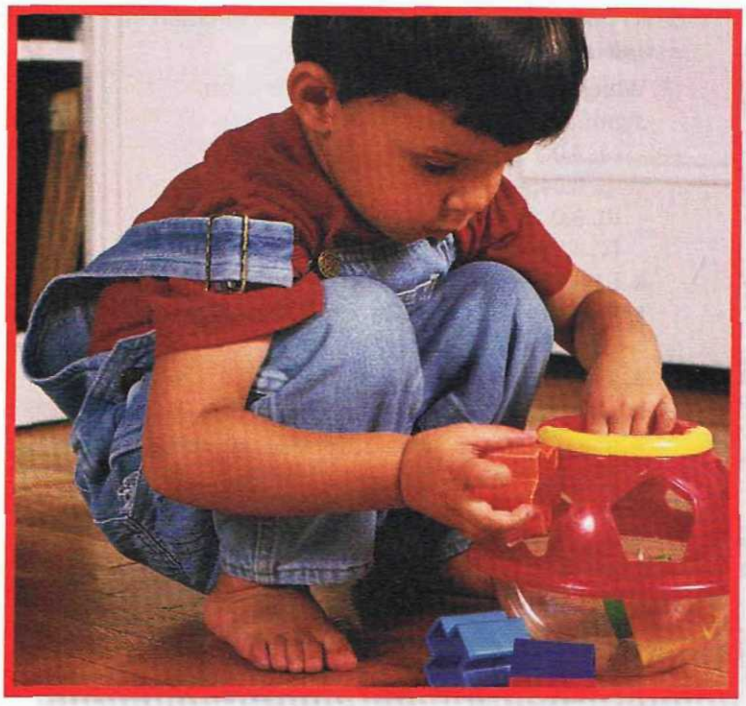
Chapter 4 PROBLEM SOLVING IN CHEMISTRY



A child practices problem solving with shape-sorter toys.

FEATURES

Stay current with **SCIENCE NEWS**
Find out more about problem solving:
www.phschool.com

DISCOVER IT! TESTING PROBLEM-SOLVING SKILLS

You need five index cards, or five sheets of paper, and five pencils.

1. Copy the following problem onto each of the index cards: "The height of a graduated cylinder is 24 cm plus one-half of its height. How tall is the graduated cylinder?"
2. Work the problem yourself and then compare your answer with the solution provided by your teacher. How did you do?
3. Ask four family members or friends (not in your chemistry class) to work the problem.
4. How did they do?

Congratulate those who got the correct answer on their first try. Ask them how they got the answer. Point out to those who could not solve the problem that if they had checked their work they might have caught their initial error in reasoning. Show them that sketching the problem statement would have been useful in solving this problem. As you solve the problems in this chapter, make note of the problem-solving skills you use.

WHAT DO I DO NOW?

objectives

- List several useful problem-solving skills
- Describe the three-step problem-solving approach

Shape-sorter toys fascinate young children. Typically, the children take one shape and try it in every hole over and over again until they find the right one. As adults, we can use information we have gathered about the distinction between shapes to evaluate the toy and place the star in the star-shaped hole. So although trial and error is one method of problem solving, it is usually not the best one. **What is the most effective way to solve problems?**

Skills Used in Solving Problems

Do you like word problems? You know the kind: "Sally is twice as old as Sara, who is three years younger than Suzy. What will Sally's age be one year from now if Suzy is one-third as old as twelve-year-old Sonja will be nine years from now?" (The answer is nine years old.) If problems such as this seem confusing, rest assured: None of the problems you will encounter in this textbook are that difficult. However, problem solving may be an area in which you feel less than proficient. This chapter will teach you how to become a good problem solver—and perhaps even to enjoy the process.

One way to become a better problem solver is to learn and use various problem-solving techniques. These techniques will turn out to apply to many situations, not just to your chemistry studies. You probably already use many problem-solving skills in everyday situations as well as in classes like algebra. Can you think of an instance in which you have used such skills today?

Problem solving involves developing a plan. Suppose one of your good friends moved to a distant state and then invited your family for a visit. You would face the problem of getting to the new location. You might fly to the airport closest to your friend's house and then rent a car to drive the rest of the way. But before you drove there, you would need to identify your destination on a road map like that in **Figure 4.1.** On the map, you see several alternate routes between the airport and your friend's town. You would have to select and plan a specific route to get from your starting point to your destination. Without the proper planning, your trip might be difficult.

Figure 4.1
Carefully planning your route helps ensure a successful trip. What are some possible routes for traveling from Meacham Field to Arlington?

A Three-Step Problem-Solving Approach

As you may have noted in Chapter 3, the techniques used in this book to solve problems are conveniently organized into a three-step problem-solving approach. While this approach is not the only strategy for solving problems, we believe it is the most helpful and effective. Thus we recommend that you follow it when working on the problems in this textbook. You will now examine the steps in detail.

Figure 4.2
The three-step approach to solving problems in chemistry is a useful and effective strategy that you should employ throughout this course—and in other problem-solving situations.

Step 1. *ANALYZE* Solving a word problem is not too different from taking a trip to a new place. You must determine where you are starting from (identify the known), where you are going (identify the unknown), and how you are going to get there (plan a solution). What is known in a word problem may include a measurement and one or more relationships or equations that link measurements. You identify the unknown by reading the problem carefully to be sure that you understand what the problem is asking you to find. If the problem is long, you might need to read it several times. If the problem is to have a numerical answer, write down the units that the answer should have before you begin your solution.

Planning a solution—figuring out how to get from the known to the unknown—is obviously at the heart of problem solving. Sketching a picture that represents the problem may help you visualize a relationship between the known and the unknown. It might also suggest a way to break the problem down into two or more simpler problems. The solutions to the simpler problems can then be combined to solve the more complex problem. At this point, you might need to use resources such as tables or figures to find other facts or relationships. For example, you might need to look up a constant or an equation that relates a known measurement to an unknown measurement.

Step 2. *CALCULATE* If you have done a good job planning your solution, doing the calculation is usually straightforward. The calculation may involve substituting known quantities and doing the arithmetic needed to solve an equation for the unknown. Sometimes more than one equation may be needed in the solution. In some problems, you might need to convert a measurement to a different form.

Step 3. *EVALUATE* Once you have done the calculation, you must evaluate your answer. Does the answer make sense? Is it reasonable? Is it written in the correct unit? Solving the problem should give an answer with the correct unit. If it does not, you may have set up the equation incorrectly. The answer should also be expressed to the correct number of significant figures. Where appropriate, the answer should be written in scientific notation. Most importantly, you must check your work. Reread the problem to make sure that what the problem asked for is what you have found. Did you copy down the given facts correctly? Check your math. Often, you can estimate an appropriate answer as a quick check.

With slight modifications, this three-step approach can be used for both numeric and nonnumeric problems. With some practice, you will soon find yourself applying it without difficulty to all sorts of situations. Sample Problem 4-1 on page 86 illustrates how the approach is used.

CHEMath

CALCULATOR SKILLS

Chemistry problems often involve calculations that are too complicated to do by hand. Thus the correct use of a calculator is essential to your success in this course. You will also find your calculator is very useful for solving a variety of problems in your everyday life.

The following instructions will help you use a typical scientific calculator. Be aware, however, that your calculator may vary slightly from the instructions that follow.

Addition, subtraction, multiplication, and division are entered much as they appear on paper. Use the change-sign key, [+/-], to enter negative numbers, and use parentheses as appropriate. For example:

Enter 4×1.25 as 4 [×] 1 [.] 25 [=].

Enter $10 \div (-0.4)$ as 10 [÷] 0 [.] 4 [+/-] [=].

Enter $3 \times (2 + 3)$ as $3 \times$ [(] 2 [+] 3 [)] [=].

In chemistry, you will encounter many numbers written in scientific notation (see page 52). You can enter these numbers using the [EXP] key (labeled [EE] or [E] on some calculators). For example, the mass of an electron is 9.11×10^{-28} g, which you would enter as 9 [.] 11 [EXP] [+/-] 28. How would you calculate the mass of three electrons?

Different calculators may have different square root keys. Some calculators have a [$\sqrt{x}$] or [SQRT] key, but others require a two-key process using [INV] [x^2]. To find the square root of 16, enter 16 [$\sqrt{x}$], 16 [SQRT], or 16 [INV] [x^2], depending on your calculator.

To calculate powers, use the [y^x] key. For example, find 5^3 by pressing 5 [y^x] 3 [=]. When the exponent is 2, you can use the [x^2] key. To calculate 8^2, enter 8 [x^2] [=].

Example 1

Use a calculator to evaluate $4^2 \times (10 + \sqrt{10\,609})$.

Enter 4 [x^2] [×] [(] 10 [+] 10 609 [$\sqrt{x}$] [)] [=].

The expression is equal to 1808.

Example 2

One atom of gold has a mass of 3.271×10^{-22} g. What is the mass of 158 atoms of gold?

The mass of 158 atoms of gold is given by $(158\ \cancel{\text{atoms gold}}) \times \dfrac{3.271 \times 10^{-22}\ \text{g}}{1\ \cancel{\text{atom gold}}}$.

158 [×] 3.271 [EXP] [+/-] 22 [=] 5.16818×10^{-20}

Rounding to four significant figures, the mass is 5.168×10^{-20} g.

Practice Problems

Prepare for upcoming problems in this chapter by using a calculator to solve each of the following problems.

A. *Evaluate 7.823×15.76.*

B. Evaluate $89^2 + 17^3 + 5^6$.

C. Evaluate $\dfrac{35 + \sqrt{529}}{2.9 \times 10^{17}}$.

D. The volume of a sphere with radius r is given by $\dfrac{4}{3}\pi r^3$. Find the volume of a sphere with a radius of 3.00 cm.

E. Find the number of atoms in 7.000 g of gold by evaluating $(7.000\ \text{g}) \times \dfrac{1\ \text{atom gold}}{3.271 \times 10^{-22}\ \text{g}}$.

Figure 4.3
The three-step problem-solving approach is much like the approach used in many non-science situations. Here, the golfer analyzes the situation, assessing what is known about variables such as the ball's position and distance from the hole. Then she acts on her analysis by attempting her putt. Her evaluation reveals she has been successful! Careful analysis and execution have produced the desired outcome.

Sample Problem 4-1

What is the mass, in grams, of a piece of lead that has a volume of 19.84 cm^3?

1. **ANALYZE** ***List the knowns and the unknown.***

   Knowns:
   - volume of lead = 19.84 cm^3
   - density = relationship between the mass and volume of a substance = $\frac{\text{mass}}{\text{volume}}$

     The density of lead is not given in the problem, so you must look it up. According to **Table 3.7** on page 69, the density of lead is 11.4 g/cm^3.
   - density of lead = 11.4 g/cm^3

   Unknown:
   - mass = ? g

   Using the known values for the volume and density of lead and the equation for density, density = $\frac{\text{mass}}{\text{volume}}$, the unknown mass can be determined.

2. **CALCULATE** ***Solve for the unknown.***

   The definition for density is an algebraic relationship that includes the unknown variable (mass) and two variables whose values are known in this problem (volume and density). Solve the equation for the unknown variable (mass) by rearranging the equation to isolate mass on one side of the equation. To do so, multiply both sides of the equation by the volume and cancel like terms.

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

$$\frac{\text{volume}}{1} \times \text{density} = \frac{\text{mass}}{\text{volume}} \times \frac{\text{volume}}{1}$$

Sample Problem 4-1 (cont.)

Canceling like terms yields:

$$\frac{\text{volume}}{1} \times \text{density} = \frac{\text{mass}}{\cancel{\text{volume}}} \times \frac{\cancel{\text{volume}}}{1}$$

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

$$(\text{or, mass} = \text{volume} \times \text{density})$$

Substitute the known values for volume and density, and carry out the calculation.

$$\text{mass} = 19.84\ \cancel{\text{cm}^3} \times 11.4\ \text{g}/\cancel{\text{cm}^3} = 226.176\ \text{g}$$

Finally, round the answer to the correct number of significant figures (three) to match the number of figures in 11.4 g/cm^3.

$$\text{mass} = 226\ \text{g}$$

3. **EVALUATE** ***Does the result make sense?***

Evaluating the answer involves a number of checks. Has the unknown been found? Yes, the problem asked for the mass of lead. Do the units in the solution cancel so that the calculated answer has the correct units? Yes, the answer is given in grams, a unit of mass. Does the numerical value of the answer make sense? Yes, estimating an answer based on the approximate volume and the approximate density gives an estimated mass close to the calculated result. Is the number of significant figures correct? Yes, the answer to a multiplication calculation can have no more significant figures than the measurement with the smallest number of significant figures.

Here is another Sample Problem. Although it is somewhat different from Sample Problem 4-1, the problem-solving process is the same. Notice that this problem includes Practice Problems for you to solve on your own.

Sample Problem 4-2

What is the volume, in cubic centimeters, of a sample of cough syrup that has a mass of 50.0 g? The density of the cough syrup is 0.950 g/cm^3.

1. **ANALYZE** ***List the knowns and the unknown.***

Knowns:
- mass of cough syrup = 50.0 g
- density of cough syrup = 0.950 g/cm^3
- density = $\frac{\text{mass}}{\text{volume}}$

Unknown:
- volume of cough syrup = ? cm^3

Using the known values for the mass and density and the equation for density, the unknown volume can be determined.

Sample Problem 4-2 (cont.)

2. **CALCULATE** ***Solve for the unknown.***
The equation for density must be solved for volume. Multiplying both sides of the equation by volume yields:

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

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

Dividing both sides of the equation by density yields the desired result—the equation solved for volume.

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

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

Substituting the known values and solving yields the volume.

$$\text{volume} = \frac{50.0\ \cancel{\text{g}}}{0.950\ \cancel{\text{g}}/\text{cm}^3} = 52.6316\ \text{cm}^3$$

Rounding to three significant figures gives 52.6 cm^3.

3. **EVALUATE** ***Does the result make sense?***
Substituting the known mass and the calculated volume into the equation for density yields a result of 0.950 g/cm^3. This agrees with the known density. The unit obtained is the desired unit of volume. The answer has three significant figures as required.

Practice Problems

1. The density of silicon is 2.33 g/cm^3. What is the volume of a piece of silicon that has a mass of 62.9 g?
2. Helium has a boiling point of 4 K. This is the lowest boiling point of any liquid. Express this temperature in degrees Celsius.

section review 4.1

3. List three useful problem-solving skills.
4. State in your own words the three suggested steps for solving word problems.
5. Identify the statements that correctly complete the sentence: Good problem solvers
   a. read a problem only once.
   b. check their work.
   c. break complex problems down into one or more simpler problems.
   d. look for relationships among pieces of information.
6. A small piece of gold has a volume of 1.35 cm^3.
   a. What is the mass, given that the density of gold is 19.3 g/cm^3?
   b. What is the value of this piece if the market value of gold is $11/g?
7. What is normal body temperature (37 °C) on the Kelvin scale?
8. Match the steps taken in the trip described on page 83 with the three problem-solving steps used in chemistry problems.

Chem ASAP! Assessment 4.1 Check your understanding of the important ideas and concepts in Section 4.1.

SIMPLE CONVERSION PROBLEMS

objectives
- Construct conversion factors from equivalent measurements
- Apply the techniques of dimensional analysis to a variety of conversion problems

key terms
- conversion factor
- dimensional analysis

Perhaps you have traveled abroad or are planning to do so. If so, you know—or will soon discover—that different countries have different currencies. As a tourist, exchanging money is essential to the enjoyment of your trip. After all, you must pay for your meals, hotel, transportation, gift purchases, and tickets to exhibits and events. Because each country's currency compares differently with the U.S. dollar, knowing how to convert currency units correctly is very important.
Is there a simple and effective method for making conversions?

Conversion Factors

If you think about any number of everyday situations, you will realize that a quantity can usually be expressed in several different ways. For example, 1 dollar = 4 quarters = 10 dimes = 20 nickels = 100 pennies. These are all expressions, or measurements, of the same amount of money. The same thing is true of scientific quantities. For example, 1 meter = 10 decimeters = 100 centimeters = 1000 millimeters. These are different ways to express the same length.

Whenever two measurements are equivalent, a ratio of the two measurements will equal 1, or unity. For example, you can divide both sides of the equation 1 m = 100 cm by 1 m or by 100 cm.

$$\frac{1\text{ m}}{1\text{ m}} = \underbrace{\frac{100\text{ cm}}{1\text{ m}}} = 1 \qquad \text{or} \qquad \underbrace{\frac{1\text{ m}}{100\text{ cm}}} = \frac{100\text{ cm}}{100\text{ cm}} = 1$$

conversion factors

A ratio of equivalent measurements, such as $\frac{100\text{ cm}}{1\text{ m}}$ or $\frac{1\text{ m}}{100\text{ cm}}$, is called a **conversion factor.** In a conversion factor, the measurement in the numerator (on the top) is equivalent to the measurement in the denominator (on the bottom). The conversion factors above are read "one hundred centimeters per meter" and "one meter per hundred centimeters." **Figure 4.4** illustrates another way to look at the relationship in a conversion factor.

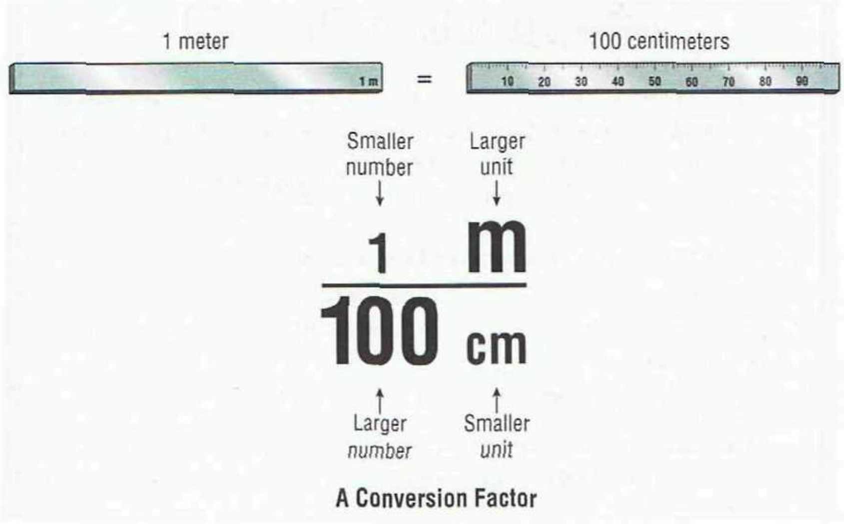


Figure 4.4
The two parts of a conversion factor, the numerator and the denominator, are equal. The smaller number is part of the quantity with the larger unit; for example, a meter is physically larger than a centimeter. The larger number is part of the quantity with the smaller unit.

Chem ASAP!
Animation 3
Learn how to select the proper conversion factor and how to use it.

Link TO

BUSINESS

Monetary Exchange Rates

The conversion of chemical units is similar to the exchange of currency. Americans who travel outside the United States must exchange U.S. dollars for foreign currency at a given rate of exchange. The exchange rate for one U.S. dollar might be 8.57 Mexican pesos, 0.855 Euro, or 129.32 Japanese yen. Exchange rates change daily. Each time an exchange is made, the current exchange rate serves as a conversion factor. For example, travelers to Britain might receive £0.6067 (British pound) for every U.S. dollar they exchange. Suppose, for example, that a traveler has saved $3500.00 to spend during a vacation in Britain. How many pounds does that represent? The conversion factors that relate dollars and pounds are

$$\frac{£0.6067}{\$1.000} \text{ and } \frac{\$1.000}{£0.6067}.$$

The conversion factor that allows dollars to cancel and gives an answer in pounds is the correct form.

$$\frac{\$3500.00}{1} \times \frac{£0.6067}{\$1.0000} = £2123.45$$

Conversion factors have many important applications!

Conversion factors are useful in solving problems in which a given measurement must be expressed in some other unit of measure. When a measurement is multiplied by a conversion factor, the numerical value is generally changed, but the actual size of the quantity measured remains the same. For example, even though the numbers in the measurements 1 g and 10 dg (decigrams) differ, both measurements represent the same mass. In addition, conversion factors within a system of measurement are defined or exact quantities. Therefore, they have an unlimited number of significant figures. How would a conversion factor affect the rounding of a calculated answer?

Here are some additional examples of pairs of conversion factors written from equivalent measurements. The relationship between grams and kilograms is 1000 g = 1 kg. Possible conversion factors are:

$$\frac{1000 \text{ g}}{1 \text{ kg}} \quad \text{and} \quad \frac{1 \text{ kg}}{1000 \text{ g}}$$

The relationship between nanometers and meters is 10^9 nm = 1 m. The possible conversion factors are:

$$\frac{10^9 \text{ nm}}{1 \text{ m}} \quad \text{and} \quad \frac{1 \text{ m}}{10^9 \text{ nm}}$$

What conversion factors can you write based on the relationship 1 L = 1000 mL?

Dimensional Analysis

No one method is best for solving every type of problem. Several good approaches are available, and generally one of the best is dimensional analysis. **Dimensional analysis** is a way to analyze and solve problems using the units, or dimensions, of the measurements. The best way to explain this problem-solving technique is to use it to solve an everyday situation and then to apply the technique to a chemistry problem.

Sample Problem 4-3 uses dimensional analysis and the problem-solving techniques you learned in Section 4.1.

Sample Problem 4-3

Your school club has sold 600 tickets to a chili-supper fundraising event, and you have volunteered to make the chili. You have a chili recipe that serves ten. The recipe calls for two teaspoons of chili powder. How much chili powder do you need for 600 servings?

1. **ANALYZE** ***List the knowns and the unknown.***

Knowns:	*Unknown:*
• servings = 600	• amount of chili powder = ? tsp
• 10 servings = 2 tsp chili powder	

The correct conversion factor has the known unit in the denominator and the unknown unit in the numerator.

Sample Problem 4-3 (cont.)

2. *CALCULATE* *Solve for the unknown.*

The known measurement (600 servings) must be converted to teaspoons. Use the relationship between servings of chili and teaspoons of chili powder from the recipe to write a conversion factor that has the unit of the known in the denominator. The known unit will cancel, resulting in an answer that has the unit of the unknown.

The correct conversion factor is $\frac{2 \text{ tsp chili powder}}{10 \text{ servings}}$.

$$600 \cancel{\text{servings}} \times \frac{2 \text{ tsp chili powder}}{10 \cancel{\text{servings}}} = 120 \text{ tsp chili powder}$$

3. *EVALUATE* *Does the result make sense?*

The known measurement has been multiplied by a conversion factor (which equals unity). This gives another measurement: 120 teaspoons of chili powder. Because the size of the recipe was increased by a factor of 60, the amount of chili powder must also increase by a factor of 60. The unit of the known (servings) has canceled leaving the answer with the correct unit (tsp).

The answer to this problem has now generated a problem of a different sort. Do you really take the time to measure out 120 teaspoons of chili powder or do you just estimate and pour in several cans? Obviously, the first option would be tedious and the second could be dangerous! Why not measure out the chili powder by the cup? The question then becomes: How many cups are there in 120 teaspoons of chili powder? To solve this problem, you need to know the relationship between teaspoons and cups. This information and other volume relationships can be found in a cookbook. The given relationships do not include the one between teaspoons and cups, but they do include the following:

$$3 \text{ teaspoons} = 1 \text{ tablespoon}$$
$$16 \text{ tablespoons} = 1 \text{ cup}$$

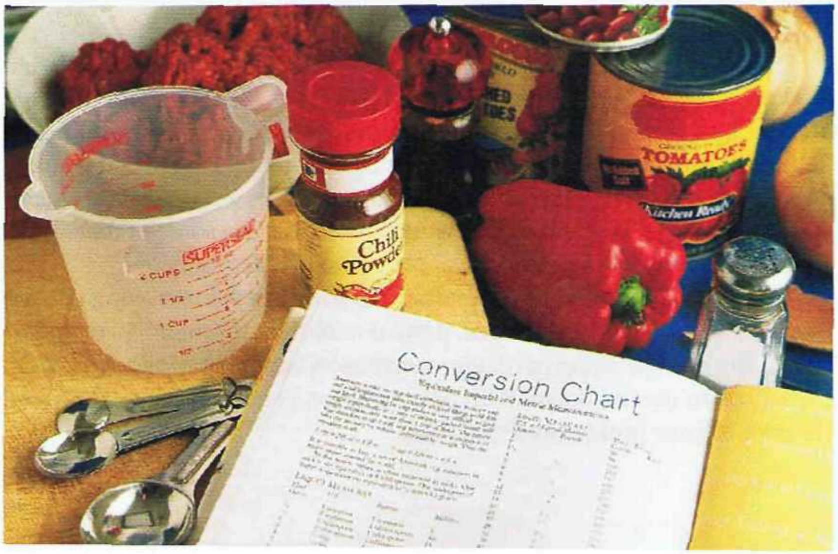


Figure 4.5
When you prepare chili, you need to know how to measure and convert units. Relationships among various measurements of volume used in cooking can be found in a conversion table in a cookbook.

Sample Problem 4-4

How many cups are in 120 teaspoons of chili powder?

1. ***ANALYZE*** ***List the knowns and the unknown.***

   Knowns:
   - amount of chili powder = 120 teaspoons
   - 3 teaspoons = 1 tablespoon
   - 16 tablespoons = 1 cup

   Unknown:
   - amount of chili powder = ? cups

   The first conversion factor must be written with the unit teaspoons in the denominator. The second conversion factor must be written with the unit tablespoons in the denominator. This will provide the desired unit in the answer.

2. ***CALCULATE*** ***Solve for the unknown.***

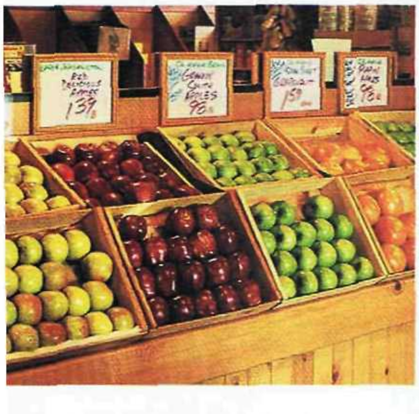
   Start with the known, 120 tsp chili powder. Use the first relationship to write a conversion factor that expresses 120 tsp as tablespoons. The unit teaspoons must be in the denominator so that the known unit will cancel. Then use the second conversion factor to change the unit tablespoons into the unit cups. This conversion factor must have the unit tablespoons in the denominator. The two conversion factors can be used together in a simple overall calculation.

$$120\ \cancel{\text{teaspoons}} \times \frac{1\ \cancel{\text{tablespoon}}}{3\ \cancel{\text{teaspoons}}} \times \frac{1\ \text{cup}}{16\ \cancel{\text{tablespoons}}} = 2.5\ \text{cups}$$

3. ***EVALUATE*** ***Does the result make sense?***

   The numerical result makes sense because there are approximately 50 tsp in a cup, and 120 tsp should be between 2 and 3 cups. The unit in the solution is the desired unit (cups). Before you do the actual arithmetic, it is a good idea to make sure that the units cancel and that the numerator and denominator of each conversion factor are equal to each other.

Figure 4.6
How many pounds of apples can you buy with $4.00 if the price of apples is $1.39/lb? Solve this problem using dimensional analysis.



There is usually more than one way to solve a problem. When you first read the previous Sample Problems, you may have thought about different and equally correct ways to approach and solve some of the problems. Some problems are easily worked with simple algebra. Dimensional analysis provides you with a different approach. In each case, you should choose the problem-solving method that works best. What are some of the advantages of mastering more than one approach to problem solving?

In solving a problem, you should try to focus on the reasoning you are using at each step. In other words, think the solution through. Try to understand why you are using particular conversion factors in progressing from the known to the unknown. With perseverance, you can learn to apply and sharpen all your problem-solving skills.

Sample Problem 4-5

The directions for an experiment ask each student to measure out 1.84 g of copper (Cu) wire. The only copper wire available is a spool with a mass of 50.0 g. How many students can do the experiment before the copper runs out?

1. **ANALYZE** ***List the knowns and the unknown.***

   Knowns:
   - mass of copper available = 50.0 g Cu
   - Each student needs 1.84 grams of copper, or $\frac{1.84 \text{ g Cu}}{\text{student}}$.

   Unknown:
   - number of students = ? students

   From the known mass of copper, calculate the number of students that can do the experiment. The desired conversion is mass of copper $\longrightarrow$ number of students.

2. **CALCULATE** ***Solve for the unknown.***

   Because students is the desired unit for the answer, the conversion factor should be written with students in the numerator.

   $$50.0 \text{ g } \cancel{\text{Cu}} \times \frac{1 \text{ student}}{1.84 \text{ g } \cancel{\text{Cu}}} = 27.174 \text{ students} = 27 \text{ students}$$

   Note that because students cannot be fractional, the result is shown rounded to a whole number.

3. **EVALUATE** ***Does the result make sense?***

   The number of students (27) seems to be a reasonable answer. The approximate calculation using the ratio $\frac{1 \text{ student}}{2 \text{ g Cu}}$ gives an approximate answer of 25 students. The unit of the answer (students) is the one desired.

Practice Problems

9. An experiment requires that each student use an 8.5-cm length of magnesium ribbon. How many students can do the experiment if there is a 570-cm length of magnesium ribbon available?
10. A 1.00-degree increase on the Celsius scale is equivalent to a 1.80-degree increase on the Fahrenheit scale. If a temperature increases by 48.0 °C, what is the corresponding temperature increase on the Fahrenheit scale?

Converting Between Units

In chemistry, as in many other subjects, you often need to express a measurement in a unit different from the one given or measured initially. For example, suppose a laboratory experiment requires 7.5 dg of magnesium metal, and 100 students will do the experiment. How many grams of magnesium should your teacher have on hand? This is a typical conversion problem because you need to express a given measurement in a different unit. As you have seen, conversion problems are easily solved using dimensional analysis.

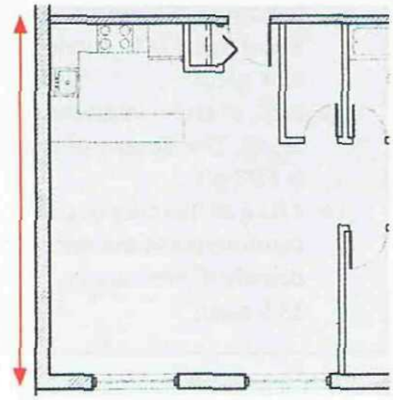


Figure 4.7
Architects use many conversion factors to draw buildings to scale accurately. If 10 mm on a scaled drawing equals 2 actual meters, what is the length of this room, front to back, as indicated by the red arrow?

As you work through the examples that follow, notice that the three-step problem-solving approach is applied to each.

Sample Problem 4-6

Express 750 dg in grams.

1. ***ANALYZE*** ***List the knowns and the unknown.***

Knowns:
- mass = 750 dg
- 1 g = 10 dg

Unknown:
- mass = ? g

The desired conversion is decigrams $\rightarrow$ grams. Using the expression relating the units, 10 dg = 1 g, multiply the given mass by the proper conversion factor.

2. ***CALCULATE*** ***Solve for the unknown.***

The correct conversion factor is $\frac{1\ \text{g}}{10\ \text{dg}}$ because the known unit is in the denominator and the unknown unit is in the numerator.

$$750\ \cancel{\text{dg}} \times \frac{1\ \text{g}}{10\ \cancel{\text{dg}}} = 75\ \text{g}$$

3. ***EVALUATE*** ***Does the result make sense?***

Because the unit gram represents a larger mass than the unit decigram, it makes sense that the number of grams is less than the given number of decigrams. The unit of the known (dg) cancels, and the answer has the correct unit (g). The answer also has the correct number of significant figures.

Practice Problems

11. Using tables from Chapter 3, convert the following.
- **a.** 0.044 km to meters
- **b.** 4.6 mg to grams
- **c.** 8.9 m to decimeters
- **d.** 0.107 g to centigrams

12. Convert the following.
- **a.** 15 cm^3 to liters
- **b.** 7.38 g to kilograms
- **c.** 0.67 s to milliseconds
- **d.** 94.5 g to micrograms

Chem ASAP!

Problem-Solving 12

Solve Problem 12 with the help of an interactive guided tutorial.

Practice Problems

13. Use dimensional analysis and the given densities to make the following conversions.
- **a.** 14.8 g of boron to cubic centimeters of boron. The density of boron is 2.34 g/cm^3.
- **b.** 2.8 L of argon to grams of argon. The density of argon is 1.78 g/L.
- **c.** 4.62 g of mercury to cubic centimeters of mercury. The density of mercury is 13.5 g/cm^3.

Sample Problem 4-7

What is the volume of a pure silver coin that has a mass of 14 g? The density of silver (Ag) is 10.5 g/cm^3.

1. ***ANALYZE*** ***List the knowns and the unknown.***

Knowns:
- mass of coin = 14 g
- density of silver = 10.5 g/cm^3

Unknown:
- volume of coin = ? cm^3

This problem can be solved by using algebra, or it can be solved by using a conversion factor. Convert the given mass of the coin into a corresponding volume. The density of silver gives the needed relationship between mass and volume. Multiply the mass of the coin by the proper conversion factor to yield an answer in cm^3.

Sample Problem 4-7 (cont.)

2. ***CALCULATE*** *Solve for the unknown.*

The correct conversion factor is $\frac{1\ \text{cm}^3\ \text{Ag}}{10.5\ \text{g Ag}}$ because the known unit is in the denominator and the unknown unit is in the numerator.

$$14\ \text{g}\ \cancel{\text{Ag}} \times \frac{1\ \text{cm}^3\ \text{Ag}}{10.5\ \text{g}\ \cancel{\text{Ag}}} = 1.3\ \text{cm}^3\ \text{Ag}$$

3. ***EVALUATE*** ***Does the result make sense?***

Because a mass of 10.5 g of silver has a volume of 1 cm^3, it makes sense that 14.0 g of silver should have a volume slightly larger than 1 cm^3. The answer has two significant figures because the given mass has two significant figures.

Practice Problems (cont.)

14. Rework the preceding problems by applying the equation:

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

Chem ASAP!

Problem-Solving 13

Solve Problem 13 with the help of an interactive guided tutorial.

section review 4.2

15. What conversion factor would you use to convert between these pairs of units?

a. minutes to hours

b. grams of water to cubic centimeters of water

c. grams to milligrams

d. cubic decimeters to milliliters

16. Make the following conversions. Express your answers in scientific notation.

a. 36 cm to meters

b. 14.8 g to micrograms

c. 1.44 kL to liters

d. 68.9 m to decimeters

e. 3.72×10^{-3} kg to grams

f. 66.3 L to cubic centimeters

g. 0.0371 m to kilometers

17. A 2.00-kg sample of bituminous coal is composed of 1.30 kg of carbon, 0.20 kg of ash, 0.15 kg of water, and 0.35 kg of volatile (gas-forming) material. Using this information, determine how many kilograms of carbon are in 125 kg of this coal.

18. Which of the following linear measures is the longest?

a. 6×10^4 cm

b. 6×10^6 mm

c. 0.06 km

d. 6×10^9 nm

19. An atom of gold has a mass of 3.271×10^{-22} g. How many atoms of gold are in 5.00 g of gold?

Chem ASAP! **Assessment 4.2** Check your understanding of the important *ideas and concepts in Section 4.2.*

portfolio project

Develop four charts of conversion factors for units of length, volume, area, and mass. Include common non-SI units such as miles, gallons, acres, and tons. Provide both the names and the abbreviations of the units.

SMALL-SCALE LAB

NOW WHAT DO I DO?

PURPOSE

To solve problems by making accurate measurements and applying mathematics.

MATERIALS

- pencil
- paper
- meter stick
- balance
- pair of dice
- aluminum can
- calculator
- small-scale pipet
- water
- a pre- and a post-1982 penny
- 8-well strip
- plastic cup

PROCEDURE

1. Determine the mass, in grams, of one drop of water. To do this, measure the mass of an empty cup. Add 50 drops of water from a small-scale pipet to the cup and measure its mass again. Subtract the mass of the empty cup from the mass of the cup with water in it. To determine the average mass in grams of a single drop, divide the mass of the water by the number of drops (50). Repeat this experiment until your results are consistent.
2. Determine the mass of a pre-1982 penny and a post-1982 penny.

ANALYSIS

Using your experimental data, record the answers to the following questions.

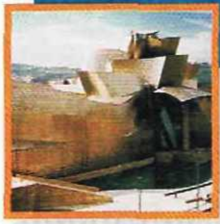
1. What is the average mass of a single drop of water in milligrams? (1 g = 1000 mg)
2. The density of water is 1.00 g/cm^3. Calculate the volume of a single drop in cm^3 and mL. (1 mL = 1 cm^3) What is the volume of a drop in microliters (μL)? (1000 μL = 1 mL)
3. What is the density of water in units of mg/cm^3 and mg/mL? (1 g = 1000 mg)
4. Pennies made before 1982 consist of 95.0% copper and 5.0% zinc. Calculate the mass of copper and the mass of zinc in the pre-1982 penny.
5. Pennies made after 1982 are made of zinc with a thin copper coating. They are 97.6% zinc and 2.4% copper. Calculate the mass of copper and the mass of zinc in the newer penny.
6. Why does one penny have less mass than the other?

YOU'RE THE CHEMIST

The following small-scale activities allow you to develop your own procedures and analyze the results.

1. **Design It!** Design an experiment to determine if the size of drops varies with the angle at which they are delivered from the pipet. Try vertical (90°), horizontal (0°), and halfway between (45°). Repeat until your results are consistent.
2. **Analyze It!** What is the best angle to hold a pipet for ease of use and consistency of measurement? Explain. Why is it important to expel the air bubble before you begin the experiment?
3. **Design It!** Make the necessary measurements to determine the volume of aluminum used to make an aluminum soda can. *Hint:* Look up the density of aluminum in your textbook.
4. **Design It!** Design and carry out some experiments to determine the volume of liquid that an aluminum soda can will hold.
5. **Design It!** Measure a room and calculate the volume of air it contains. Estimate the percent error associated with not taking into account the furniture and people in the room.
6. **Design It!** Make the necessary measurements and do the necessary calculations to determine the volume of a pair of dice. First ignore the volume of the dots on each face, and then account for the volume of the dots. What is your error and percent error when you ignore the holes?
7. **Design It!** Design an experiment to determine the volume of your body. Write down what measurements you would need to make and what calculations you would do. What additional information might be helpful?

MORE-COMPLEX PROBLEMS



Architectural wonders like the Guggenheim Museum in Bilbao, Spain, are a testament to the vision, knowledge, and skills of all those associated with the construction. Solving the myriad problems that accompany the building of such structures is an essential first step that often involves converting complex units.
How can complex conversions be calculated?

objectives

- Solve problems by breaking the solution into steps
- Convert complex units, using dimensional analysis

Multistep Problems

Many complex tasks in your everyday life are best handled by breaking them down into manageable parts. For example, if you were cleaning a car, you might first vacuum the inside, then wash the exterior, then dry the exterior, and finally put on a fresh coat of wax. Similarly, many complex word problems are more easily solved by breaking the solution down into steps.

When converting between units, it is often necessary to use more than one conversion factor. Sample Problem 4-8 illustrates the use of multiple conversion factors.

Sample Problem 4-8

What is 0.073 cm in micrometers?

1. ***ANALYZE*** ***List the knowns and the unknown.***

   Knowns:
   - length = 0.073 cm = 7.3×10^{-2} cm
   - 10^2 cm = 1 m
   - 1 m = 10^6 μm

   Unknown:
   - length = ? μm

   The desired conversion is from centimeters to micrometers. The problem can be solved in a two-step conversion.

2. ***CALCULATE*** ***Solve for the unknown.***

   First, change centimeters to meters; then change meters to micrometers: centimeters ⟶ meters ⟶ micrometers. Each conversion factor must be written so that the unit in the denominator cancels the unit in the numerator of the previous factor.

   $$7.3 \times 10^{-2}\,\cancel{\text{cm}} \times \frac{1\,\cancel{\text{m}}}{10^2\,\cancel{\text{cm}}} \times \frac{10^6\,\mu\text{m}}{1\,\cancel{\text{m}}} = 7.3 \times 10^2\,\mu\text{m}$$

3. ***EVALUATE*** ***Does the result make sense?***

   Because a micrometer is a much smaller unit than a centimeter, the answer should be numerically larger than the given measurement. The units have canceled correctly, and the answer has the correct number of significant figures.

Practice Problems

20. The radius of a potassium atom is 0.227 nm. Express this radius in centimeters.

21. Earth's diameter is 1.3×10^4 km. What is the diameter expressed in decimeters?

Figure 4.8

A complex process, such as building a house, must be broken down into several simpler steps. Each of those steps is generally executed in logical order so that the product of the process is the desired one. Obviously one of the steps in this example involved the removal of a tree!

Here is another example of a multistep problem. You probably do not know how many seconds are in one day. However, you can easily calculate this quantity by using dimensional analysis and equivalent expressions of time that you do know.

Sample Problem 4-9

How many seconds are there in exactly one day?

1. **ANALYZE** *List the knowns and the unknown.*

   Knowns:
   - length of time = 1 day
   - 1 day = 24 hr
   - 1 hr = 60 min
   - 1 min = 60 s

   Unknown:
   - length of time = ? s

   The desired conversion is days $\longrightarrow$ seconds.

2. **CALCULATE** *Solve for the unknown.*

   As identified in the first step, the conversion required is from days to seconds. This conversion can be carried out by the following sequence of conversions: day $\longrightarrow$ hours $\longrightarrow$ minutes $\longrightarrow$ seconds. Each conversion factor in the series must be written so that the unit in the denominator cancels the unit in the numerator of the previous factor.

   $$1\ \cancel{\text{day}} \times \frac{24\ \cancel{\text{h}}}{\cancel{\text{day}}} \times \frac{60\ \cancel{\text{min}}}{\cancel{\text{h}}} \times \frac{60\ \text{s}}{\cancel{\text{min}}} = 8.6400 \times 10^4\ \text{s}$$

3. **EVALUATE** *Does the result make sense?*

   A large number is expected because a second is a much smaller unit than a day. The numerator and denominator of the conversion factors have canceled correctly to yield the desired unit.

Practice Problems

22. How many minutes are there in exactly one week?

23. How many seconds are in exactly a 40-hr work week?

Chem ASAP!

Problem-Solving 23

Solve Problem 23 with the help of an interactive guided tutorial.

Converting Complex Units

Many common measurements are expressed as *a ratio of two units*. For example, the results of international car races often give average lap speeds in kilometers per hour. You measure the densities of solids and liquids in grams per cubic centimeter. You measure the gas mileage in a car in miles per gallon of gasoline. If you use dimensional analysis, converting these complex units is just as easy as converting single units. It will just take multiple steps to arrive at an answer.

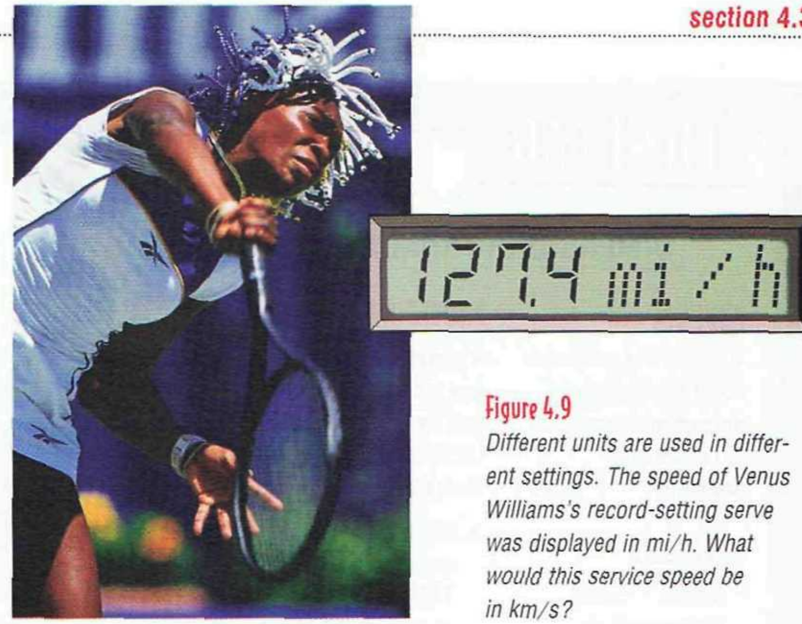


Figure 4.9
Different units are used in different settings. The speed of Venus Williams's record-setting serve was displayed in mi/h. What would this service speed be in km/s?

Sample Problem 4-10

The density of manganese is 7.21 g/cm^3. What is the density of manganese expressed in units of kg/m^3?

1. **ANALYZE** *List the knowns and the unknown.*

   Knowns:
   - density of manganese = 7.21 g/cm^3
   - 10^3 g = 1 kg
   - 10^6 cm^3 = 1 m^3

   Unknown:
   - density of manganese = ? kg/m^3

   The desired conversion is $g/cm^3 \longrightarrow kg/m^3$. The mass unit in the numerator must be changed from grams to kilograms: $g \longrightarrow kg$. In the denominator, the volume unit must be changed from cubic centimeters to cubic meters: $cm^3 \longrightarrow m^3$. Note that the relationship between cm^3 and m^3 was determined from the relationship between cm and m. Cubing the relationship 10^2 cm = 1 m yields $(10^2 \text{ cm})^3 = (1 \text{ m})^3$, or $10^6 \text{ cm}^3 = 1 \text{ m}^3$.

2. **CALCULATE** *Solve for the unknown.*

$$\frac{7.21 \cancel{\text{g}}}{1 \cancel{\text{cm}^3}} \times \frac{1 \text{ kg}}{10^3 \cancel{\text{g}}} \times \frac{10^6 \cancel{\text{cm}^3}}{1 \text{ m}^3} = 7.21 \times 10^3 \text{ kg/m}^3$$

3. **EVALUATE** *Does the result make sense?*

   Because the physical size of the volume unit m^3 is so much larger than cm^3 (10^6 times), the calculated value of the density should be larger than the given value even though the mass unit is also larger (10^3 times). The units cancel, the conversion factors are correct, and the answer has the correct ratio of units.

Practice Problems

24. Gold has a density of 19.3 g/cm^3. What is the density in kilograms per cubic meter?

25. There are 7.0×10^6 red blood cells (RBC) in 1.0 mm^3 of blood. How many red blood cells are in 1.0 L of blood?

Chem ASAP!
Problem-Solving 25
Solve Problem 25 with the help of an interactive guided tutorial.

MINI LAB

DIMENSIONAL ANALYSIS

PURPOSE

To apply the problem-solving technique of dimensional analysis to conversion problems.

MATERIALS

- 3 inch × 5 inch index cards or paper cut to approximately the same size
- pen

PROCEDURE

A conversion factor is a ratio of equivalent measurements. For any relationship, you can write two ratios. On a conversion factor card you can write one ratio on each side of the card.

1. Make a conversion factor card for each metric relationship shown in **Tables 3.3, 3.4,** and **3.5.** Show the inverse of the conversion factor on the back of each card.
2. Make a conversion factor card showing the mass–volume relationship for water (1.00 g H_2O = 1.00 mL H_2O). Show the inverse of the conversion factor on the back of the card.
3. Use the appropriate conversion factor cards to set up solutions to Sample Problems 4-6 and 4-8. Notice that in each solution, the unit in the denominator of the conversion factor cancels the unit in the numerator of the previous conversion factor.
4. Use conversion factor cards to set up solutions to Problem 28, below.

ANALYSIS AND CONCLUSIONS

1. What is the effect of multiplying a given measurement by one or more conversion factors?
2. Use your conversion factor cards to set up solutions to these problems.

   a. 78.5 cm = ? m

   b. 0.056 L = ? cm^3

   c. 77 kg =? mg

   d. 4.54 mL H_2O = ? mg H_2O

   e. 0.087 nm = ? dm

   f. 78.5 g H_2O = ? L H_2O

   g. 0.96 cm = ? μm

   h. 0.0067 mm = ? nm

section review 4.3

26. How can you solve a complicated problem more easily?

27. How are complex units dealt with in calculations?

28. Convert the following. Express your answers in scientific notation.

a. 7.5×10^4 nm to kilometers

b. 3.9×10^5 mg to decigrams

c. 0.764 km to centimeters

d. 2.21×10^{-4} dL to microliters

29. Light travels at a speed of 3.00×10^{10} cm/s. What is the speed of light in kilometers per hour?

30. A bar of gold measures 4.5 cm by 6.5 cm by 1.6 dm. Calculate the mass of the gold bar in kilograms. The density of gold is 19.3 g/cm^3.

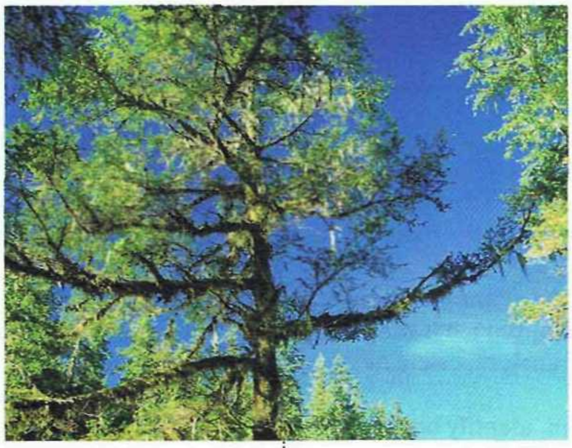
31. What is the mass, in kilograms, of 14.0 L of gasoline? (Assume that the density of gasoline is 0.680 g/cm^3.)

Chem ASAP! **Assessment 4.3** Check your understanding of the important ideas and concepts in Section 4.3.

Chemistry Serving...the Consumer

NATURE'S MEDICINE CABINET

You have probably taken drugs such as aspirin and decongestants several times in your life. Have you ever wondered whom you should thank for the welcome relief these drugs provide? In some cases, the "inventor" of the drug was not a white-coated chemist but a green-leafed plant!



In many ways, plants are the master chemists of the world. For millions of years, they have been busily evolving the ability to manufacture an array of chemical compounds. Many of these compounds have obvious uses for the plant — defense against plant-eating insects, for example. Others are by-products of growth processes of plants. A sizable number of plant compounds have some kind of property or chemical activity that makes them useful to humans as medicine.

Humans have known about the medicinal properties of plants for a long time. Before modern science, humans used plant extracts to treat illnesses and injuries, without understanding the chemical basis of the treatment. Today, chemists and medical researchers continue to look to plants as either the source or inspiration for new drugs.

The story of aspirin is a good example of the ongoing link between plant compounds and drugs for humans. The first aspirin-like drug was an extract from the bark of willow trees, which was used by native North Americans to alleviate pain and fever.

In many ways, plants are the master chemists of the world.

In the 1800s, chemists begin to search for the active ingredient in willow bark. They isolated a substance that had the fever-reducing effect and called it salicin, after *Salix*, the Latin name for the willow. Then chemists worked on synthesizing a compound in the laboratory with the same effects. They succeeded in making salicylic acid, which worked well to reduce fever but was very irritating to the stomach. Finally, in 1899, a German company began marketing a derivative of salicylic acid that did not upset the stomach but that still reduced fever and pain. They called it aspirin.

Many other common drugs have their roots in plant chemistry. The active ingredient in many decongestants, for example, is closely related to a compound in the ephedra plant called ephedrine. Plants are also a continuing source of new drugs. For example, a drug called taxol, extracted from the bark of the Pacific yew tree, has been shown to be effective in fighting both breast and ovarian cancer.

There are also some plant compounds that have been known for a long time to have medicinal properties but that are only now beginning to be recognized as effective drugs by scientists. One of these is contained in the plant called St. John's wort. Extracts of this plant have been shown to counteract depression, one of the most common mental disorders. The active ingredient in St. John's wort is related to a new class of drugs called selective serotonin re-uptake inhibitors (SSRIs), which are also used to treat depression. St. John's wort and the SSRI drugs both work by changing how the body uses serotonin, a hormone that plays a key part in mood regulation.

The next time you take a stroll in the woods, think about the wealth of chemical compounds contained in the flora around you. One of those compounds might someday offer a cure for what ails you.

CHEMISTRY IN CAREERS

TAKE IT TO THE NET

Find out more about career opportunities:

www.phschool.com

MEDICAL LABORATORY TECHNICIAN

Process sera for blood tests; determine cholesterol and enzyme levels.

See page 869.

CHEMICAL SPECIALIST

Local food service distributor seeks responsible self-motivated individ

CHEMIST NEEDED

Chapter 4 STUDENT STUDY GUIDE

Take It to the NET
For interactive study and review, go to www.phschool.com

KEY TERMS

- conversion factor *p. 89*
- dimensional analysis *p. 90*

CONCEPT SUMMARY

4.1 What Do I Do Now?

- Problem solving is a skill learned through practice. The more you practice, the more proficient you become.
- Problem solving involves developing a plan. In this textbook, a three-step approach is the plan used. The three steps are: analyze, calculate, and evaluate.
- To analyze a word problem, identify both the knowns and the unknown. Then plan a solution and do the calculations.
- In the final step, evaluate whether the answer to a word problem seems reasonable and whether the answer has the correct number of significant figures.
- No problem-solving method can replace the need for you to read carefully and to think through the steps needed to solve a given problem.
- A good problem-solving strategy can be applied to all sorts of situations—not just chemistry problems.

4.2 Simple Conversion Problems

- Any two measurements that are equal to one another but expressed in different units can be written as a ratio.
- A ratio of equivalent measurements is called a conversion factor and is equal to unity.
- Conversion factors are used in the problem-solving technique of dimensional analysis.
- A ratio of equivalent measurements has two forms. The correct conversion factor for solving a particular problem will have the known unit in the denominator and the unknown unit in the numerator.
- Conversion problems in which you are asked to express a measurement in some other unit are easily solved using dimensional analysis.
- In dimensional analysis, units are used to help write the solution to a problem.

4.3 More-Complex Problems

- Many complex problems, whether they be in chemistry or in your daily life, can be successfully solved by breaking the solution down into steps.
- More than one conversion factor may be required in some more-complex conversion problems.
- The given measurement in a rate problem has a ratio of units.
- Rate problems are solved by converting the unit in the numerator followed by converting the unit in the denominator.

CHAPTER CONCEPT MAP

Use these terms to construct a concept map that organizes the major ideas of this chapter.

algebra | conversion factor | denominator | dimensional analysis | numerator | problem solving

Chem ASAP! Concept Map 4
Create your Concept Map using the computer.

CONCEPT PRACTICE

32. In which step of the three-step problem-solving approach is a problem-solving strategy developed? *4.1*

33. A volume of 5.00 mL of mercury is added to a beaker that has a mass of 87.3 g. What is the mass of the beaker with the added mercury? *4.1*

34. What is the name given to a ratio of two equivalent measurements? *4.2*

35. One measure of area is the hectare, which is equal to 10 000 m^2. What does the ratio $\frac{10^4\ m^2}{\text{hectare}}$ equal? *4.2*

36. Write six conversion factors involving these units of measure: $1\ g = 100\ cg = 10^3\ mg$. *4.2*

37. What must be true for a ratio of two measurements to be a conversion factor? *4.2*

38. One of the first mixtures of metals used by dentists for tooth fillings consisted of 26.0 g of silver, 10.8 g of tin, 2.4 g of copper, and 0.8 g of zinc. How much silver is in a 25.0 g sample of this amalgam? *4.2*

39. How do you know which unit of a conversion factor must be in the denominator (on the bottom)? *4.2*

40. The density of dry air measured at 25 °C is $1.19 \times 10^{-3}\ g/cm^3$. What is the volume of 50.0 g of air? *4.2*

41. List at least two things you should do after you have calculated the answer to a problem on your calculator. *4.2*

42. Have you ever found yourself sitting through a terrible movie, counting the minutes that remain? If a movie has 0.20 hour remaining, how many seconds of movie remain? *4.3*

43. Make the following conversions. *4.3*
- **a.** 157 cs to seconds
- **b.** 42.7 L to milliliters
- **c.** 261 nm to millimeters
- **d.** 0.065 km to decimeters
- **e.** 642 cg to kilograms
- **f.** 8.25×10^2 cg to nanograms

44. Make the following conversions. *4.3*
- **a.** 0.44 mL/min to microliters per second
- **b.** 7.86 g/cm^2 to milligrams per square millimeter
- **c.** 1.54 kg/L to grams per cubic centimeter

45. How many milliliters are contained in 1 m^3? *4.3*

46. Complete this table so that the measurements in each row have the same value. *4.3*

mg	g	cg	kg
		28.3	
6.6×10^3			
	2.8×10^{-4}		

47. A cheetah can run 112 km/h over a 100-m distance. What is this speed in meters per second? *4.3*

CONCEPT MASTERY

48. A flask that can hold 158 g of water at 4 °C can hold only 127 g of ethanol. What is the density of ethanol?

49. A watch loses 0.15 s every minute. How many minutes will the watch lose in 1 day?

50. A tank measuring 28.6 cm by 73.0 mm by 0.72 m is filled with olive oil that has a mass of 1.38×10^4 g. What is the density of olive oil in kilograms per liter?

51. Alkanes are a class of molecules that have the general formula C_nH_{2n+2}, where n is an integer. The table below gives the boiling points for the first five alkanes with an odd number of carbon atoms. Using the table, construct a graph with number of carbon atoms on the x-axis.

Boiling point (°C)	Number of carbon atoms
−162.0	1
−42.0	3
36.0	5
98.0	7
151.0	9

- **a.** What are the approximate boiling points for the C_2, C_4, C_6, and C_8 alkanes?
- **b.** Which of these nine alkanes are gases at room temperature (20 °C)?
- **c.** How many of these nine alkanes are liquids at 350 K?
- **d.** What is the approximate increase in boiling point per additional carbon atom in this series of alkanes?

52. Earth is approximately 1.5×10^8 km from the sun. How many minutes does it take light to travel from the sun to Earth? The speed of light is 3.0×10^8 m/s.

53. What is the mass of a cube of aluminum that is 3.0 cm on each edge? The density of aluminum is 2.7 g/cm^3.

54. The average density of Earth is 5.52 g/cm^3. Express this density in units of kg/dm^3.

55. How many kilograms of water (at 4 °C) are needed to fill an aquarium that measures 40.0 cm by 20.0 cm by 30.0 cm?

CRITICAL THINKING

56. Choose the term that best completes the second relationship.

a. journey:route problem:_______
(1) unknown (3) known
(2) plan (4) calculate

b. meter:100 cm gram:_______
(1) 0.001 kL (3) 1000 mg
(2) 100 cm (4) 100 kg

57. You have solved many word problems up to this point. Review the techniques for solving word problems. Which step is most difficult for you? What kind of problems do you find most difficult to solve?

58. Why are units so important in working word problems?

CUMULATIVE REVIEW

59. Describe how the law of conservation of mass applies to a burning campfire.

60. List three physical properties of each of the following objects in the accompanying photo.
a. the glass
b. the soda
c. the ice cube
d. the bubbles

61. Classify each of the following as an element, compound, or mixture.
a. an egg **c.** dry ice (CO_2)
b. a cake **d.** iron powder

62. The melting point of silver is 962 °C. Express this temperature in kelvins.

63. Identify the larger quantity in each of these pairs of measurements.
a. centigram, milligram
b. deciliter, kiloliter
c. millisecond, microsecond
d. cubic decimeter, milliliter
e. micrometer, nanometer

64. Name three physical and three chemical changes that you have seen today.

65. How many significant figures are in each of these measurements?
a. 5.12 g **d.** 0.045 04 mm
b. 3.456×10^6 kg **e.** 985.20 K
c. 0.000 078 dm^3 **f.** 65.02 s

66. Round each of the measurements in Problem 65 to two significant figures.

CONCEPT CHALLENGE

67. Sea water contains 8.0×10^{-1} cg of the element strontium per kilogram of sea water. Assuming that all the strontium could be recovered, how many grams of strontium could be obtained from one cubic meter of sea water? Assume the density of sea water is 1.0 g/mL.

68. When 121 g of sulfuric acid is added to 400 mL of water, the resulting solution's volume is 437 mL. What is the specific gravity of the resulting solution?

69. How tall is a rectangular block of balsa wood measuring 4.4 cm wide and 3.5 cm deep that has a mass of 98.0 g? The specific gravity of balsa wood is 0.20.

70. The density of dry air at 20 °C is 1.20 g/L. What is the mass of air, in kilograms, of a room that measures 25.0 m by 15.0 m by 4.0 m?

71. Different volumes of the same liquid were added to a flask on a balance. After each addition of liquid, the mass of the flask with the liquid was measured. Graph the data using mass as the dependent variable. Use the graph to answer these questions.

Volume (mL)	14	27	41	55	82
Mass (g)	103.0	120.4	139.1	157.9	194.1

a. What is the mass of the flask?
b. What is the density of the liquid?

Chapter 4 STANDARDIZED TEST PREP

Select the choice that best answers each question or completes each statement.

1. Which of these conversion factors is *not* correct?
   a. 1 m/10^2 mm
   b. 10^9 ns/1 s
   c. 1 dm^3/1 L
   d. 1 g/10^6 μg
2. An over-the-counter medicine has 325 mg of its active ingredient per tablet. How many grams does this mass represent?
   a. 325 000 g
   b. 32.5 g
   c. 3.25 g
   d. 0.325 g
3. The density of zinc is 9.394 g/cm^3 at 20 °C. What is the volume of a sphere of zinc that has a mass of 15.6 g? ($V = 4/3\pi r^3$; $\pi = 3.14$)
   a. 1.66 cm^3
   b. 6.21 cm^3
   c. 0.602 cm^3
   d. 147 cm^3
4. If 10^4 μm = 1 cm, how many μm^3 = 1 cm^3?
   a. 10^4
   b. 10^6
   c. 10^8
   d. 10^{12}
5. How many meters does a car moving at 95 km/h travel in 1.0 s?
   a. 1.6 m
   b. 340 m
   c. 1600 m
   d. 26 m
6. If a substance contracts when it freezes, its
   a. density will remain the same.
   b. density will increase.
   c. density will decrease.
   d. change in density cannot be predicted.

For questions 7–10, identify the known and the unknown. Include units in your answers.

7. The density of water is 1.0 g/mL. How many deciliters of water will fill a 0.5-L bottle.
8. A 34.5-g gold nugget is dropped into a graduated cylinder containing water. By how many milliliters does the measured volume increase? The density of water is 1.0 g/mL. The density of gold is 19.3 g/cm^3.
9. A watch loses 0.2 s every minute. How many minutes will the watch lose in a day?
10. Eggs shipped to market are packed 12 eggs to a carton and 20 cartons to a box. A crate holds 4 boxes. Crates are stacked on a truck 5 crates wide, 6 crates deep, and 5 crates high. How many eggs are there in 5 truckloads?
11. Based on the prices displayed on the gas pumps, which station offers a lower price for gasoline? (1 gal = 3.79 L)

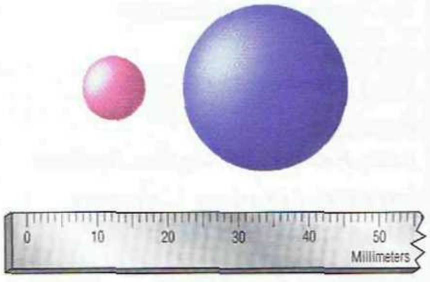
The lettered choices below refer to questions 12–15. A lettered choice may be used once, more than once, or not at all.

(A) 60 min/h
(B) 1 min/60 s
(C) 1 h/60 min
(D) 60 s/1 min

Which conversion factors are needed to do each of the following conversions?

12. number of seconds to cook a 3-minute egg
13. number of hours in 1000 s
14. number of minutes in "Wait just a second."
15. number of minutes in an 8-hour workday

Use the drawing to answer questions 16–18. The scale models show the relative sizes of a helium atom (left) and a xenon atom (right).



16. Use the metric ruler provided to determine the diameter of each model atom in millimeters.
17. Calculate the ratio of the diameter of the helium atom to the diameter of the xenon atom.
18. Calculate the ratio of the volume of the helium atom to the volume of the xenon atom. Assume that the atoms are perfect spheres. ($V = 4/3\pi r^3$; $\pi = 3.14$)