown

mass = ? g

2 Solve for the Unknown

volume of sample = final volume − initial volume   **State the equation for volume.**

volume of sample = 13.5 mL − 10.5 mL   **Substitute final volume = 13.5 mL and initial volume = 10.5 mL.**

volume of sample = 3.0 mL

$density = \dfrac{mass}{volume}$ **State the equation for density.**

mass = volume × density   **Solve the density equation for mass.**

mass = 3.0 mL × 2.7 g/mL   **Substitute volume = 3.0mL and density = 2.7 g/mL.**

mass = 3.0 mL × 2.7 g/mL = **8.1 g**   **Multiply, and cancel units.**

3 Evaluate the Answer

Check your answer by using it to calculate the density of aluminum.

$density = \dfrac{mass}{volume} = \dfrac{8.1\ g}{3.0\ mL} = 2.7\ g/mL$

Because the calculated density for aluminum is correct, the mass value must also be correct.

PRACTICE Problems
Extra Practice Page 976 and **glencoe.com**

1. Is the cube pictured at right made of pure aluminum? Explain your answer.

2. What is the volume of a sample that has a mass of 20 g and a density of 4 g/mL?

3. **Challenge** A 147-g piece of metal has a density of 7.00 g/mL. A 50-mL graduated cylinder contains 20.0 mL of water. What is the final volume after the metal is added to the graduated cylinder?

Mass = 20 g
Volume = 5 cm^3

MiniLab

Determine Density

What is the density of an unknown and irregularly shaped solid? To calculate the density of an object, you need to know its mass and volume. The volume of an irregularly shaped solid can be determined by measuring the amount of water it displaces.

Procedure 👓 🥼 ✋

1. Read and complete the lab safety form.
2. Obtain several **unknown objects** from your teacher. Note: Your teacher will identify each object as A, B, C, and so on.
3. Create a data table to record your observations.
4. Measure the mass of the object using a **balance.** Record the mass and the identity of the object in your data table.
5. Add about 15 mL of **water** to a **graduated cylinder.** Measure and record the initial volume in your data table. 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, as shown in the figure. The curved surface is called a meniscus.
6. Tilt the graduated cylinder, and carefully slide the object down the inside of the cylinder. Be sure not to cause a splash. Measure and record the final volume in your data table.

Meniscus
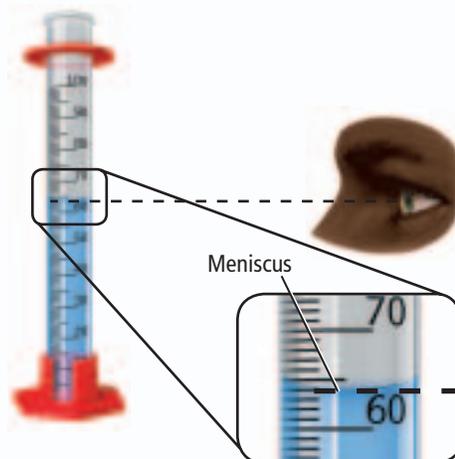
Analysis

1. **Calculate** Use the initial and final volume readings to calculate the volume of each mystery object.
2. **Calculate** Use the calculated volume and the measured mass to calculate the density of each unknown object.
3. **Explain** Why can't you use the water displacement method to find the volume of a sugar cube?
4. **Describe** how you can determine a washer's volume without using the water displacement method. Note, that a washer is similar to a short cylinder with a hole through it.

Section 2.1 Assessment

Section Summary

▶ SI measurement units allow scientists to report data to other scientists.

▶ Adding prefixes to SI units extends the range of possible measurements.

▶ To convert to Kelvin temperature, add 273 to the Celsius temperature.

▶ Volume and density have derived units. Density, which is a ratio of mass to volume, can be used to identify an unknown sample of matter.

4. **MAIN Idea Define** the SI units for length, mass, time, and temperature.
5. **Describe** how adding the prefix *mega-* to a unit affects the quantity being described.
6. **Compare** a base unit and a derived unit, and list the derived units used for density and volume.
7. **Define** the relationships among the mass, volume, and density of a material.
8. **Apply** Why does oil float on water?
9. **Calculate** Samples A, B, and C have masses of 80 g, 12 g, and 33 g, and volumes of 20 mL, 4 cm^3, and 11 mL, respectively. Which of the samples have the same density?
10. **Design** a concept map that shows the relationships among the following terms: *volume*, *derived unit*, *mass*, *base unit*, *time*, and *length*.

Objectives

▶ **Express** numbers in scientific notation.

▶ **Convert** between units using dimensional analysis.

Review Vocabulary

quantitative data: numerical information describing how much, how little, how big, how tall, how fast, and so on

New Vocabulary

scientific notation
dimensional analysis
conversion factor

Scientific Notation and Dimensional Analysis

MAIN ◁Idea Scientists often express numbers in scientific notation and solve problems using dimensional analysis.

Real-World Reading Link If you have ever had a job, one of the first things you probably did was figure out how much you would earn per week. If you make 10 dollars per hour and work 20 hours per week, how much money will you make? Performing this calculation is an example of dimensional analysis.

Scientific Notation

The Hope Diamond, which is shown in **Figure 2.6,** contains approximately 460,000,000,000,000,000,000,000 atoms of carbon. Each of these carbon atoms has a mass of 0.00000000000000000000002 g. If you were to use these numbers to calculate the mass of the Hope Diamond, you would find that the zeros would get in your way. Using a calculator offers no help, as it won't let you enter numbers this large or this small. Numbers such as these are best expressed in scientific notation. Scientists use this method to conveniently restate a number without changing its value.

   Scientific notation can be used to express any number as a number between 1 and 10 (known as the coefficient) multiplied by 10 raised to a power (known as the exponent). When written in scientific notation, the two numbers above appear as follows.

Coefficient   Exponent

$$\text{carbon atoms in the Hope Diamond} = 4.6 \times 10^{23}$$

$$\text{mass of one carbon atom} = 2 \times 10^{-23} \text{ g}$$

■ **Figure 2.6** At more than 45 carats, the Hope Diamond is the world's largest deep-blue diamond. Originally mined in India, the diamond's brilliant blue color is due to trace amounts of boron within the diamond. Diamonds are formed from a unique structure of carbon atoms, creating one of nature's hardest known substances. Note that a carat is a unit of measure used for gemstones (1 carat = 200 mg).

Let's look at these two numbers more closely. In each case, the number 10 raised to an exponent replaced the zeros that preceded or followed the nonzero numbers. For numbers greater than 1, a positive exponent is used to indicate how many times the coefficient must be multiplied by 10 in order to obtain the original number. Similarly, for numbers less than 1, a negative exponent indicates how many times the coefficient must be divided by 10 in order to obtain the original number.

Determining the exponent to use when writing a number in scientific notation is easy: simply count the number of places the decimal point must be moved to give a coefficient between 1 and 10. The number of places moved equals the value of the exponent. The exponent is positive when the decimal moves to the left and the exponent is negative when the decimal moves to the right.

$$460,000,000,000,000,000,000,000. \rightarrow 4.6 \times 10^{23}$$

Because the decimal point moves 23 places to the left, the exponent is 23.

$$0.00000000000000000000002 \rightarrow 2 \times 10^{-23}$$

Because the decimal point moves 23 places to the right, the exponent is −23.

EXAMPLE Problem 2.2

Scientific Notation Write the following data in scientific notation.
- **a.** The diameter of the Sun is 1,392,000 km.
- **b.** The density of the Sun's lower atmosphere is 0.000000028 g/cm^3.

1 Analyze the Problem

You are given two values, one much larger than 1 and the other much smaller than 1. In both cases, the answers will have a coefficient between 1 and 10 multiplied by a power of 10.

2 Solve for the Unknown

Move the decimal point to give a coefficient between 1 and 10. Count the number of places the decimal point moves, and note the direction.

1,392,000.	**Move the decimal point six places to the left.**
0.000000028	**Move the decimal point eight places to the right.**

a. 1.392×10^6 km   **Write the coefficients, and multiply them by 10^n where n equals the number of places moved. When the decimal point moves to the left, n is positive; when the**

b. 2.8×10^{-8} g/cm^3 **decimal point moves to the right, n is negative. Add units to the answers.**

3 Evaluate the Answer

The answers are correctly written as a coefficient between 1 and 10 multiplied by a power of 10. Because the diameter of the Sun is a number greater than 1, its exponent is positive. Because the density of the Sun's lower atmosphere is a number less than 1, its exponent is negative.

PRACTICE Problems

Extra Practice Page 976 and **glencoe.com**

11. Express each number in scientific notation.
- **a.** 700
- **b.** 38,000
- **c.** 4,500,000
- **d.** 685,000,000,000
- **e.** 0.0054
- **f.** 0.00000687
- **g.** 0.000000076
- **h.** 0.0000000008

12. Challenge Express each quantity in regular notation along with its appropriate unit.
- **a.** 3.60×10^5 s
- **b.** 5.4×10^{-5} g/cm^3
- **c.** 5.060×10^3 km
- **d.** 8.9×10^{10} Hz

Addition and subtraction In order to add or subtract numbers written in scientific notation, the exponents must be the same. Suppose you need to add 7.35×10^2 m and 2.43×10^2 m. Because the exponents are the same, you can simply add the coefficients.

$$(7.35 \times 10^2 \text{ m}) + (2.43 \times 10^2 \text{ m}) = 9.78 \times 10^2 \text{ m}$$

How do you add numbers in scientific notation when the exponents are not the same? To answer this question, consider the amounts of energy produced by renewable energy sources in the United States. Wind-powered turbines, shown in **Figure 2.7,** are one of several forms of renewable energy used in the United States. Other sources of renewable energy include hydroelectric, biomass, geothermal, and solar power. In 2004, the energy production amounts from renewable sources were as follows.

Hydroelectric	2.840×10^{18} J*
Biomass	3.146×10^{18} J
Geothermal	3.60×10^{17} J
Wind	1.50×10^{17} J
Solar	6.9×10^{16} J

* J stands for joules, a unit of energy.

To determine the sum of these values, they must be rewritten with the same exponent. Because the two largest values have an exponent of 10^{18}, it makes sense to convert the other numbers to values with this exponent. These other exponents must increase to become 10^{18}. As you learned earlier, each place the decimal shifts to the left decreases the exponent by 1. Rewriting the values with exponents of 10^{18} and adding yields the following.

Hydroelectric	2.840×10^{18} J
Biomass	3.146×10^{18} J
Geothermal	0.360×10^{18} J
Wind	0.150×10^{18} J
Solar	0.069×10^{18} J
Total	6.565×10^{18} J

✔ **Reading Check** Restate the process used to add two numbers that are expressed in scientific notation.

VOCABULARY ....

ACADEMIC VOCABULARY

Sum
the whole amount; the result of adding numbers
At the checkout counter, all of the items came to a sizable sum. ....

■ **Figure 2.7** The uneven heating of Earth's surface causes wind, which powers these turbines and generates electricity.

PRACTICE Problems   **Extra Practice** Page 976 and **glencoe.com**

13. Solve each problem, and express the answer in scientific notation.
   a. $(5 \times 10^{-5}) + (2 \times 10^{-5})$ **c.** $(9 \times 10^2) - (7 \times 10^2)$
   b. $(7 \times 10^8) - (4 \times 10^8)$ **d.** $(4 \times 10^{-12}) + (1 \times 10^{-12})$

14. Challenge Express each answer in scientific notation in the units indicated.
   a. $(1.26 \times 10^4 \text{ kg}) + (2.5 \times 10^6 \text{ g})$ in kg
   b. $(7.06 \text{ g}) + (1.2 \times 10^{-4} \text{ kg})$ in kg
   c. $(4.39 \times 10^5 \text{ kg}) - (2.8 \times 10^7 \text{ g})$ in kg
   d. $(5.36 \times 10^{-1} \text{ kg}) - (7.40 \times 10^{-2} \text{ kg})$ in g

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Multiplication and division Multiplying and dividing numbers in scientific notation is a two-step process, but it does not require the exponents to be the same. For multiplication, multiply the coefficients and then add the exponents. For division, divide the coefficients, then subtract the exponent of the divisor from the exponent of the dividend.

To calculate the mass of the Hope Diamond, multiply the number of carbon atoms by the mass of a single carbon atom.

$$(4.6 \times 10^{23} \text{ atoms})(2 \times 10^{-23} \text{ g/atom}) = 9.2 \times 10^0 \text{ g} = 9.2 \text{ g}$$

Note that any number raised to a power of 0 is equal to 1; thus, 9.2×10^0 g is equal to 9.2 g.

EXAMPLE Problem 2.3

Multiplying and Dividing Numbers in Scientific Notation 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 numbers written in scientific notation to multiply and divide. For the multiplication problem, multiply the coefficients and add the exponents. For the division problem, divide the coefficients and subtract the exponent of the divisor from the exponent of the dividend.

$\dfrac{9 \times 10^8}{3 \times 10^{-4}}$ ⎤———— **The exponent of the dividend is 8.**
⎦———— **The exponent of the divisor is −4.**

2 Solve for the Unknown

a. $(2 \times 10^3) \times (3 \times 10^2)$	State the problem.
$2 \times 3 = 6$	Multiply the coefficients.
$3 + 2 = 5$	Add the exponents.
6×10^5	Combine the parts.
b. $(9 \times 10^8) \div (3 \times 10^{-4})$	State the problem.
$9 \div 3 = 3$	Divide the coefficients.
$8 - (-4) = 8 + 4 = 12$	Subtract the exponents.
3×10^{12}	Combine the parts.

3 Evaluate the Answer

To test the answers, write out the original data and carry out the arithmetic. For example, Problem **a** becomes $2000 \times 300 = 600{,}000$, which is the same as 6×10^5.

PRACTICE Problems   **Extra Practice** Page 976 and <u>glencoe.com</u>

15. Solve each problem, and express the answer in scientific notation.

a. $(4 \times 10^2) \times (1 \times 10^8)$ **c.** $(6 \times 10^2) \div (2 \times 10^1)$
b. $(2 \times 10^{-4}) \times (3 \times 10^2)$ **d.** $(8 \times 10^4) \div (4 \times 10^1)$

16. Challenge Calculate the areas and densities. Report the answers in the correct units.

a. the area of a rectangle with sides measuring 3×10^1 cm and 3×10^{-2} cm

b. the area of a rectangle with sides measuring 1×10^3 cm and 5×10^{-1} cm

c. the density of a substance having a mass of 9×10^5 g and a volume of 3×10^{-1} cm^3

d. the density of a substance having a mass of 4×10^{-3} g and a volume of 2×10^{-2} cm^3

Figure 2.8 Dimensional analysis can be used to calculate the number of pizzas that must be ordered for a party. How many pizzas will you need if 32 people eat 3 slices per person and there are 8 slices in each pizza?

$$(32 \text{ people})\left(\frac{3 \text{ slices}}{\text{person}}\right)\left(\frac{1 \text{ pizza}}{8 \text{ slices}}\right) = 12 \text{ pizzas}$$

Dimensional Analysis

When planning a pizza party for a group of people, you might want to use dimensional analysis to figure out how many pizzas to order. **Dimensional analysis** is a systematic approach to problem solving that uses conversion factors to move, or convert, from one unit to another. A **conversion factor** is a ratio of equivalent values having different units.

How many pizzas do you need to order if 32 people will attend a party, each person eats 3 slices of pizza, and each pizza has 8 slices? **Figure 2.8** shows how conversion factors are used to calculate the number of pizzas needed for the party.

Writing conversion factors As you just read, conversion factors are ratios of equivalent values. Not surprisingly, these conversion factors are derived from equality relationships, such as 12 eggs = 1 dozen eggs, or 12 inches = 1 foot. Multiplying a quantity by a conversion factor changes the units of the quantity without changing its value.

Most conversion factors are written from relationships between units. For example, the prefixes in **Table 2.2** on page 33 are the source of many conversion factors. From the relationship 1000 m = 1 km, the following conversion factors can be written.

$$\frac{1 \text{ km}}{1000 \text{ m}} \quad \text{and} \quad \frac{1000 \text{ m}}{1 \text{ km}}$$

A derived unit, such as a density of 2.5 g/mL, can also be used as a conversion factor. The value shows that 1 mL of the substance has a mass of 2.5 g. The following two conversion factors can be written.

$$\frac{2.5 \text{ g}}{1 \text{ mL}} \quad \text{and} \quad \frac{1 \text{ mL}}{2.5 \text{ g}}$$

Percentages can also be used as conversion factors. A percentage is a ratio; it relates the number of parts of one component to 100 total parts. For example, a fruit drink containing 10% sugar by mass contains 10 g of sugar in every 100 g of fruit drink. The conversion factors for the fruit drink are as follows.

$$\frac{10 \text{ g sugar}}{100 \text{ g fruit drink}} \quad \text{and} \quad \frac{100 \text{ g fruit drink}}{10 \text{ g sugar}}$$

17. Write two conversion factors for each of the following.

  a. a 16% (by mass) salt solution
  b. a density of 1.25 g/mL
  c. a speed of 25 m/s

18. Challenge What conversion factors are needed to convert:

  a. nanometers to meters?
  b. density given in g/cm^3 to a value in kg/m^3?

Using conversion factors A conversion factor used in dimensional analysis must accomplish two things: it must cancel one unit and introduce a new one. While working through a solution, all of the units except the desired unit must cancel. Suppose you want to know how many meters there are in 48 km. The relationship between kilometers and meters is 1 km = 1000 m. The conversion factors are as follows.

$$\frac{1\ km}{1000\ m} \qquad and \qquad \frac{1000\ m}{1\ km}$$

Because you need to convert km to m, you should use the conversion factor that causes the km unit to cancel.

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

When converting a value with a large unit, such as km, to a value with a smaller unit, such as m, the numerical value increases. For example, 48 km (a value with a large unit) converts to 48,000 m (a larger numerical value with a smaller unit). **Figure 2.9** illustrates the connection between the numerical value and the size of the unit for a conversion factor.

Now consider this question: How many eight-packs of water would you need if the 32 people attending your party each had two bottles of water? To solve the problem, identify the given quantities and the desired result. There are 32 people and each of them drinks two bottles of water. The desired result is the number of eight-packs. Using dimensional analysis yields the following.

$$32\ \cancel{people} \times \frac{2\ \cancel{bottles}}{\cancel{person}} \times \frac{1\ eight\text{-}pack}{8\ \cancel{bottles}} = 8\ eight\text{-}packs$$

$$\frac{\textbf{1 km}}{\textbf{1000 m}}$$

■ **Figure 2.9** The two quantities shown above are equivalent; that is, 1 km = 1000 m. Note that a smaller numerical value (1) accompanies the larger unit (km), and a larger numerical value (1000) accompanies the smaller unit (m).

Use Table 2.2 on page 33 to solve each of the following.

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

  e. Convert 2.45×10^2 ms to s.
  f. Convert 5 μm to km.
  g. Convert 6.800×10^3 cm to km.
  h. Convert 2.5×10^1 kg to Mg.

20. Challenge Write the conversion factors needed to determine the number of seconds in one year.

Using Conversion Factors In ancient Egypt, small distances were measured in Egyptian cubits. An Egyptian cubit was equal to 7 palms, and 1 palm was equal to 4 fingers. If 1 finger was equal to 18.75 mm, convert 6 Egyptian cubits to meters.

1 Analyze the Problem

A length of 6 Egyptian cubits needs to be converted to meters.

Known

length = 6 Egyptian cubits   1 palm = 4 fingers   1 m = 0.001 mm

7 palms = 1 cubit   1 finger = 18.75 mm

Unknown

length = ? m

2 Solve for the Unknown

Use dimensional analysis to convert the units in the following order.

cubits → palms → fingers → millimeters → meters

$$6 \text{ cubits} \times \frac{7 \text{ palms}}{1 \text{ cubit}} \times \frac{4 \text{ fingers}}{1 \text{ palm}} \times \frac{18.75 \text{ mm}}{1 \text{ finger}} \times \frac{1 \text{ meter}}{1000 \text{ m}} = \textbf{? m}$$

Multiply by a series of conversion factors that cancels all the units except meter, the desired unit.

$$6 \text{ cubits} \times \frac{7 \text{ palms}}{1 \text{ cubit}} \times \frac{4 \text{ fingers}}{1 \text{ palm}} \times \frac{18.75 \text{ mm}}{1 \text{ finger}} \times \frac{1 \text{ meter}}{1000 \text{ mm}} = \textbf{3.150 m}$$

Multiply and divide the numbers as indicated, and cancel the units.

3 Evaluate the Answer

Each conversion factor is a correct restatement of the original relationship, and all units except for the desired unit meters cancel.

PRACTICE Problems   **Extra Practice** Page 976 and **glencoe.com**

21. The speedometer at right displays a car's speed in miles per hour. What is the car's speed in km/h? (1 km = 0.62 mile)

22. How many seconds are in 24 h?

23. Challenge Vinegar is 5% acetic acid by mass and has a density of 1.02 g/mL. What mass of acetic acid, in grams, is present in 185 mL of vinegar?

Section 2.2 Assessment

Section Summary

▶ A number expressed in scientific notation is written as a coefficient between 1 and 10 multiplied by 10 raised to a power.

▶ To add or subtract numbers in scientific notation, the numbers must have the same exponent.

▶ To multiply or divide numbers in scientific notation, multiply or divide the coefficients and then add or subtract the exponents, respectively.

▶ Dimensional analysis uses conversion factors to solve problems.

24. MAIN Idea Describe how scientific notation makes it easier to work with very large or very small numbers.

25. Express the numbers 0.00087 and 54,200,000 in scientific notation.

26. Write the measured distance quantities 3×10^{-4} cm and 3×10^4 km in regular notation.

27. Write a conversion factor relating cubic centimeters and milliliters.

28. Solve How many millimeters are there in 2.5×10^2 km?

29. Explain how dimensional analysis is used to solve problems.

30. Apply Concepts A classmate converts 68 km to meters and gets 0.068 m as the answer. Explain why this answer is incorrect, and identify the likely source of the error.

31. Organize Create a flowchart that outlines when to use dimensional analysis and when to use scientific notation.

Chemistry Online Self-Check Quiz **glencoe.com**

Objectives

▶ **Define** and compare accuracy and precision.

▶ **Describe** the accuracy of experimental data using error and percent error.

▶ **Apply** rules for significant figures to express uncertainty in measured and calculated values.

Review Vocabulary

experiment: a set of controlled observations that test a hypothesis

New Vocabulary

accuracy
precision
error
percent error
significant figure

Uncertainty in Data

MAIN ‹Idea **Measurements contain uncertainties that affect how a calculated result is presented.**

Real-World Reading Link When making cookies from a recipe, amounts are measured in cups, tablespoons, and teaspoons. Would a batch of cookies turn out well if you measured all of the ingredients using only a teaspoon? Most likely not, because measurement errors would build up.

Accuracy and Precision

Just as each teaspoon you measure in the kitchen contains some amount of error, so does every scientific measurement made in a laboratory. When scientists make measurements, they evaluate both the accuracy and the precision of the measurements. Although you might think that the terms accuracy and precision basically mean the same thing, to a scientist, they have very different meanings.

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 2.10** illustrates the difference between accuracy and precision. For this example, the center of the target is the accepted value.

■ **Figure 2.10** An archery target illustrates the difference between accuracy and precision. An accurate shot is located near the bull's-eye; precise shots are grouped closely together.

Apply *Why doesn't it make sense to discuss the precision of the arrow location in the drawing labeled* Accurate*?*
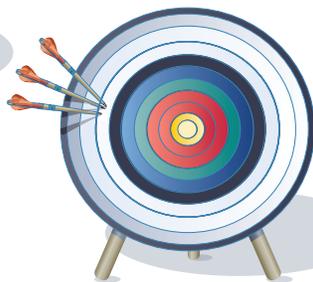
C⌂ncepts In M⌂tion
Interactive Figure To see an animation of precision and accuracy, visit **glencoe.com**.

Accurate

An arrow in the center indicates high accuracy.

Precise but not accurate

Arrows far from the center indicate low accuracy. Arrows close together indicate high precision.

Accurate and precise

Arrows in the center indicate high accuracy. Arrows close together indicate high precision.

Not accurate or precise

Arrows far from the center indicate low accuracy. Arrows far apart indicate low precision.

Table 2.3	Student Density and Error Data (Unknown was sucrose; density = 1.59 g/cm³)					
	Student A		Student B		Student C	
	Density	Error (g/cm³)	Density	Error (g/cm³)	Density	Error (g/cm³)
Trial 1	1.54 g/cm³	−0.05	1.40 g/cm³	−0.19	ⓐ 1.70 g/cm³	+0.11
Trial 2	1.60 g/cm³	+0.01	1.68 g/cm³	+0.09	1.69 g/cm³	+0.10
Trial 3	1.57 g/cm³	−0.02	1.45 g/cm³	−0.14	1.71 g/cm³	+0.12
Average	ⓑ 1.57 g/cm³		1.51 g/cm³		1.70 g/cm³	

ⓐ These trial values are the most precise.
ⓑ This average is the most accurate.

Chemistry Online

Personal Tutor For an online tutorial on precision measurement, visit **glencoe.com**.

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, sucrose (table sugar), has a density of 1.59 g/cm³. Which student collected the most accurate data? Who collected the most precise data? Student A's measurements are the most accurate because they are closest to the accepted value of 1.59 g/cm³. Student C's measurements are the most precise because they are the closest to one another.

Recall that precise measurements might 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, nor are they close to one another.

Error and percent error The density values reported in **Table 2.3** are experimental values, which means they are values measured during an experiment. The known density of sucrose is an accepted value, which is a value that is considered true. To evaluate the accuracy of experimental data, you can compare how close the experimental value is to the accepted value. **Error** is defined as the difference between an experimental value and an accepted value. The errors for the experimental density values are also given in **Table 2.3.**

Error Equation

$$\text{error} = \text{experimental value} - \text{accepted value}$$

The error associated with an experimental value is the difference between the experimental value and the accepted value.

Scientists often want to know what percent of the accepted value an error represents. **Percent error** expresses error as a percentage of the accepted value.

Percent Error Equation

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

The percent error of an experimental value equals to the absolute value of its error divided by the accepted value, multiplied by 100.

Notice that the percent-error equation uses the absolute value of the error. This is because only the size of the error matters; it does not matter whether the experimental value is larger or smaller than the accepted value.

✓ **Reading Check** **Name** the type of error that involves a ratio.

Percent error is an important concept for the machinist who made the nut shown in **Figure 2.11.** The machinist must check the tolerances of the nut. Tolerances are a narrow range of allowable dimensions based on acceptable amounts of error. If the dimensions of the nut do not fall within the acceptable range—that is, the nut exceeds its tolerances—it will be retooled or possibly discarded.
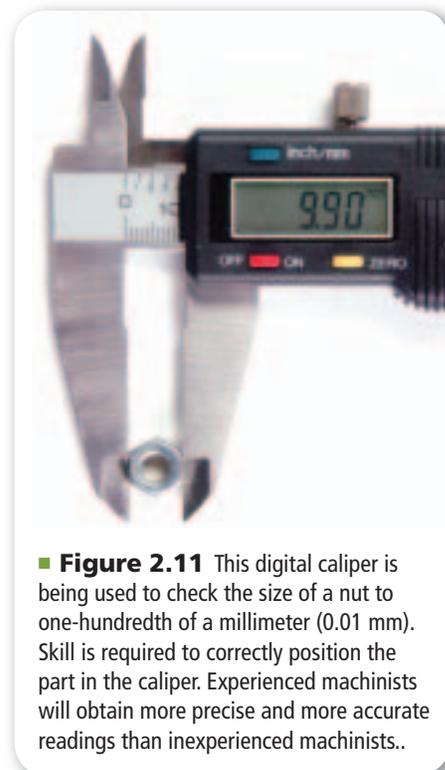
■ **Figure 2.11** This digital caliper is being used to check the size of a nut to one-hundredth of a millimeter (0.01 mm). Skill is required to correctly position the part in the caliper. Experienced machinists will obtain more precise and more accurate readings than inexperienced machinists..

EXAMPLE Problem 2.5

Calculating Percent Error Use Student A's density data in **Table 2.3** to calculate the percent error in each trial. Report your answers to two places after the decimal point.

> **Math Handbook**
> Percents
> page 965

1 Analyze the Problem
You are given the errors for a set of density calculations. 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

$$\text{percent error} = \frac{|\text{error}|}{\text{accepted value}} \times 100$$ State the percent error equation.

$$\text{percent error} = \frac{|-0.05 \text{ g/cm}^3|}{1.59 \text{ g/cm}^3} \times 100 = \textbf{3.14\%}$$ Substitute error = −0.05 g/cm^3, and solve.

$$\text{percent error} = \frac{|0.01 \text{ g/cm}^3|}{1.59 \text{ g/cm}^3} \times 100 = \textbf{0.63\%}$$ Substitute error = 0.01 g/cm^3, and solve.

$$\text{percent error} = \frac{|-0.02 \text{ g/cm}^3|}{1.59 \text{ g/cm}^3} \times 100 = \textbf{1.26\%}$$ Substitute error = −0.02 g/cm^3, and solve.

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.

PRACTICE Problems   Extra Practice Page 976 and **glencoe.com**

Answer the following questions using data from Table 2.3.

32. Calculate the percent errors for Student B's trials.

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

34. Challenge Based on percent error, which student's trial was the most accurate? The least accurate?

Identify an Unknown

How can mass and volume data for an unknown sample be used to identify the unknown? A student collected several samples from a stream bed that looked like gold. She measured the mass of each sample and used water displacement to determine each sample's volume. Her data are given in the table.

Mass and Volume Data for an Unknown Sample			
Sample	Mass	Initial Volume (water only)	Final Volume (water + sample)
1	50.25 g	50.1 mL	60.3 mL
2	63.56 g	49.8 mL	62.5 mL
3	57.65 g	50.2 mL	61.5 mL
4	55.35 g	45.6 mL	56.7 mL
5	74.92 g	50.3 mL	65.3 mL
6	67.78 g	47.5 mL	60.8 mL

Analysis

For a given sample, the difference in the volume measurements made with the graduated cylinder yields the volume of the sample. Thus, for each sample, the mass and volume are known, and the density can be calculated. Note that density is a property of matter that can often be used to identify an unknown sample.

Think Critically

1. **Calculate** the volume and density for each sample and the average density of the six samples. Be sure to use significant figure rules.
2. **Apply** The student hopes the samples are gold, which has a density of 19.3 g/cm^3. A local geologist suggested the samples might be pyrite, which is a mineral with a density of 5.01 g/cm^3. What is the identity of the unknown sample?
3. **Calculate** the error and percent error of each sample. Use the density value given in Question 2 as the accepted value.
4. **Conclude** Was the data collected by the student accurate? Explain your answer.
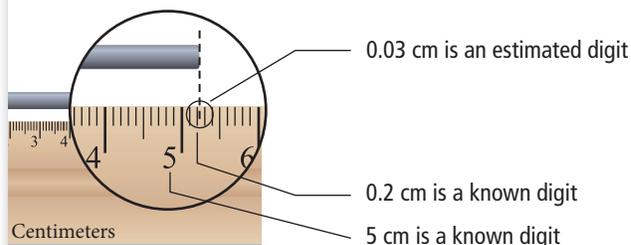
Significant Figures

Often, precision is limited by the tools available. For example, a digital clock that displays the time as 12:47 or 12:48 can record the time only to the nearest minute. With a stopwatch, however, you might record time to the nearest hundredth second. As scientists have developed better measuring devices, they have been able to make more precise measurements. Of course, for measurements to be both accurate and precise, the measuring devices must be in good working order. Additionally, accurate and precise measurements rely on the skill of the person using the instrument; the user must be trained and use proper techniques.

The precision of a measurement is indicated by the number of digits reported. A value of 3.52 g is more precise than a value of 3.5 g. The reported digits are called significant figures. **Significant figures** include all known digits plus one estimated digit. Consider the rod in **Figure 2.12**. The end of the rod falls between 5.2 cm and 5.3 cm. The 5 and 2 are known digits corresponding to marks on the ruler. To these known digits, an estimated digit is added. This last digit estimates the rod's location between the second and third millimeter marks. Because it is an estimate, one person might report the measurement as 5.22 cm and another as 5.23 cm. Either way, the measurement has three significant figures—two known and one estimated.

Remember that measurements reported with a lot of significant figures might be precise but not accurate. For example, some chemistry labs have balances that report mass to the nearest hundreth of a gram. If you and each of your classmates measured the same copper cylinder on the same scale, you would probably have a group of very precise measurements. But what if the scale had been previously damaged by an object that was too large for it? Your precise measurements would not be very accurate.

■ **Figure 2.12** The markings on the ruler represent known digits. The reported measurement includes the known digits plus the estimated digit. The measurement is 5.23 cm.

Infer *What is the estimated digit if the length of an object being measured falls exactly on the 5-cm mark?*

0.03 cm is an estimated digit

0.2 cm is a known digit

5 cm is a known digit

Centimeters

Problem-Solving Strategy
Recognizing Significant Figures

Learning these five rules for recognizing significant figures will help you when solving problems. Examples of each rule are shown below. Note that each of the highlighted examples has three significant figures.

Rule 1. Nonzero numbers are always significant.

72.3 g has three.

Rule 2. Zeros between nonzero numbers are always significant.

60.5 g has three.

Rule 3. All final zeros to the right of the decimal are significant.

6.20 g has three.

Rule 4. Placeholder zeroes are not significant. To remove placeholder zeros, rewrite the number in scientific notation.

0.0253 g and 4320 g (each has three)

Rule 5. Counting numbers and defined constants have an infinite number of significant figures.

6 molecules
60 s = 1 min

EXAMPLE Problem 2.6

Significant Figures Determine the number of significant figures in the following masses.

Math Handbook
Significant Figures
pages 949–951

    a. 0.00040230 g
    b. 405,000 kg

1 Analyze the Problem

You are given two measured mass values. Apply the appropriate rules to determine the number of significant figures in each value.

2 Solve for the Unknown

Count all nonzero numbers, zeros between nonzero numbers, and final zeros to the right of the decimal place. **(Rules 1, 2, and 3)**
Ignore zeros that act as placeholders. **(Rule 4)**
a. 0.00040230 g has five significant figures.
b. 405,000 kg has three significant figures.

3 Evaluate the Answer

One way to verify your answers is to write the values in scientific notation: 4.0230×10^{-4} g and 4.05×10^5 kg. Without the placeholder zeros, it is clear that 0.00040230 g has five significant figures and that 405,000 kg has three significant figures.

PRACTICE Problems   **Extra Practice** Page 977 and **glencoe.com**

Determine the number of significant figures in each measurement.

35. a. 508.0 L
    b. 820,400.0 L

  c. 1.0200×10^5 kg
  d. 807,000 kg

36. a. 0.049450 s
    b. 0.000482 mL

  c. 3.1587×10^{-4} g
  d. 0.0084 mL

37. Challenge Write the numbers 10, 100, and 1000 in scientific notation with two, three, and four significant figures, respectively.

Figure 2.13 You need to apply the rules of significant figures and rounding to report a calculated value correctly.

Rounding Numbers

Calculators perform flawless arithmetic, but they are not aware of the number of significant figures that should be reported in the answer. For example, a density calculation should not have more significant figures than the original data with the fewest significant figures. To report a value correctly, you often need to round. Consider an object with a mass of 22.44 g and volume of 14.2 cm^3. When you calculate the object's density using a calculator, the displayed answer is 1.5802817 g/cm^3, as shown in **Figure 2.13.** Because the measured mass had four significant figures and the measured volume had three, it is not correct to report the calculated density value with eight significant figures. Instead, the density must be rounded to three significant figures, or 1.58 g/cm^3.

Consider the value 3.515014. How would you round this number to five significant figures? To three significant figures? In each case, you need to look at the digit that follows the desired last significant figure.

To round to five digits, first identify the fifth significant figure, in this case 0, and then look at the number to its right, in this case 1.

Last significant figure
3.515014
Number to right of last significant figure

Do not change the last significant figure if the digit to its right is less than five. Because a 1 is to the right, the number rounds to 3.5150. If the number had been 5 or greater, you would have rounded up.

To round to three digits, identify the third significant figure, in this case 1, and then look at the number to its right, in this case 5.

Last significant figure
3.515014
Number to right of last significant figure

If the digits to the right of the last significant figure are a 5 followed by 0, then look at the last significant figure. If it is odd, round it up; if it is even, do not round up. Because the last significant digit is odd (1), the number rounds up to 3.52.

Problem-Solving Strategy
Rounding Numbers

Learn these four rules for rounding, and use them when solving problems. Examples of each rule are shown below. Note that each example has three significant figures.

2.532 → 2.53	**Rule 1.**	If the digit to the right of the last significant figure is less than 5, do not change the last significant figure.
2.536 → 2.54	**Rule 2.**	If the digit to the right of the last significant figure is greater than 5, round up the last significant figure.
2.5351 → 2.54	**Rule 3.**	If the digits to the right of the last significant figure are a 5 followed by a nonzero digit, round up the last significant figure.
2.5350 → 2.54 2.5250 → 2.52	**Rule 4.**	If the digits to the right of the last significant figure are a 5 followed by 0 or no other number at all, look at the last significant figure. If it is odd, round it up; if it is even, do not round up.

Matt Meadows

38. Round each number to four significant figures.

    a. 84,791 kg   **c.** 256.75 cm

    b. 38.5432 g   **d.** 4.9356 m

39. Challenge Round each number to four significant figures, and write the answer in scientific notation.

    a. 0.00054818 g   **c.** 308,659,000 mm

    b. 136,758 kg   **d.** 2.0145 mL

Addition and subtraction When you add or subtract measurements, the answer must have the same number of digits to the right of the decimal as the original value having the fewest number of digits to the right of the decimal. For example, the measurements 1.24 mL, 12.4 mL, and 124 mL have two, one, and zero digits to the right of the decimal, respectively. When adding or subtracting, arrange the values so that the decimal points align. Identify the value with the fewest places after the decimal point, and round the answer to that number of places.

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.

EXAMPLE Problem 2.7

Math Handbook

Calculations with Significant Figures pages 952–953

Rounding Numbers When Adding A student measured the length of his lab partners' shoes. If the lengths are 28.0 cm, 23.538 cm, and 25.68 cm, what is the total length of the shoes?

1 Analyze the Problem

The three measurements 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

    28.0 cm

    23.538 cm   **Align the measurements and add the values.**

+ 25.68 cm

    77.218 cm

The answer is **77.2 cm.**   **Round to one place after the decimal; Rule 1 applies.**

3 Evaluate the Answer

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

40. Add and subtract as indicated. Round off when necessary.

    a. 43.2 cm + 51.0 cm + 48.7 cm   **b.** 258.3 kg + 257.11 kg + 253 kg

41. Challenge Add and subtract as indicated. Round off when necessary.

    a. $(4.32 \times 10^3 \text{ cm}) - (1.6 \times 10^6 \text{ mm})$ **b.** $(2.12 \times 10^7 \text{ mm}) + (1.8 \times 10^3 \text{ cm})$

Rounding Numbers When Multiplying Calculate the volume of a book with the following dimensions: length = 28.3 cm, width = 22.2 cm, height = 3.65 cm.

1 Analyze the Problem

Volume is calculated by multiplying length, width, and height. Because all of the measurements have three significant figures, the answer also will.

Known

length = 28.3 cm   height = 3.65 cm

width = 22.2 cm

Unknown

Volume = ? cm^3

2 Solve for the Unknown

Calculate the volume, and apply the rules of significant figures and rounding.

Volume = length × width × height — State the formula for the volume of a rectangle.

Volume = 28.3 cm × 22.2 cm × 3.65 cm = 2293.149 cm^3 — Substitute values, and solve.

Volume = **2290 cm^3** — Round the answer to three significant figures.

3 Evaluate the Answer

To check if your answer is reasonable, round each measurement to one significant figure and recalculate the volume. Volume = 30 cm × 20 cm × 4 cm = 2400 cm^3. Because this value is close to your calculated value of 2290 cm^3, it is reasonable to conclude the answer is correct.

PRACTICE Problems

Extra Practice Page 976 and **glencoe.com**

Perform the following calculations. Round the answers.

42. **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

43. **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

44. Challenge $(1.32 \times 10^3 \text{ g}) \div (2.5 \times 10^2 \text{ cm}^3)$

Section **2.3** Assessment

Section Summary

◗ An accurate measurement is close to the accepted value. A set of precise measurements shows little variation.

◗ The measurement device determines the degree of precision possible.

◗ Error is the difference between the measured value and the accepted value. Percent error gives the percent deviation from the accepted value.

◗ The number of significant figures reflects the precision of reported data.

◗ Calculations are often rounded to the correct number of significant figures.

45. MAIN Idea **State** how a measured value is reported in terms of known and estimated digits.

46. Define *accuracy* and *precision*.

47. Identify the number of significant figures in each of these measurements of an object's length: 76.48 cm, 76.47 cm, and 76.59 cm.

48. Apply The object in Question 47 has an actual length of 76.49 cm. Are the measurements in Question 47 accurate? Are they precise?

49. Calculate the error and percent error for each measurement in Question 47.

50. Apply Write an expression for the quantity 506,000 cm in which it is clear that all the zeros are significant.

51. Analyze Data Students collected mass data for a group of coins. The mass of a single coin is 5.00 g. Determine the accuracy and precision of the measurements.

Number of coins	5	10	20	30	50
Mass (g)	23.2	54.5	105.9	154.5	246.2

Chemistry Online Self-Check Quiz **glencoe.com**

Objectives

▶ **Create** graphs to reveal patterns in data.

▶ **Interpret** graphs.

Review Vocabulary

independent variable: the variable that is changed during an experiment

New Vocabulary

graph

Representing Data

MAIN Idea **Graphs visually depict data, making it easier to see patterns and trends.**

Real-World Reading Link Have you ever heard the saying, "A picture is worth a thousand words"? A graph is a "picture" of data. Scientists use graphs to present data in a form that allows them to analyze their results and communicate information about their experiments.
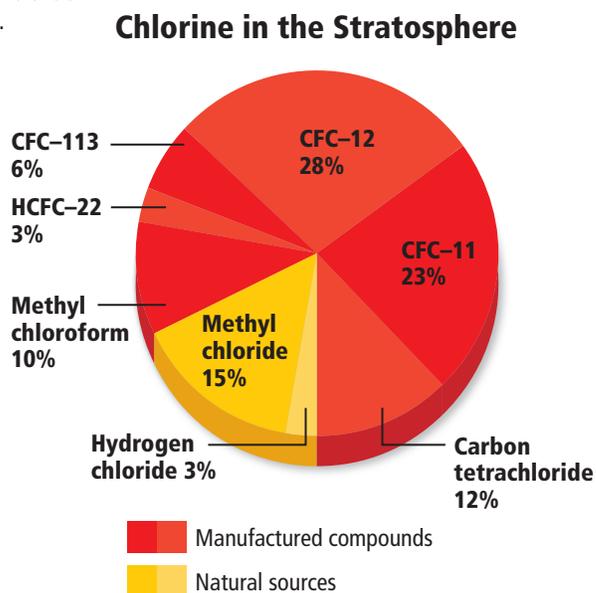
Graphing

When you analyze data, you might 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 navigate a maze? When data are listed as shown in **Table 2.4,** a pattern might not be obvious. However, using data to create a graph can help to reveal a pattern if one exists. A **graph** is a visual display of data.

Circle graphs Newspapers and magazines often feature circle graphs. A circle graph, like the one shown in **Figure 2.14,** is sometimes called a pie chart because it is divided into wedges that look like a pie. A circle graph is useful for showing parts of a fixed whole. The parts are usually labeled as percents with the whole circle representing 100%. The circle graph shown in **Figure 2.14** is based on the percentage data given in **Table 2.4.**

■ **Figure 2.14** Although the percentage data presented in the table and the circle graph are basically the same, the circle graph makes it much easier to analyze.
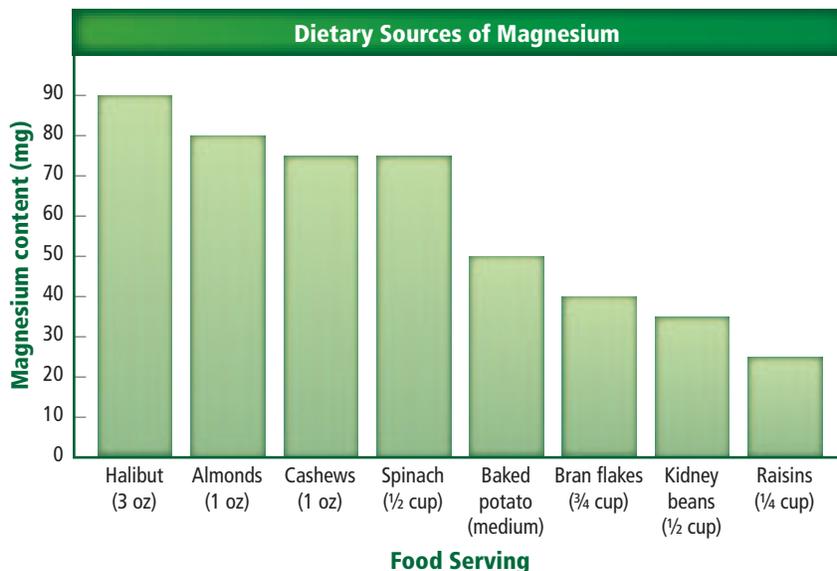
Chlorine in the Stratosphere

Table 2.4	Sources of Chlorine in the Stratosphere
Source	**Percent**
Hydrogen chloride (HCl)	3
Methyl chloride (CH$_2$Cl)	15
Carbon tetrachloride (CCl$_4$)	12
Methyl chloroform (C$_2$H$_3$Cl$_3$)	10
CFC-11	23
CFC-12	28
CFC-13	6
HCFC-22	3

■ Manufactured compounds
■ Natural sources

Graph Check

Analyze What percent of the chlorine sources are natural? What percent are manufactured compounds?

Dietary Sources of Magnesium

Graph Check

Interpret Which two food servings provide equal amounts of magnesium?

Bar graphs A bar graph is often used to show how a quantity varies across categories. Examples of categories include time, location, and temperature. 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 single country by decade or the populations of multiple countries at the same point in time. In **Figure 2.15,** the quantity being measured is magnesium, and the category being varied is food servings. When examining the graph, you can quickly see how the magnesium content varies for these food servings.

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.

Independent and dependent 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 2.16a,** 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 2.16b** is a graph of temperature versus elevation. Because the data points do not fit perfectly, the line cannot pass exactly through all of the 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.

Relationships between variables If the best-fit line for a set of data is straight, there is a linear relationship between the variables and the variables are said to be directly related. The relationship between the variables can be described further by analyzing the steepness, or slope, of the line.

If the best-fit line rises to the right, then the slope of the line is positive. A positive slope indicates that the dependent variable increases as the independent variable increases. If the best-fit line sinks to the right, then the slope of the line is negative. A negative slope indicates that the dependent variable decreases as the independent variable increases. In either case, the slope of the line is constant.

You can use two pairs of data points to calculate the slope of the line. The slope is the rise, or change in y, denoted as Δy, divided by the run, or change in x, denoted as Δx.

Slope Equation

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

$y_2, y_1, x_2,$ and x_1 are values from data points (x_1, y_1) and (x_2, y_2).

The slope of a line is equal to the change in y divided by the change in x.

When the mass of a material is plotted against its volume, the slope of the line represents the material's density. An example of this is shown in **Figure 2.16a.** To calculate the slope of the line, substitute the x and y values for Points A and B in the slope equation and solve.

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

Thus, the slope of the line, and the density, is 2.7g/cm^3.

When the best-fit line is curved, the relationship between the variables is nonlinear. In chemistry, you will study nonlinear relationships called inverse relationships.
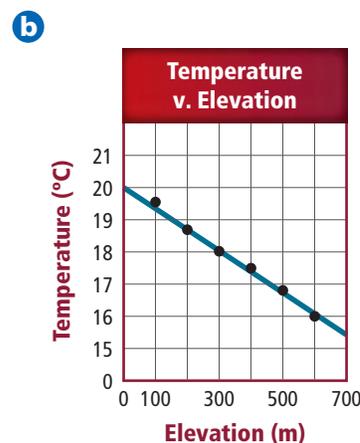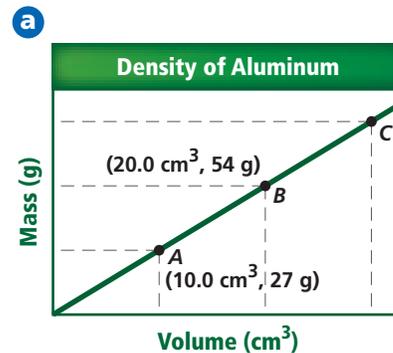
Interpreting Graphs

You should use an organized approach when analyzing graphs. First, note the independent and dependent variables. Recall that the y-axis data depends on the x-axis value. Next, decide if the relationship between the variables is linear or nonlinear. If the relationship is linear, is the slope positive or negative?

Interpolation and extrapolation When points on a line graph are connected, the data is considered to be continuous. Continuous data allows you to read the value from any point that falls between the recorded data points. This process is called interpolation. For example, from **Figure 2.16b,** what is the temperature at an elevation of 350 m? To interpolate this value, first locate 350 m on the x-axis; it is located halfway between 300 m and 400 m. Project upward until you hit the plotted line, and then project that point horizontally to the left until you reach the y-axis. The temperature at 350 m is approximately 17.8°C.

You can also extend a line beyond the plotted points in order to estimate values for the variables. This process is called extrapolation. It is important to be very careful with extrapolation, however, as it can easily lead to errors and result in very inaccurate predictions.

✔ **Reading Check** **Explain** why extrapolation might be less reliable than interpolation.

Density of Aluminum

Mass (g)

(20.0 cm³, 54 g)

C

B

A
(10.0 cm³, 27 g)

Volume (cm³)

Temperature v. Elevation

Temperature (°C)

21
20
19
18
17
16
15
0

0 100   300   500   700

Elevation (m)

■ **Figure 2.16** Both of these line graphs show linear relationships. The slope of each line is defined as the ratio of rise over run.

✔ **Graph Check**
Identify the graph that shows a direct relationship.

■ **Figure 2.17** The two lines in this graph represent average ozone levels for two time periods, 1957–1972 and 1999–2000. The graph shows clearly that ozone levels in recent years have been lower overall than in 1957–1972.

Ozone Measurements at Halley

Graph Check
Interpret By how much did the total ozone vary during the 9-month period shown for 1999–2000?
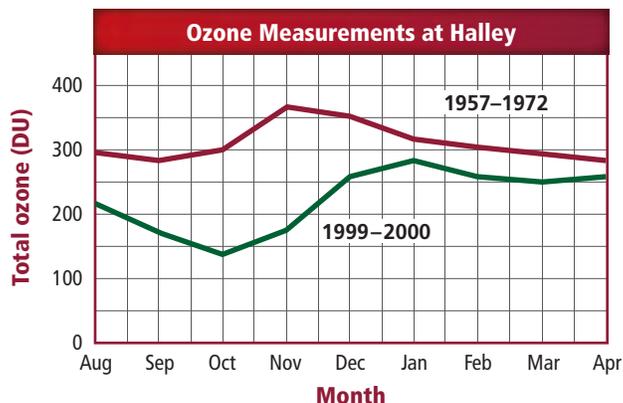
Interpreting ozone data The value of using graphs to visualize data is illustrated by **Figure 2.17.** These important ozone measurements were taken at the Halley Research Station in Antarctica. The graph shows how ozone levels vary from August to April. The independent and dependent variables are the month and the total ozone, respectively.

Each line on the graph represents a different period of time. The red line represents average ozone levels from 1957 to 1972, during which time ozone levels varied from about 285 DU (Dobson units) to 360 DU. The green line shows the ozone levels from the 1999–2000 survey. At no point during this nine-month period were the ozone levels as high as they were at corresponding times during 1957–1972.

The graph makes the ozone hole clearly evident—it is represented by the dip in the green line. Having data from two time periods on the same graph allows scientists to compare recent data with data from a time before the ozone hole existed. Graphs similar to **Figure 2.17** helped scientists identify a significant trend in ozone levels and verify the depletion in ozone levels over time.

Section 2.4 Assessment

Section Summary

▶ Circle graphs show parts of a whole. Bar graphs show how a factor varies with time, location, or temperature.

▶ Independent (*x*-axis) variables and dependent (*y*-axis) variables can be related in a linear or a nonlinear manner. The slope of a straight line is defined as rise/run, or $\Delta y/\Delta x$.

▶ Because line-graph data are considered continuous, you can interpolate between data points or extrapolate beyond them.

52. **MAIN Idea Explain** why graphing can be an important tool for analyzing data.

53. **Infer** What type of data must be plotted on a graph for the slope of the line to represent density?

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

55. **Summarize** What data are best displayed on a circle graph? On a bar graph?

56. **Construct** a circle graph for the composition of air: 78.08% N, 20.95% O_2, 0.93% Ar, and 0.04% CO_2 and other gases.

57. **Infer** from **Figure 2.17** how long the ozone hole lasts.

58. **Apply** Graph mass versus volume for the data given in the table. What is the slope of the line?

Volume (cm³)	7.5	12	15	22
Mass (g)	24.1	38.5	48.0	70.1

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Toxicology: Assessing Health Risk

It is likely that a closet or cupboard in your home or school contains products labeled with the symbol shown in **Figure 1.** Many cleaning, painting, and gardening products contain poisonous chemicals. Exposure to these chemicals can be dangerous. Possible effects are headaches, nausea, rashes, convulsions, coma, and even death. A toxicologist works to protect human health by studying the harmful effects of the chemicals and determining safe levels of exposure to them.

Figure 1 A skull-and-crossbones is the symbol for poison.

Keys to toxicity Warfarin is a drug used to prevent blood clots in people who have had a stroke or heart attack. It is also an effective rat poison. How is this possible? One key to toxicity is the dose—the amount of the chemical taken in by an organism. Exposure time can also be a factor; even low-dose exposure to some chemicals over long periods of time can be hazardous. Toxicity is also affected by the presence of other chemicals in the body, the age and gender of the individual, and the chemical's ability to be absorbed and excreted.

A dose-response curve, such as the one shown in **Figure 2,** relates the toxicity of a substance to its physical effects. This dose-response curve shows the results of an experiment in which different doses of a possible carcinogen were given to mice. The mice were checked for tumors 90 days after exposure. The graph indicates a noticeable increase in the incidence of tumors.
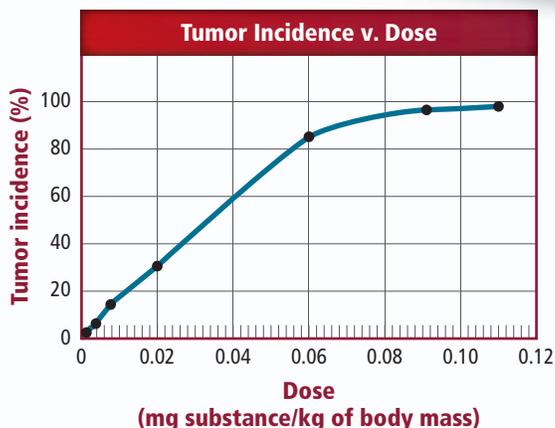
Figure 2 The seven data points correspond to seven groups of mice that were given different doses of a possible carcinogen.

Applying toxicity data How do toxicologists predict health risks to people? Toxicity data might be available from studies of routine chemical exposure in the workplace, as well as from medical records of accidental chemical contact. Toxicity testing is often carried out using bacteria and cell cultures. Toxicologists observe the effect of chemical doses on bacteria. If mutations occur, the chemical is considered potentially harmful.

MSDS Toxicologists apply mathematical models and knowledge of similar substances to toxicity data to estimate safe human exposure levels. How can you obtain this information? Every employer is required to keep Material Safety Data Sheets (MSDS) of the potentially hazardous chemicals they use in their workplace. The MSDS describe possible health effects, clothing and eye protection that should be worn, and first-aid steps to follow after exposure. You can also consult the Household Products Database, which provides health and safety information on more than 5000 commonly used products.

WRITING in Chemistry

Research Access the MSDS for several products used at home. Compare the possible adverse health effects of exposure to the products and list the first aid requirements. For more information about toxicology, visit **glencoe.com**.

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CHEMLAB

FORENSICS: USE DENSITY TO DATE A COIN

Background: A penny that has had its date scratched off is found at a crime scene. The year the coin was minted is important to the case. A forensics technician claims she can determine if the coin was minted before 1982 without altering the coin in any way. Knowing that pennies minted from 1962 to 1982 are 95% copper and 5% zinc, whereas those minted after 1982 are 97.5% zinc and 2.5% copper, hypothesize about what the technician will do.

Question: *How can you use density to determine whether a penny was minted before 1982?*

Data Table for the Density of a Penny				
Trial	Mass of Pennies Added (g)	Total Number of Pennies	Total Mass of Pennies (g)	Total Volume of Water Displaced (mL)
1		5		
2		10		
3		15		
4		20		
5		25		

Materials
water
100-mL graduated cylinder
small plastic cup
balance
pre-1982 pennies (25)
post-1982 pennies (25)
metric ruler
pencil
graph paper
graphing calculator (optional)

Safety Precautions 🥽 👕 🧤

Procedure
1. Read and complete the lab safety form.
2. Record all measurements in your data table.
3. Measure the mass of the plastic cup.
4. Pour about 50 mL of water into the graduated cylinder. Record the actual volume.
5. Add 5 pre-1982 pennies to the cup, and measure the mass again.
6. Add the 5 pennies to the graduated cylinder, and read the volume.
7. Repeat Steps 5 and 6 four times. After five trials there will be 25 pennies in the graduated cylinder.
8. **Cleanup and Disposal** Pour the water from the graduated cylinder down a drain, being careful not to lose any of the pennies. Dry the pennies with a paper towel.
9. Repeat Steps 3 through 7, using post-1982 pennies.

Analyze and Conclude
1. **Calculate** Complete the data table by calculating the total mass and the total volume of water displaced for each trial.
2. **Make and Use Graphs** Graph total mass versus total volume for the pre-1982 and post-1982 pennies. Plot and label two sets of points on the graph, one for pre-1982 pennies and one for post-1982 pennies.
3. **Make and Use Graphs** Draw a best-fit line through each set of points. Use two points on each line to calculate the slope.
4. **Infer** What do the slopes of the lines tell you about the two groups of pennies?
5. **Apply** Can you determine if a penny was minted before or after 1982 if you know only its mass? Explain how the relationships among volume, mass, and density support using a mass-only identification technique.
6. **Error Analysis** Determine the percent error in the density of each coin.

INQUIRY EXTENSION
Compare your results with those from the rest of the class. Are they consistent? If not, explain how you could refine your investigation to ensure more accurate results. Calculate a class average density of the pre-1982 pennies and the density of the post-1982 pennies. Determine the percent error of each average.

Study Guide

BIG Idea Chemists collect and analyze data to determine how matter interacts.

Section 2.1 Units and Measurements

MAIN Idea Chemists use an internationally recognized system of units to communicate their findings.

Vocabulary
- base unit (p. 33)
- density (p. 36)
- derived unit (p. 35)
- kelvin (p. 35)
- kilogram (p. 34)
- liter (p. 35)
- meter (p. 33)
- second (p. 33)

Key Concepts
- SI measurement units allow scientists to report data to other scientists.
- Adding prefixes to SI units extends the range of possible measurements.
- To convert to Kelvin temperature, add 273 to the Celsius temperature.

$$K = °C + 273$$

- Volume and density have derived units. Density, which is a ratio of mass to volume, can be used to identify an unknown sample of matter.

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

Section 2.2 Scientific Notation and Dimensional Analysis

MAIN Idea Scientists often express numbers in scientific notation and solve problems using dimensional analysis.

Vocabulary
- conversion factor (p. 44)
- dimensional analysis (p. 44)
- scientific notation (p. 40)

Key Concepts
- A number expressed in scientific notation is written as a coefficient between 1 and 10 multiplied by 10 raised to a power.
- To add or subtract numbers in scientific notation, the numbers must have the same exponent.
- To multiply or divide numbers in scientific notation, multiply or divide the coefficients and then add or subtract the exponents, respectively.
- Dimensional analysis uses conversion factors to solve problems.

Section 2.3 Uncertainty in Data

MAIN Idea Measurements contain uncertainties that affect how a calculated result is presented.

Vocabulary
- accuracy (p. 47)
- error (p. 48)
- percent error (p. 48)
- precision (p. 47)
- significant figure (p. 50)

Key Concepts
- An accurate measurement is close to the accepted value. A set of precise measurements shows little variation.
- The measurement device determines the degree of precision possible.
- Error is the difference between the measured value and the accepted value. Percent error gives the percent deviation from the accepted value.

$$error = experimental\ value - accepted\ value$$

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

- The number of significant figures reflects the precision of reported data.
- Calculations are often rounded to the correct number of significant figures.

Section 2.4 Representing Data

MAIN Idea Graphs visually depict data, making it easier to see patterns and trends.

Vocabulary
- graph (p. 55)

Key Concepts
- Circle graphs show parts of a whole. Bar graphs show how a factor varies with time, location, or temperature.
- Independent (x-axis) variables and dependent (y-axis) variables can be related in a linear or a nonlinear manner. The slope of a straight line is defined as rise/run, or $\Delta y/\Delta x$.

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

- Because line graph data are considered continuous, you can interpolate between data points or extrapolate beyond them.

Section 2.1

Mastering Concepts

59. Why must a measurement include both a number and a unit?

60. Explain why standard units of measurement are particularly important to scientists.

61. What role do prefixes play in the metric system?

62. How many meters are in one kilometer? In one decimeter?

63. **SI Units** What is the relationship between the SI unit for volume and the SI unit for length?

64. Explain how temperatures on the Celsius and Kelvin scales are related.

65. Examine the density values for several common liquids and solids given in **Table 2.5.** Sketch the results of an experiment that layered each of the liquids and solids in a 1000-mL graduated cylinder.

Table 2.5 Density Values			
Liquids (g/mL)		Solids (g/cm^3)	
Ethyl alcohol	0.789	bone	1.85
Glycerin	1.26	cork	0.24
Isopropyl alcohol	0.870	plastic	0.91
Corn syrup	1.37	wood (oak)	0.84
Motor oil	0.860		
Vegetable oil	0.910		
Water at 4°C	1.000		

Mastering Problems

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

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

68. 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?

69. **Candy Making** The directions in the candy recipe for pralines instruct the cook to remove the pot containing the candy mixture from the heat when the candy mixture reaches the soft-ball stage. The soft-ball stage corresponds to a temperature of 236°F. After the soft-ball stage is reached, the pecans and vanilla are added. Can a Celsius thermometer with a range of −10°C to 110°C be used to determine when the soft-ball stage is reached in the candy mixture?

Section 2.2

Mastering Concepts

70. How does scientific notation differ from ordinary notation?

71. If you move the decimal place to the left to convert a number to scientific notation, will the power of 10 be positive or negative?

72. Two undefined numbers expressed in regular notation are shown below, along with the number of places the decimal must move to express each in scientific notation. If each X represents a significant figure, write each number in scientific notation.
   a. XXX.XX
   b. 0.000 000 XXX

73. When dividing numbers in scientific notation, what must you do with the exponents?

74. When you convert from a small unit to a large unit, what happens to the number of units?

75. When converting from meters to centimeters, how do you decide which values to place in the numerator and denominator of the conversion factor?
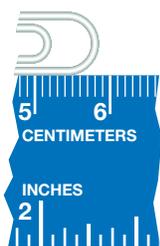
Mastering Problems

76. Write the following numbers in scientific notation.
   a. 0.0045834 mm   **c.** 438,904 s
   b. 0.03054 g   **d.** 7,004,300,000 g

77. Write the following numbers in ordinary notation.
   a. 8.348×10^6 km   **c.** 7.6352×10^{-3} kg
   b. 3.402×10^3 g   **d.** 3.02×10^{-5} s

78. Complete the following addition and subtraction problems in scientific notation.
   a. $(6.23 \times 10^6$ kL$) + (5.34 \times 10^6$ kL$)$
   b. $(3.1 \times 10^4$ mm$) + (4.87 \times 10^5$ mm$)$
   c. $(7.21 \times 10^3$ mg$) + (43.8 \times 10^2$ mg$)$
   d. $(9.15 \times 10^{-4}$ cm$) + (3.48 \times 10^{-4}$ cm$)$
   e. $(4.68 \times 10^{-5}$ cg$) + (3.5 \times 10^{-6}$ cg$)$
   f. $(3.57 \times 10^2$ mL$) - (1.43 \times 10^2$ mL$)$
   g. $(9.87 \times 10^4$ g$) - (6.2 \times 10^3$ g$)$
   h. $(7.52 \times 10^5$ kg$) - (5.43 \times 10^5$ kg$)$
   i. $(6.48 \times 10^{-3}$ mm$) - (2.81 \times 10^{-3}$ mm$)$
   j. $(5.72 \times 10^{-4}$ dg$) - (2.3 \times 10^{-5}$ dg$)$

79. 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$)$

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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

81. Gold A troy ounce is equal to 480 grains, and 1 grain is equal to 64.8 milligrams. If the price of gold is $560 per troy ounce, what is the cost of 1 g of gold?

82. Popcorn The average mass of a kernel of popcorn is 0.125 g. If 1 pound = 16 ounces, and 1 ounce = 28.3 g, then how many kernels of popcorn are there in 0.500 pounds of popcorn?

83. Blood You have 15 g of hemoglobin in every 100 mL of your blood. 10.0 mL of your blood can carry 2.01 mL of oxygen. How many milliliters of oxygen does each gram of hemoglobin carry?

84. Nutrition The recommended calcium intake for teenagers is 1300 mg per day. A glass of milk contains 305 mg of calcium. One glass contains a volume of 8 fluid ounces. How many liters of milk should a teenager drink per day to get the recommended amount of calcium? One fluid ounce equals 29.6 mL.

Section 2.3

Mastering Concepts

85. Which zero is significant in the number 50,540? What is the other zero called?

86. Why are percent error values never negative?

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

88. Which number will produce the same number when rounded to three significant figures: 3.456, 3.450, or 3.448?

■ **Figure 2.18**

89. Record the measurement shown in **Figure 2.18** to the correct number of significant figures.

90. When subtracting 61.45 g from 242.6 g, which value determines the number of significant figures in the answer? Explain.

Mastering Problems

91. Round each number to four significant figures.
- **a.** 431,801 kg
- **b.** 10,235.0 mg
- **c.** 1.0348 m
- **d.** 0.004384010 cm
- **e.** 0.00078100 mL
- **f.** 0.0098641 cg

92. Round the answer for each problem 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.** 38,736 km ÷ 4784 km

93. 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

94. 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

Section 2.4

Mastering Concepts

95. Heating Fuels Which type of graph would you use to depict how many households heat with gas, oil, or electricity? Explain.

96. Gasoline Consumption Which type of graph would you choose to depict gasoline consumption over a 10-year period? Explain.

97. How can you find the slope of a line graph?

Mastering Problems
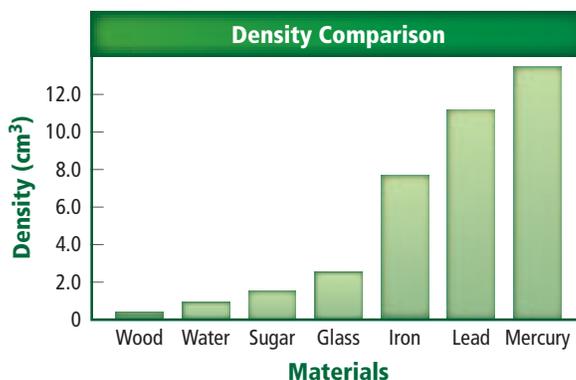
■ **Figure 2.19**

98. Use **Figure 2.19** 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/cm³?
- **d.** Which substance has a density of 11.4 g/cm³?

Mixed Review

99. Complete these problems in scientific notation. Round 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. $(9.33 \times 10^4 \text{ mm}) \div (3.0 \times 10^2 \text{ mm})$
  e. $(4.42 \times 10^{-3} \text{ kg}) \div (2.0 \times 10^2 \text{ kg})$
  f. $(6.42 \times 10^{-2} \text{ g}) \div (3.21 \times 10^{-3} \text{ g})$

100. Convert each quantity to the indicated units.
  a. $3.01 \text{ g} \longrightarrow \text{cg}$ **d.** $0.2 \text{ L} \longrightarrow \text{dm}^3$
  b. $6200 \text{ m} \longrightarrow \text{km}$ **e.** $0.13 \text{ cal/g} \longrightarrow \text{kcal/g}$
  c. $6.24 \times 10^{-7} \text{ g} \longrightarrow \mu\text{g}$ **f.** $3.21 \text{ mL} \longrightarrow \text{L}$

101. Students used a balance and a graduated cylinder to collect the data shown in **Table 2.6.** Calculate the density of the sample. If the accepted density of this sample is 6.95 g/mL, calculate the percent error.

Table 2.6 Volume and Mass Data	
Mass of sample	20.46 g
Volume of water	40.0 mL
Volume of water + sample	43.0 mL

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

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

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

104. **Zinc** Two separate masses of zinc were measured on a laboratory balance. The first zinc sample had a mass of 210.10 g, and the second zinc sample had a mass of 235.10 g. The two samples were combined. The volume of the combined sample was found to be 62.3 mL. Express the mass and density of the zinc sample in the correct number of significant figures.

105. What mass of lead (density 11.4 g/cm³) would have a volume identical to 15.0 g of mercury (density 13.6 g/cm³)?

106. Three students use a meterstick with millimeter markings to measure a length of wire. Their measurements are 3 cm, 3.3 cm, and 2.87 cm, respectively. Explain which answer was recorded correctly.

107. **Astronomy** The black hole in the M82 galaxy has a mass about 500 times the mass of the Sun. It has about the same volume as the Moon. What is the density of this black hole?

$$\text{mass of the Sun} = 1.9891 \times 10^{30} \text{ kg}$$
$$\text{volume of the Moon} = 2.1968 \times 10^{10} \text{ km}^3$$

108. The density of water is 1 g/cm³. Use your answer from Question 107 to compare the densities of water and a black hole.

109. When multiplying 602.4 m by 3.72 m, which value determines the number of significant figures in the answer? Explain.

110. Round each figure to three significant figures.
  a. 0.003210 g   **d.** 25.38 L
  b. 3.8754 kg   **e.** 0.08763 cm
  c. 219,034 m   **f.** 0.003109 mg

111. Graph the data in **Table 2.7,** 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	5.4
4.0	10.8
6.0	16.2
8.0	21.6
10.0	27.0

112. **Cough Syrup** A common brand of cough syrup comes in a 4-fluid ounce bottle. The active ingredient in the cough syrup is dextromethorphan. For an adult, the standard dose is 2 teaspoons, and a single dose contains 20.0 mg of dextromethorphan. Using the relationships, 1 fluid ounce = 29.6 mL and 1 teaspoon = 5.0 mL, determine how many grams of dextromethorphan are contained in the bottle.

Think Critically

113. **Interpret** Why does it make sense for the line in **Figure 2.16a** to extend to (0, 0) even though this point was not measured?

114. **Infer** 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.

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

116. **Compare and Contrast** What advantages do SI units have over the units commonly used in the United States? Are there any disadvantages to using SI units?

117. **Hypothesize** Why do you think the SI standard for time was based on the distance light travels through a vacuum?

118. Infer Why does knowing the mass of an object not help you identify what material the object is made from?

119. Conclude Why might property owners hire a surveyor to determine property boundaries rather than measure the boundaries themselves?

Nutrition Facts

Serving Size ¾ cup (29 g)
Servings Per Container about 17

Amount Per Serving

Calories 120   Calories from Fat 10

	% Daily Value *
Total Fat 1g	2%
Saturated Fat 1 g	5%
Cholesterol 0 mg	0%
Sodium 160 mg	7%
Potassium 25 mg	1%
Total Carbohydrate 25 g	9%
Dietary Fiber less than 1 g	2%
Sugars 13 g	
Protein 1 g	
Vitamin A	4%

■ **Figure 2.20**

120. Apply Dimensional Analysis Evaluate the breakfast cereal nutritional label shown in **Figure 2.20.** This product contains 160 mg of salt in each serving. If you eat 2.0 cups of cereal a day, how many grams of salt are you ingesting? What percent of your daily recommended salt intake does this represent?

121. Predict Four graduated cylinders each contain a different liquid: A, B, C, and D.

Liquid A: mass = 18.5 g; volume = 15.0 mL
Liquid B: mass = 12.8 g; volume = 10.0 mL
Liquid C: mass = 20.5 g; volume = 12.0 mL
Liquid D: mass = 16.5 g; volume = 8.0 mL

Examine the information given for each liquid, and predict the layering of the liquids if they were carefully poured into a larger graduated cylinder.

Challenge Problem

122. Carboplatin ($C_6H_{12}N_2O_4Pt$) is a platinum-containing compound that is used to treat certain forms of cancer. This compound contains 52.5% platinum. If the price for platinum is $1047/troy ounce, what is the cost of the platinum in 2.00 g of this compound? A troy ounce is equal to 480 grains, and one grain is equal to 64.8 mg.

Cumulative Review

123. 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)*

Additional Assessment

WRITING in Chemistry

124. Kilogram Standard 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 alternative standards that have been proposed. Find out why no alternative standard has been chosen.

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

126. Product Volume Research the range of volumes used for packaging liquids sold in supermarkets.

127. Dosing Error In hospitals, medicines are given by dose. Find out what amount of error in the administered dose is acceptable for various medicines.

DBQ Document-Based Questions

Ocean Water *The density of pure water is 1.00 g/cm³ at 4°C. Ocean water is denser because it contains salt and other dissolved substances. The graph in* **Figure 2.21** *shows the relationships among temperature, density, and salinity versus depth for ocean water.*

Data obtained from: *Windows to the Universe,* at the University Corporation for Atmospheric Research (UCAR).
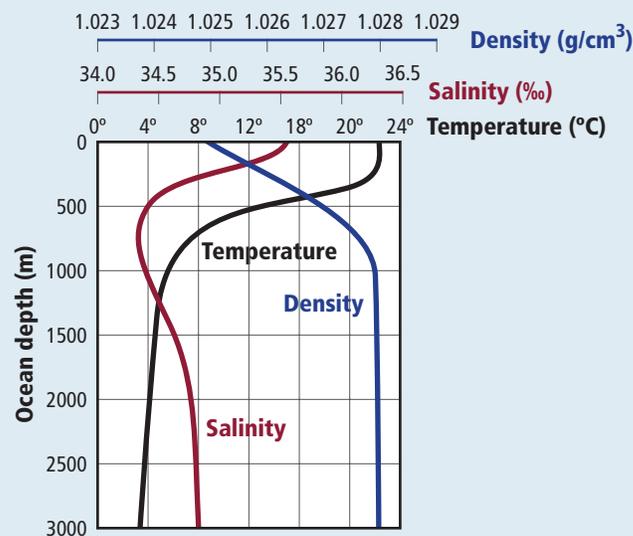
■ **Figure 2.21**

128. How is temperature related to the density of ocean water at depths less than 1000 m?

129. Describe the effect of depth on salinity.

130. Describe how salinity changes as the ocean water cools.

Multiple Choice

1. Which is NOT an SI base unit?
   A. second
   B. kilogram
   C. degree Celsius
   D. meter

2. Which value is NOT equivalent to the others?
   A. 500 m
   B. 0.5 km
   C. 5000 cm
   D. 5×10^{11} nm

3. What is the correct representation of 702.0 g in 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

Use the table below to answer Questions 4 and 5.

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

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.

5. What is the percent error for Student 1's averaged value?
   A. 1.48%
   B. 1.85%
   C. 3.70%
   D. 4.51%

6. Solve the following problem with the correct number of significant figures.

   $$5.31 \text{ cm} + 8.4 \text{ cm} + 7.932 \text{ cm}$$

   A. 22 cm
   B. 21.64 cm
   C. 21.642 cm
   D. 21.6 cm

7. 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

8. How many significant figures are there in a distance measurement of 20.070 km?
   A. 2
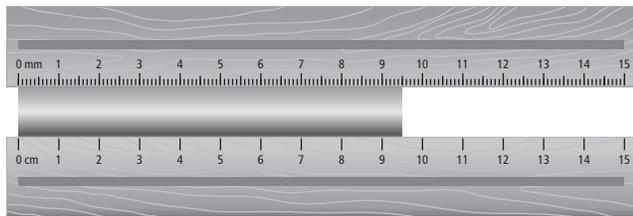   B. 3
   C. 4
   D. 5

Use the graph below to answer Questions 9 and 10.
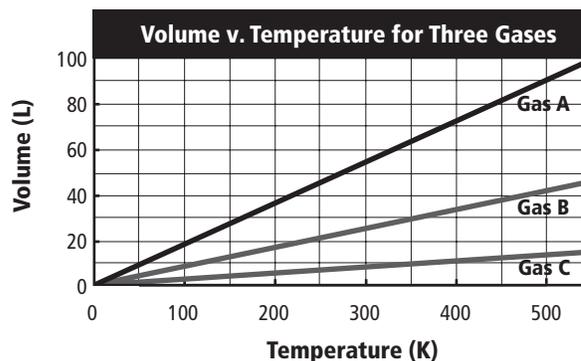
9. What volume will Gas A have at 450 K?
   A. 23 L
   B. 31 L
   C. 38 L
   D. 80 L

10. At what temperature will Gas B have a volume of 30 L?
    A. 170 K
    B. 350 K
    C. 443 K
    D. 623 K

11. Which is NOT a quantitative measurement of a pencil?
    A. length
    B. mass
    C. color
    D. diameter

Use the diagram below to answer Questions 12 and 13.

12. Explain which ruler you would use to make the more precise measurement. Explain which is more accurate.

13. What is the length of the rod using significant digits?

Extended Response

Use the table below to answer Questions 14 to 16.

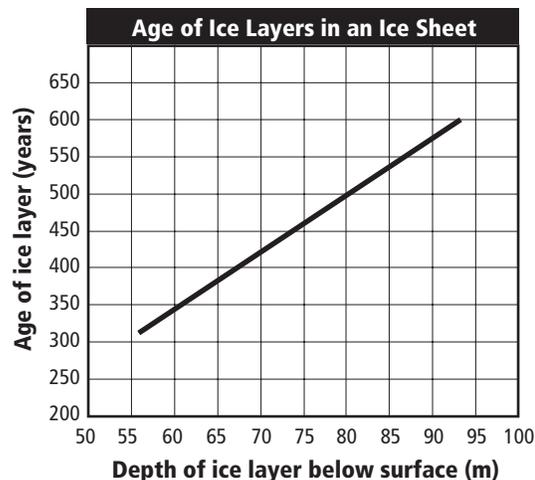| Temperature of a Solution While Heating	
Time (s)	Temperature (°C)
0	22
30	35
60	48
90	61
120	74
150	87
180	100

14. A student recorded the temperature of a solution every 30 s for 3 min while the solution was heating on a Bunsen burner. Graph the data.

15. Show the setup to calculate the slope of the graph you created in Question 14.

16. Choose and explain two safety precautions the student should use with this experiment.

SAT Subject Test: Chemistry

Use the graph below to answer Questions 17 to 21.

17. A student reported the age of an ice layer at 70 m as 425 years. The accepted value is 427 years. What is the percent error of the student's value?
   A. 0.468%   **D.** 49.9%
   B. 0.471%   **E.** 99.5%
   C. 1.00%

18. What is the approximate slope of the line?
   A. 0.00 m/y   **D.** 7.5 m/y
   B. 0.13 m/y   **E.** 7.5 y/m
   C. 0.13 y/m

19. What is the depth of an ice layer 450 years old?
   A. 74 m   **D.** 77 m
   B. 75 m   **E.** 78 m
   C. 76 m

20. What is the relationship between ice depth and age?
   A. linear, positive slope
   B. linear, negative slope
   C. linear, slope = 0
   D. nonlinear, positive slope
   E. nonlinear, negative slope

NEED EXTRA HELP?																				
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Review Section . . .	2.1	2.1	2.2	2.3	2.3	2.3	2.2	2.3	2.4	2.4	1.3	2.1	2.3	2.4	2.4	1.4	2.4	2.4	2.4	2.4