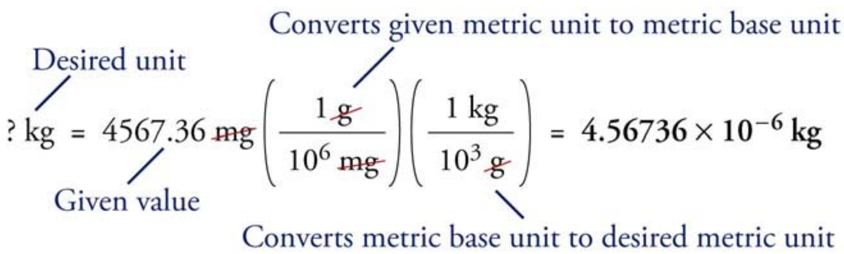
Chapter 2
Unit Conversions



Section Goals and Introductions

Be sure that you can do the things listed in the Review Skills section before you spend too much time studying this chapter. They are especially important. You might also want to look at Appendices A and B. Appendix A (*Measurement and Units*) provides tables that show units, their abbreviations, and relationships between units that lead to conversion factors. Appendix B (*Scientific Notation*) describes how to convert between regular decimal numbers and numbers expressed in scientific notation, and it shows how calculations using scientific notation are done.

Section 2.1 Unit Analysis

Goals

- *To describe a procedure for making unit conversions called unit analysis.*
- *To describe metric-metric unit conversions.*
- *To describe English-metric unit conversions.*

Many chemical calculations include the conversion from a value expressed in one unit to the equivalent value expressed in a different unit. Unit analysis, which is described in this section, provides you with an organized format for making these unit conversions and gives you a logical thought process that will help you to reason through such calculations. It is extremely important that you master this technique. You'll be glad you have when you go on to other chapters, which describe chemical calculations that can be done using the unit analysis technique.

Section 2.2 Rounding Off and Significant Figures

Goal: To describe the procedures for rounding off answers to calculations.

When you use a calculator to complete your calculations, it's common that most of the numbers you see on the display at the end of the calculation are meaningless. This section describes why this is true and shows you simple techniques that you can use to round off your answers.

Section 2.3 Density and Density Calculations

Goal: To describe what density is, how it can be used as a conversion factor, and how density can be calculated.

Density calculations are common in chemistry. The examples in this section show you how these calculations are done, and perhaps more important, these density calculations provide more examples of the unit analysis techniques and the procedures for rounding.

Section 2.4 Percentage and Percentage Calculations

Goal: To show how percentages can be made into conversion factors and show how they are used in making unit conversions.

Some people have trouble with calculations using percentages. They multiply when they should divide or divide when they should multiply. This section shows you how to make conversion factors out of percentages and how these conversions can be used to do percent calculations with confidence.

Section 2.5 A Summary of the Unit Analysis Process

Goal: To summarize the unit analysis process.

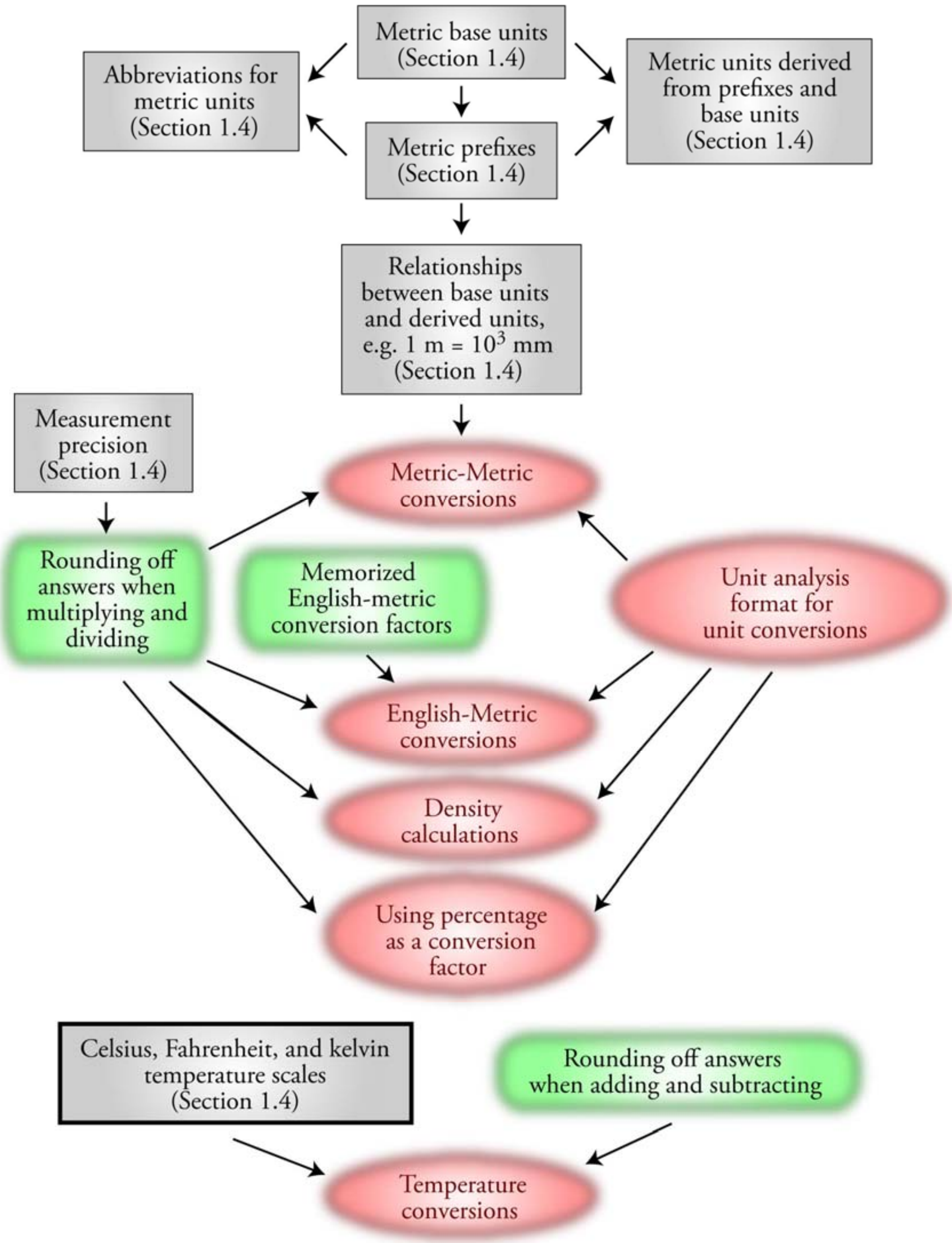
This section summarizes the different types of unit conversions described in this chapter. It should help you organize your thought process for making unit conversions. Pay special attention to Figure 2.3.

Section 2.6 Temperature Conversions

Goal: To show how to convert among temperatures expressed in degrees Celsius, degrees Fahrenheit, and kelvins.

This section shows how to convert from one temperature unit to another. Pay close attention to the subtleties that arise in rounding off answers to temperature conversions.

Chapter 2 Map



Chapter Checklist

- ☐ Read the Review Skills section. If there is any skill mentioned that you have not yet mastered, review the material on that topic before reading the present chapter.
- ☐ Read the chapter quickly before the lecture that describes it.
- ☐ Attend class meetings, take notes, and participate in class discussions.
- ☐ Work the Chapter Exercises, perhaps using the Chapter Examples as guides.
- ☐ Study the Chapter 2 Glossary and test yourself on our Web site:

  Internet: Glossary Quiz
- ☐ Study all of the Chapter Objectives. You might want to write a description of how you will meet each objective. (Although it is best to master all of the objectives, the following objectives are especially important because they pertain to skills that you will need while studying other chapters of this text: 2, 3, 5, 8, 9, 11, 14, 15, and 16.)
- ☐ Reread the Study Sheets in this chapter and decide whether you will use them or some variation on them to complete the tasks they describe.

  Sample Study Sheet 2.1: Rounding Off Numbers Calculated Using Multiplication and Division

  Sample Study Sheet 2.2: Rounding Off Numbers Calculated Using Addition and Subtraction

  Sample Study Sheet 2.3: Calculations Using Unit Analysis
- ☐ Memorize the following.

  Be sure to check with your instructor to determine how much you are expected to know of the following.

  - English-metric conversion factors

Type of Measurement	Probably Most Useful to Know	Others Useful to Know		
Length	$\frac{2.54\text{ cm}}{1\text{ in.}}$ (exact)	$\frac{1.609\text{ km}}{1\text{ mi}}$	$\frac{39.37\text{ in.}}{1\text{ m}}$	$\frac{1.094\text{ yd}}{1\text{ m}}$
Mass	$\frac{453.6\text{ g}}{1\text{ lb}}$	$\frac{2.205\text{ lb}}{1\text{ kg}}$		
Volume	$\frac{3.785\text{ L}}{1\text{ gal}}$	$\frac{1.057\text{ qt}}{1\text{ L}}$		

  - Equations for temperature conversions

$$? \,°\text{F} = \text{number of } °\text{C}\left(\frac{1.8\,°\text{F}}{1\,°\text{C}}\right) + 32\,°\text{F}$$

$$? \,°\text{C} = \left(\text{number of } °\text{F} - 32\,°\text{F}\right)\left(\frac{1\,°\text{C}}{1.8\,°\text{F}}\right)$$

$$? \text{ K} = \text{number of } °\text{C} + 273.15$$

$$? \,°\text{C} = \text{number of K} - 273.15$$

- ☐ To get a review of the most important topics in the chapter, fill in the blanks in the Key Ideas section.
- ☐ Work all of the selected problems at the end of the chapter, and check your answers with the solutions provided in this chapter of the study guide.
- ☐ Ask for help if you need it.

Web Resources

Internet: Glossary Quiz

Exercises Key

Exercise 2.1 - Conversion Factors: Write two conversion factors that relate the following pairs of metric units. Use positive exponents for each. *(Obj 2)*

a. meter and kilometer $\frac{10^3 \text{ m}}{1 \text{ km}}$ and $\frac{1 \text{ km}}{10^3 \text{ m}}$

b. meter and centimeter $\frac{10^2 \text{ cm}}{1 \text{ m}}$ and $\frac{1 \text{ m}}{10^2 \text{ cm}}$

c. liter and gigaliter $\frac{10^9 \text{ L}}{1 \text{ GL}}$ and $\frac{1 \text{ GL}}{10^9 \text{ L}}$

d. gram and microgram $\frac{10^6\ \mu\text{g}}{1 \text{ g}}$ and $\frac{1 \text{ g}}{10^6\ \mu\text{g}}$

e. gram and megagram $\frac{10^6 \text{ g}}{1 \text{ Mg}}$ and $\frac{1 \text{ Mg}}{10^6 \text{ g}}$

Exercise 2.2 - Unit Conversions: Convert 4.352 micrograms to megagrams. *(Obj 3)*

$$? \text{ Mg} = 4.352\ \mu\text{g}\left(\frac{1 \text{ g}}{10^6\ \mu\text{g}}\right)\left(\frac{1 \text{ Mg}}{10^6 \text{ g}}\right) = \mathbf{4.352 \times 10^{-12}\ Mg}$$

Exercise 2.3 - Unit Conversions: The volume of the earth's oceans is estimated to be 1.5×10^{18} kiloliters. What is this volume in gallons? *(Obj 5)*

$$? \text{ gal} = 1.5 \times 10^{18} \text{ kL}\left(\frac{10^3 \text{ L}}{1 \text{ kL}}\right)\left(\frac{1 \text{ gal}}{3.785 \text{ L}}\right) = \mathbf{4.0 \times 10^{20}\ gal}$$

Exercise 2.4 - Rounding Off Answers Derived from Multiplication and Division: A first-class stamp allows you to send letters weighing up to 1 oz. (There are 16 ounces per pound.) You weigh a letter and find that it has a mass of 10.5 g. Can you mail this letter with one stamp? The unit analysis setup for converting 10.5 g to ounces follows. Identify whether each value in the setup is exact. Then determine the number of significant figures in each inexact value, calculate the answer, and report it to the correct number of significant figures. *(Obj 8)*

$$? \text{ oz} = 10.5 \text{ g}\left(\frac{1 \text{ lb}}{453.6 \text{ g}}\right)\left(\frac{16 \text{ oz}}{1 \text{ lb}}\right) = \mathbf{0.370 \text{ oz}}$$

The 10.5 comes from a measurement and has three significant figures. The 453.6 is calculated and rounded off. It has four significant figures. The 16 comes from a definition and is exact. We report three significant figures in our answer.

Exercise 2.5 - Rounding Off Answers Derived from Multiplication and Division: The re-entry speed of the Apollo 10 space capsule was 11.0 km/s. How many hours would it have taken for the capsule to fall through 25.0 miles of the stratosphere? The unit analysis setup for this calculation follows. Identify whether each value in the setup is exact. Then determine the number of significant figures in each inexact value, calculate the answer, and report it to the correct number of significant figures. *(Obj 8)*

$$? \text{ hr} = 25.0 \text{ mi}\left(\frac{5280 \text{ ft}}{1 \text{ mi}}\right)\left(\frac{12 \text{ in.}}{1 \text{ ft}}\right)\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{1 \text{ s}}{11.0 \text{ km}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)\left(\frac{1 \text{ hr}}{60 \text{ min}}\right)$$

$$= \mathbf{1.02 \times 10^{-3} \text{ hr}}$$

The 25.0 comes from a measurement and has three significant figures. The 11.0 comes from a blend of measurement and calculations. It also has three significant figures. All of the other numbers come from definitions and are therefore exact. We report three significant figures in our answer.

Exercise 2.6 – Rounding Off Answers Derived from Addition and Subtraction: Report the answers to the following calculations to the correct number of decimal positions. Assume that each number is ±1 in the last decimal position reported. *(Obj 9)*

a. 684 – 595.325 = **89**   b. 92.771 + 9.3 = **102.1**

Exercise 2.7 - Density Conversions: *(Obj 11)*

a. What is the mass in kilograms of 15.6 gallons of gasoline?

$$? \text{ kg} = 15.6 \text{ gal}\left(\frac{3.785 \text{ L}}{1 \text{ gal}}\right)\left(\frac{10^3 \text{ mL}}{1 \text{ L}}\right)\left(\frac{0.70 \text{ g gas.}}{1 \text{ mL gas.}}\right)\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right)$$

$$\text{or} \quad ? \text{ kg} = 15.6 \text{ gal}\left(\frac{3.785 \text{ L}}{1 \text{ gal}}\right)\left(\frac{0.70 \text{ kg gas.}}{1 \text{ L gas.}}\right) = \mathbf{41 \text{ kg gasoline}}$$

b. A shipment of iron to a steel-making plant has a mass of 242.6 metric tons. What is the volume in liters of this iron?

$$? \text{ L} = 242.6 \text{ t}\left(\frac{10^3 \text{ kg}}{1 \text{ t}}\right)\left(\frac{10^3 \text{ g}}{1 \text{ kg}}\right)\left(\frac{1 \text{ mL Fe}}{7.86 \text{ g Fe}}\right)\left(\frac{1 \text{ L}}{10^3 \text{ mL}}\right)$$

$$\text{or} \quad ? \text{ L} = 242.6 \text{ t}\left(\frac{10^3 \text{ kg}}{1 \text{ t}}\right)\left(\frac{1 \text{ L Fe}}{7.86 \text{ kg Fe}}\right) = \mathbf{3.09 \times 10^4 \text{ L Fe}}$$

Exercise 2.8 - Density Calculations: *(Obj 12)*

a. A graduated cylinder is weighed and found to have a mass of 48.737 g. A sample of hexane, C_6H_{14}, is added to the graduated cylinder, and the total mass is measured as 57.452 g. The volume of the hexane is 13.2 mL. What is the density of hexane?

$$\frac{?\ \text{g}}{\text{mL}} = \frac{(57.452 - 48.737)\ \text{g}}{13.2\ \text{mL}}\ \mathbf{= 0.660\ g/mL}$$

b. A tree trunk is found to have a mass of 1.2×10^4 kg and a volume of 2.4×10^4 L. What is the density of the tree trunk in g/mL?

$$\frac{?\ \text{g}}{1\ \text{mL}} = \frac{1.2 \times 10^4\ \text{kg}}{2.4 \times 10^4\ \text{L}}\left(\frac{10^3\ \text{g}}{1\ \text{kg}}\right)\left(\frac{1\ \text{L}}{10^3\ \text{mL}}\right)\ \mathbf{= 0.50\ g/mL}$$

Exercise 2.9 - Unit Conversions: *(Obj 14)*

a. The mass of the ocean is about 1.8×10^{21} kg. If the ocean contains 0.014% by mass hydrogen carbonate ions, HCO_3^-, how many pounds of HCO_3^- are in the ocean?

$$?\ \text{lb}\ \text{HCO}_3^- = 1.8 \times 10^{21}\ \text{kg ocean}\left(\frac{0.014\ \text{kg HCO}_3^-}{100\ \text{kg ocean}}\right)\left(\frac{2.205\ \text{lb}}{1\ \text{kg}}\right)$$

$$\mathbf{= 5.6 \times 10^{17}\ lb\ HCO_3^-}$$

b. When you are doing heavy work, your muscles get about 75 to 80% by volume of your blood. If your body contains 5.2 liters of blood, how many liters of blood are in your muscles when you are working hard enough to send them 78% by volume of your blood?

$$?\ \text{L blood to muscles} = 5.2\ \text{L blood total}\left(\frac{78\ \text{L blood to muscles}}{100\ \text{L blood total}}\right)$$

= 4.1 L blood to muscles

Exercise 2.10 - Unit Conversions: *(Obj 15)*

a. The diameter of a proton is 2×10^{-15} meter. What is this diameter in nanometers?

$$?\ \text{nm} = 2 \times 10^{-15}\ \text{m}\left(\frac{10^9\ \text{nm}}{1\ \text{m}}\right)\ \mathbf{= 2 \times 10^{-6}\ nm}$$

b. The mass of an electron is $9.1093897 \times 10^{-31}$ kg. What is this mass in nanograms?

$$?\ \text{ng} = 9.1093897 \times 10^{-31}\ \text{kg}\left(\frac{10^3\ \text{g}}{1\ \text{kg}}\right)\left(\frac{10^9\ \text{ng}}{1\ \text{g}}\right)\ \mathbf{= 9.1093897 \times 10^{-19}\ ng}$$

c. There are 4.070×10^6 lb of sulfuric acid used to make Jell-O each year. Convert this to kilograms.

$$?\ \text{kg} = 4.070 \times 10^6\ \text{lb}\left(\frac{453.6\ \text{g}}{1\ \text{lb}}\right)\left(\frac{1\ \text{kg}}{10^3\ \text{g}}\right)\ \mathbf{= 1.846 \times 10^6\ kg}$$

d. A piece of Styrofoam has a mass of 88.978 g and a volume of 2.9659 L. What is its density in g/mL?

$$\frac{?\ \text{g}}{\text{mL}} = \frac{88.978\ \text{g}}{2.9659\ \text{L}}\left(\frac{1\ \text{L}}{10^3\ \text{mL}}\right)\ \mathbf{= 0.030000\ g/mL}$$

e. The density of blood plasma is 1.03 g/mL. A typical adult has about 2.5 L of blood plasma. What is the mass in kilograms of the blood plasma in this person?

$$? \text{ kg} = 2.5 \text{ L}\left(\frac{10^3 \text{ mL}}{1 \text{ L}}\right)\left(\frac{1.03 \text{ g}}{1 \text{ mL}}\right)\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right)$$

or $$? \text{ kg} = 2.5 \text{ L}\left(\frac{1.03 \text{ kg}}{1 \text{ L}}\right) = \mathbf{2.6 \text{ kg}}$$

f. Pain signals are transferred through the nervous system at a speed between 12 and 30 meters per second. If a student drops a textbook on her toe, how long will it take for the signal, traveling at a velocity of 18 meters per second, to reach her brain 6.0 feet away?

$$? \text{ s} = 6.0 \text{ ft}\left(\frac{12 \text{ in.}}{1 \text{ ft}}\right)\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ s}}{18 \text{ m}}\right) = \mathbf{0.10 \text{ s}}$$

g. An electron takes 6.2×10^{-9} second to travel across a TV set that is 22 inches wide. What is the velocity of the electron in km/hr?

$$\frac{? \text{ km}}{\text{hr}} = \frac{22 \text{ in.}}{6.2 \times 10^{-9} \text{ s}}\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)$$

$$= \mathbf{3.2 \times 10^8 \text{ km/hr}}$$

h. The mass of the ocean is about 1.8×10^{21} kg. If the ocean contains 0.041% by mass calcium ions, Ca^{2+}, how many tons of Ca^{2+} are in the ocean? (There are 2000 pounds per ton.)

$$? \text{ ton } Ca^{2+} = 1.8 \times 10^{21} \text{ kg ocean}\left(\frac{0.041 \text{ kg } Ca^{2+}}{100 \text{ kg ocean}}\right)\left(\frac{2.205 \text{ lb}}{1 \text{ kg}}\right)\left(\frac{1 \text{ ton}}{2000 \text{ lb}}\right)$$

$$= \mathbf{8.1 \times 10^{14} \text{ ton } Ca^{2+}}$$

i. When you are at rest, your heart pumps about 5.0 liters of blood per minute. Your brain gets about 15% by volume of your blood. What volume of blood, in liters, is pumped through your brain in 1.0 hour of rest?

$$? \text{ L to brain} = 1.0 \text{ hr}\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{5.0 \text{ L total}}{1 \text{ min}}\right)\left(\frac{15 \text{ L to brain}}{100 \text{ L total}}\right) = \mathbf{45 \text{ L}}$$

Exercise 2.11 - Temperature Conversions: *(Obj 16)*

a. N,N-dimethylaniline, $C_6H_5N(CH_3)_2$, which is used to make dyes, melts at 2.5 °C. What is N,N-dimethylaniline's melting point in °F and K?

$$°\text{F} = 2.5 \text{ °C}\left(\frac{1.8 \text{ °F}}{1 \text{ °C}}\right) + 32 \text{ °F} = \mathbf{36.5 \text{ °F}}$$

K = 2.5 °C + 273.15 **= 275.7 K**

b. Benzenethiol, C_6H_5SH, a mosquito larvicide, melts at 5.4 °F. What is benzenethiol's melting point in °C and K?

$$°\text{C} = (5.4 \text{ °F} - 32 \text{ °F})\frac{1 \text{ °C}}{1.8 \text{ °F}} = \mathbf{-14.8 \text{ °C}}$$

K = –14.8 °C + 273.15 **= 258.4 K**

c. The hottest part of the flame on a Bunsen burner is found to be 2.15×10^3 K. What is this temperature in °C and °F?

$$°C = 2.15 \times 10^3 \text{ K} - 273.15 = \mathbf{1.88 \times 10^3\ °C}$$

$$°F = 1.88 \times 10^3\ °C \left(\frac{1.8\ °F}{1\ °C}\right) + 32\ °F = \mathbf{3.42 \times 10^3\ °F}$$

or $\mathbf{3.41 \times 10^3\ °F}$ if the unrounded answer to the first calculation is used in the second calculation.

Review Questions Key

The following questions give you a review of some of the important skills from earlier chapters that you will use in this chapter.

1. Write the metric base units and their abbreviations for length, mass, and volume. (See Section 1.4.)

   Length, **meter (m)**, *mass,* **gram (g)**, *and volume,* **liter (L)**

2. Complete the following table by writing the type of measurement that the unit represents (mass, length, volume, or temperature) and either the name of a unit or the abbreviation for each unit. (See Section 1.4.)

Unit	Type of Measurement	Abbreviation	Unit	Type of Measurement	Abbreviation
milliliter	**volume**	**mL**	kilometer	**length**	**km**
microgram	**mass**	μg	**kelvin**	**temperature**	K

3. Complete the following relationships between units. (See Section 1.4.)

   a. $\mathbf{10^{-6}}$ m = 1 μm
   b. $\mathbf{10^{6}}$ g = 1 Mg
   c. $\mathbf{10^{-3}}$ L = 1 mL
   d. $\mathbf{10^{-9}}$ m = 1 nm
   e. **1** cm^3 = 1 mL
   f. $\mathbf{10^{3}}$ L = m^3
   g. $\mathbf{10^{3}}$ kg = 1 t (t = metric ton)
   h. **1** Mg = 1 t (t = metric ton)

4. An empty 2-L graduated cylinder is weighed on a balance and found to have a mass of 1124.2 g. Liquid methanol, CH_3OH, is added to the cylinder, and its volume is measured as 1.20 L. The total mass of the methanol and the cylinder is measured as 2073.9 g. On the basis of the way these data are reported, what do you assume is the range of possible values that each represents? (See Section 1.5.)

   We assume that each reported number is ±1 in the last decimal position reported. Therefore, we assume the mass of the graduated cylinder **between 1124.1 g and 1124.3 g**, *the volume of the methanol is between* **1.19 L and 1.21 L**, *and the total mass is between* **2073.8 g and 2074.0 g**.

Key Ideas Answers

5. You will find that the stepwise thought process associated with the procedure called unit analysis not only guides you in figuring out how to set up **unit conversion** problems but also gives you confidence that your answers are **correct**.
7. In the unit analysis process, we multiply by one or more conversion factors that cancel the **unwanted** units and generate the **desired** units.
9. If you have used correct conversion factors in a unit analysis setup, and if your units **cancel** to yield the desired unit or units, you can be confident that you will arrive at the correct answer.
11. Unless we are told otherwise, we assume that values from measurements have an uncertainty of plus or minus **one** in the last decimal place reported.
13. When an answer is calculated by multiplying or dividing, we round it off to the same number of significant figures as the **inexact** value with the **fewest** significant figures.
15. Numbers that come from definitions and from **counting** are exact.
17. When adding or subtracting, round your answer to the same number of **decimal places** as the inexact value with the **fewest decimal places**.
19. The densities of liquids and solids are usually described in **grams per milliliter** or **grams per cubic centimeter**.
21. Because the density of a substance depends on the substance's **identity** and its temperature, it is possible to identify an unknown substance by comparing its density at a particular temperature to the **known** densities of substances at the same temperature.
23. Percentage by mass, the most common form of percentage used in chemical descriptions, is a value that tells us the number of mass units of the **part** for each 100 mass units of the **whole**.
25. Note that the numbers 1.8, 32, and 273.15 in the equations used for temperature conversions all come from **definitions**, so they are all exact.

Problems Key

Problems Relating to Appendices

26. Convert the following ordinary decimal numbers to scientific notation.
    a. 67,294 — $\mathbf{6.7294 \times 10^4}$
    b. 438,763,102 — $\mathbf{4.38763102 \times 10^8}$
    c. 0.000073 — $\mathbf{7.3 \times 10^{-5}}$
    d. 0.0000000435 — $\mathbf{4.35 \times 10^{-8}}$
28. Convert the following numbers expressed in scientific notation to ordinary decimal numbers.
    a. 4.097×10^3 — **4,097**
    b. 1.55412×10^4 — **15,541.2**
    c. 2.34×10^{-5} — **0.0000234**
    d. 1.2×10^{-8} — **0.000000012**

30. Use your calculator to complete the following calculations.

a. $34.25 \times 84.00 =$ **2,877**

b. $2607 \div 8.25 =$ **316**

c. $425 \div 17 \times 0.22$ **= 5.5**

d. $(27.001 - 12.866) \div 5.000$ **= 2.827**

32. Use your calculator to complete the following calculations.

a. $10^9 \times 10^3 = \mathbf{10^{12}}$

b. $10^{12} \div 10^3 = \mathbf{10^{9}}$

c. $10^3 \times 10^6 \div 10^2 = \mathbf{10^{7}}$

d. $10^9 \times 10^{-4} = \mathbf{10^{5}}$

e. $10^{23} \div 10^{-6} = \mathbf{10^{29}}$

f. $10^{-4} \times 10^2 \div 10^{-5} = \mathbf{10^{3}}$

34. Use your calculator to complete the following calculations.

a. $(9.5 \times 10^5) \times (8.0 \times 10^9) = \mathbf{7.6 \times 10^{15}}$

b. $(6.12 \times 10^{19}) \div (6.00 \times 10^3) = \mathbf{1.02 \times 10^{16}}$

c. $(2.75 \times 10^4) \times (6.00 \times 10^7) \div (5.0 \times 10^6) = \mathbf{3.3 \times 10^{5}}$

d. $(8.50 \times 10^{-7}) \times (2.20 \times 10^3) = \mathbf{1.87 \times 10^{-3}}$ **or 0.00187**

e. $(8.203 \times 10^9) \div 10^{-4} = \mathbf{8.203 \times 10^{13}}$

f. $(7.679 \times 10^{-4} - 3.457 \times 10^{-4}) \div 2.000 \times 10^{-8} = \mathbf{2.111 \times 10^{4}}$

Section 2.1 Unit Analysis

36. Complete each of the following conversion factors by filling in the blank on the top of the ratio. *(Objs 2 & 4)*

a. $\left(\dfrac{\mathbf{10^3}\ \text{m}}{1\,\text{km}}\right)$

b. $\left(\dfrac{\mathbf{10^2}\ \text{cm}}{1\,\text{m}}\right)$

c. $\left(\dfrac{\mathbf{10^3}\ \text{mm}}{1\,\text{m}}\right)$

d. $\left(\dfrac{\mathbf{1}\ \text{cm}^3}{1\,\text{mL}}\right)$

e. $\left(\dfrac{\mathbf{2.54}\ \text{cm}}{1\,\text{in.}}\right)$

f. $\left(\dfrac{\mathbf{453.6}\ \text{g}}{1\,\text{lb}}\right)$

38. Complete each of the following conversion factors by filling in the blank on the top of the ratio. *(Objs 2 & 4)*

a. $\left(\dfrac{\mathbf{10^3}\ \text{g}}{1\,\text{kg}}\right)$

b. $\left(\dfrac{\mathbf{10^3}\ \text{mg}}{1\,\text{g}}\right)$

c. $\left(\dfrac{\mathbf{1.094}\ \text{yd}}{1\,\text{m}}\right)$

d. $\left(\dfrac{\mathbf{2.205}\ \text{lb}}{1\,\text{kg}}\right)$

40. The mass of an electron is $9.1093897 \times 10^{-31}$ kg. What is this mass in grams? *(Obj 3)*

$$?\ \text{g} = 9.1093897 \times 10^{-31}\ \text{kg}\left(\frac{10^3\ \text{g}}{1\,\text{kg}}\right) = \mathbf{9.1093897 \times 10^{-28}\ g}$$

42. The diameter of typical bacteria cells is 0.00032 centimeter. What is this diameter in micrometers? *(Obj 3)*

$$? \mu\text{m} = 0.00032\text{ cm}\left(\frac{1\text{ m}}{10^2\text{ cm}}\right)\left(\frac{10^6\ \mu\text{m}}{1\text{ m}}\right) = \mathbf{3.2\ \mu m}$$

44. The thyroid gland is the largest of the endocrine glands with a mass between 20 and 25 grams. What is the mass in pounds of a thyroid gland with a mass of 22.456 grams? *(Obj 5)*

$$? \text{lb} = 22.456\text{ g}\left(\frac{1\text{ lb}}{453.6\text{ g}}\right) = \mathbf{0.04951\ lb}$$

or $$? \text{lb} = 22.456\text{ g}\left(\frac{1\text{ lb}}{453.59237\text{ g}}\right) = \mathbf{0.049507\ lb}$$

46. The mass of a neutron is 1.674929×10^{-27} kg. Convert this to ounces. *(Obj 5)* (There are 16 oz/lb.)

$$? \text{oz} = 1.674929 \times 10^{-27}\text{ kg}\left(\frac{10^3\text{ g}}{1\text{ kg}}\right)\left(\frac{1\text{ lb}}{453.6\text{ g}}\right)\left(\frac{16\text{ oz}}{1\text{ lb}}\right) = \mathbf{5.908 \times 10^{-26}\ oz}$$

$$? \text{oz} = 1.674929 \times 10^{-27}\text{ kg}\left(\frac{10^3\text{ g}}{1\text{ kg}}\right)\left(\frac{1\text{ lb}}{453.59237\text{ g}}\right)\left(\frac{16\text{ oz}}{1\text{ lb}}\right) = \mathbf{5.908138 \times 10^{-26}\ oz}$$

48. A red blood cell is 8.7×10^{-5} inches thick. What is this thickness in micrometers? *(Obj 5)*

$$? \mu\text{m} = 8.7 \times 10^{-5}\text{ in.}\left(\frac{2.54\text{ cm}}{1\text{ in.}}\right)\left(\frac{1\text{ m}}{10^2\text{ cm}}\right)\left(\frac{10^6\ \mu\text{m}}{1\text{ m}}\right) = \mathbf{2.2\ \mu m}$$

Section 2.2 Rounding Off and Significant Figures

50. Decide whether each of the numbers shown in boldface type is exact. If it is not exact, write the number of significant figures in it. *(Objs 6 and 7)*

   a. The approximate volume of the ocean, **1.5×10^{21}** L.

      The value 1.5×10^{21} must have come from an estimate or a calculation, so it is **not exact** *and has* **two significant figures.**

   b. A count of **24** instructors in the physical sciences division of a state college

      Counting leads to exact values. The 24 is **exact.**

   c. The **54**% of the instructors in the physical sciences division who are women (determined by counting 13 women in the total of 24 instructors and then calculating the percentage)

      Even if a value is calculated from exact values, if the answer is rounded off, the rounded answer is not exact. 13 divided by 24 and multiplied by 100 yields 54.166667 on a typical calculator. Thus the 54% includes a value that was rounded off. The 54 is **not exact** *and has* **two significant figures.**

d. The **25**% of the instructors in the physical sciences division who are left-handed (determined by counting 6 left-handed instructors in the total of 24 and then calculating the percentage)

Values calculated from exact values and not rounded off are exact. The 25 is **exact**.

e. $\frac{\mathbf{16}\ \text{oz}}{1\ \text{lb}}$

English-English conversion factors with units of the same type of measurement top and bottom come from definitions, so the values in them are exact. The 16 is **exact**.

f. $\frac{\mathbf{10^6}\ \mu\text{m}}{1\ \text{m}}$

Metric-metric conversion factors with units of the same type of measurement top and bottom come from definitions, so the values in them are exact. The 10^6 *is* **exact**.

g. $\frac{\mathbf{1.057}\ \text{qt}}{1\ \text{L}}$

Except for $\frac{2.54\ \text{cm}}{1\ \text{in.}}$*, the values in English-metric conversion factors that we will see are calculated and rounded off. They are* **not exact**. *The 1.057 is* **four significant figures.**

h. A measurement of **107.200** g water

Measurements never lead to exact values. Zeros in numbers that have decimal points are significant, and zeros between nonzero digits are significant. The 107.200 is **not exact** *and is* **six significant figures.**

i. A mass of **0.2363** lb water [calculated from Part (h), using $\frac{453.6\ \text{g}}{1\ \text{lb}}$ as a conversion factor]

Measurements never lead to exact values. Thus values calculated from measurements are not exact. The 0.2363 is **not exact** *and has* **four significant figures.**

j. A mass of $\mathbf{1.182 \times 10^{-4}}$ tons [calculated from the 0.2363 lb of the water described in Part (i).]

Values calculated from nonexact values are not exact. The 1.182×10^{-4} *is* **not exact** *and has* **four significant figures.**

52. Assuming that each of the following are not exact, how many significant figures does each number have? *(Obj 7)*

a. 13.811 **5**
b. 0.0445 **3**
c. 505 **3**
d. 9.5004 **5**
e. 81.00 **4**

54. Assuming that each of the following are not exact, how many significant figures does each number have? *(Obj 7)*
    a. 4.75×10^{23} **3**
    b. 3.009×10^{-3} **4**
    c. 4.000×10^{13} **4**

56. Convert each of the following to a number with 3 significant figures.
    a. 34.579 **34.6**
    b. 193.405 **193**
    c. 23.995 **24.0**
    d. 0.003882 **0.00388**
    e. 0.023 **0.0230**
    f. 2,846.5 **2.85×10^3**
    g. 7.8354×10^4 **7.84×10^4**

58. Complete the following calculations and report your answers to the correct number of significant figures. The exponential factors, such as 10^3, are exact, and the 2.54 in Part (c) is exact. All other numbers are not exact. *(Obj 8)*
    a. $\dfrac{2.45\times10^{-5}\left(10^{12}\right)}{\left(10^{3}\right)237.00} = \mathbf{103}$
    b. $\dfrac{16.050\left(10^{3}\right)}{\left(24.8-19.4\right)\left(1.057\right)\left(453.6\right)} = \mathbf{6.2}$ *Note that the subtraction yields 5.4, which limits the final number of significant figures to 2.*
    c. $\dfrac{4.77\times10^{11}\left(2.54\right)^{3}\left(73.00\right)}{\left(10^{3}\right)} = \mathbf{5.71 \times 10^{11}}$

60. Report the answers to the following calculations to the correct number of decimal places. Assume that each number is ±1 in the last decimal place reported. *(Obj 9)*
    a. 0.8995 + 99.24 = **100.14** b. 88 – 87.3 = **1**

Section 2.3 Density and Density Calculations

62. A piece of balsa wood has a mass of 15.196 g and a volume of 0.1266 L. What is its density in g/mL? *(Obj 12)*

$$\frac{?\ \text{g}}{\text{mL}} = \frac{15.196\ \text{g}}{0.1266\ \text{L}}\left(\frac{1\ \text{L}}{10^{3}\ \text{mL}}\right) = \mathbf{0.1200\ g/mL}$$

64. The density of water at 0 °C is 0.99987 g/mL. What is the mass in kilograms of 185.0 mL of water? *(Obj 11)*

$$?\ \text{kg} = 185.0\ \text{mL}\left(\frac{0.99987\ \text{g}}{1\ \text{mL}}\right)\left(\frac{1\ \text{kg}}{10^{3}\ \text{g}}\right) = \mathbf{0.1850\ kg}$$

66. The density of a piece of ebony wood is 1.174 g/mL. What is the volume in quarts of a 2.1549-lb piece of this ebony wood? *(Obj 11)*

$$? \text{ qt} = 2.1549 \text{ lb}\left(\frac{453.6 \text{ g}}{1 \text{ lb}}\right)\left(\frac{1 \text{ mL}}{1.174 \text{ g}}\right)\left(\frac{1 \text{ L}}{10^3 \text{ mL}}\right)\left(\frac{1 \text{ gal}}{3.785 \text{ L}}\right)\left(\frac{4 \text{ qt}}{1 \text{ gal}}\right) = \mathbf{0.8799\ qt}$$

Section 2.4 Percentage and Percentage Calculations

68. The mass of the ocean is about 1.8×10^{21} kg. If the ocean contains 1.076% by mass sodium ions, Na^+, what is the mass in kilograms of Na^+ in the ocean? *(Obj 14)*

$$? \text{ kg Na}^+ = 1.8 \times 10^{21} \text{ kg ocean}\left(\frac{1.076 \text{ kg Na}^+}{100 \text{ kg ocean}}\right) = \mathbf{1.9 \times 10^{19}\ kg\ Na^+}$$

70. While you are doing heavy work, your heart pumps up to 25.0 L of blood per minute. Your brain gets about 3-4% by volume of your blood under these conditions. What volume of blood in liters is pumped through your brain in 125 minutes of work that causes your heart to pump 22.0 L per minute, 3.43% of which goes to your brain? *(Obj 14)*

$$? \text{ L to brain} = 125 \text{ min}\left(\frac{22.0 \text{ L total}}{1 \text{ min}}\right)\left(\frac{3.43 \text{ L to brain}}{100 \text{ L total}}\right) = \mathbf{94.3\ L\ to\ brain}$$

72. In chemical reactions that release energy, from 10^{-8}% to 10^{-7}% of the mass of the substances involved is converted into energy. Consider a chemical reaction for which 1.8×10^{-8}% of the mass is converted into energy. What mass in milligrams is converted into energy when 1.0×10^3 kilograms of substance reacts? *(Obj 14)*

$$? \text{ mg to energy} = 1.0 \times 10^3 \text{ kg reacts}\left(\frac{1.8 \times 10^{-8} \text{ kg to energy}}{100 \text{ kg reacts}}\right)\left(\frac{10^3 \text{ g}}{1 \text{ kg}}\right)\left(\frac{10^3 \text{ mg}}{1 \text{ g}}\right)$$

$$= \mathbf{0.18\ mg\ to\ energy}$$

Section 2.5 A Summary of the Unit Analysis Process

74. If an elevator moves 1340 ft to the 103rd floor of the Sears Tower in Chicago in 45 seconds, what is the velocity of the elevator in kilometers per hour? *(Obj 15)*

$$\frac{? \text{ km}}{\text{hr}} = \frac{1340 \text{ ft}}{45 \text{ s}}\left(\frac{12 \text{ in.}}{1 \text{ ft}}\right)\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right) = \mathbf{33\ km/hr}$$

76. Sound travels at a velocity of 333 m/s. How long does it take for sound to travel the length of a 100-yard football field? *(Obj 15)*

$$? \text{ s} = 100 \text{ yd}\left(\frac{3 \text{ ft}}{1 \text{ yd}}\right)\left(\frac{12 \text{ in.}}{1 \text{ ft}}\right)\left(\frac{2.54 \text{ cm}}{1 \text{ in.}}\right)\left(\frac{1 \text{ m}}{10^2 \text{ cm}}\right)\left(\frac{1 \text{ s}}{333 \text{ m}}\right) = \mathbf{0.275\ s}$$

78. A peanut butter sandwich provides about 1.4×10^3 kJ of energy. A typical adult uses about 95 kcal/hr of energy while sitting. If all of the energy in one peanut butter sandwich were to be burned off by sitting, how many hours would it be before this energy was used? (A kcal is a dietary calorie. There are 4.184 J/cal.) *(Obj 15)*

$$? \text{ hr} = 1.4 \times 10^3 \text{ kJ}\left(\frac{1 \text{ kcal}}{4.184 \text{ kJ}}\right)\left(\frac{1 \text{ hr}}{95 \text{ kcal}}\right) = \mathbf{3.5\ hr}$$

80. When one gram of hydrogen gas, $H_2(g)$, is burned, 141.8 kJ of heat is released. How much heat is released when 2.3456 kg of hydrogen gas is burned? *(Obj 15)*

$$? \text{ kJ} = 2.3456 \text{ kg } H_2 \left(\frac{10^3 \text{ g}}{1 \text{ kg}}\right)\left(\frac{141.8 \text{ kJ}}{1 \text{ g } H_2}\right) = \mathbf{3.326 \times 10^5 \ kJ}$$

82. When one gram of carbon in the graphite form is burned, 32.8 kJ of heat is released. How many kilograms of graphite must be burned to release 1.456×10^4 kJ of heat? *(Obj 15)*

$$? \text{ kg C} = 1.456 \times 10^4 \text{ kJ} \left(\frac{1 \text{ g C}}{32.8 \text{ kJ}}\right)\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right) = \mathbf{0.444 \ kg \ C}$$

84. The average adult male needs about 58 g of protein in the diet each day. A can of vegetarian refried beans has 6.0 g of protein per serving. Each serving is 128 g of beans. If your only dietary source of protein were vegetarian refried beans, how many pounds of beans would you need to eat each day? *(Obj 15)*

$$\frac{? \text{ lb beans}}{\text{day}} = \frac{58 \text{ g protein}}{1 \text{ day}}\left(\frac{1 \text{ serving}}{6.0 \text{ g protein}}\right)\left(\frac{128 \text{ g beans}}{1 \text{ serving}}\right)\left(\frac{1 \text{ lb}}{453.6 \text{ g}}\right)$$

= 2.7 lb beans per day

86. About 6.0×10^5 tons of 30% by mass hydrochloric acid, HCl(*aq*), is used each year to remove metal oxides from metals to prepare them for painting or for the addition of a chrome covering. How many kilograms of pure HCl would be used to make this hydrochloric acid? (Assume that 30% has two significant figures. There are 2000 lb/ton.) *(Obj 15)*

$$? \text{ kg HCl} = 6.0 \times 10^5 \text{ ton HCl soln} \left(\frac{30 \text{ ton HCl}}{100 \text{ ton HCl soln}}\right)\left(\frac{2000 \text{ lb}}{1 \text{ ton}}\right)\left(\frac{1 \text{ kg}}{2.205 \text{ lb}}\right)$$

$$? \text{ kg HCl} = 6.0 \times 10^5 \text{ ton soln} \left(\frac{30 \text{ ton HCl}}{100 \text{ ton soln}}\right)\left(\frac{2000 \text{ lb}}{1 \text{ ton}}\right)\left(\frac{453.6 \text{ g}}{1 \text{ lb}}\right)\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right)$$

= 1.6 × 10⁸ kg HCl

88. A typical nonobese male has about 11 kg of fat. Each gram of fat can provide the body with about 38 kJ of energy. If this person requires 8.0×10^3 kJ of energy per day to survive, how many days could he survive on his fat alone? *(Obj 15)*

$$? \text{ day} = 11 \text{ kg fat} \left(\frac{10^3 \text{ g}}{1 \text{ kg}}\right)\left(\frac{38 \text{ kJ}}{1 \text{ g}}\right)\left(\frac{1 \text{ day}}{8.0 \times 10^3 \text{ kJ}}\right) = \mathbf{52 \ days}$$

90. During quiet breathing, a person breathes in about 6 L of air per minute. If a person breathes in an average of 6.814 L of air per minute, what volume of air in liters does this person breathe in 1 day? *(Obj 15)*

$$? \text{ L} = 1 \text{ day}\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{6.814 \text{ L air}}{1 \text{ min}}\right) = \mathbf{9812 \ L \ air}$$

92. The kidneys of a normal adult female filter 115 mL of blood per minute. If this person has 5.345 quarts of blood, how many minutes will it take to filter all of her blood once? *(Obj 15)*

$$? \text{ min} = 5.345 \text{ qt blood}\left(\frac{1\text{ gal}}{4\text{ qt}}\right)\left(\frac{3.785\text{ L}}{1\text{ gal}}\right)\left(\frac{10^3\text{ mL}}{1\text{ L}}\right)\left(\frac{1\text{ min}}{115\text{ mL blood}}\right)$$

$$\text{or} \quad ? \text{ min} = 5.345 \text{ qt blood}\left(\frac{1\text{ L}}{1.057\text{ qt}}\right)\left(\frac{10^3\text{ mL}}{1\text{ L}}\right)\left(\frac{1\text{ min}}{115\text{ mL blood}}\right) = \mathbf{44.0\ minutes}$$

94. We lose between 0.2 and 1 liter of water from our skin and sweat glands each day. For a person who loses an average of 0.89 L H_2O per day in this manner, how many quarts of water are lost from the skin and sweat glands in 30 days? *(Obj 15)*

$$? \text{ qt} = 30 \text{ day}\left(\frac{0.89\text{ L}}{1\text{ day}}\right)\left(\frac{1\text{ gal}}{3.785\text{ L}}\right)\left(\frac{4\text{ qt}}{1\text{ gal}}\right)$$

$$\text{or} \quad ? \text{ qt} = 30 \text{ day}\left(\frac{0.89\text{ L}}{1\text{ day}}\right)\left(\frac{1.057\text{ qt}}{1\text{ L}}\right) = \mathbf{28\ qt}$$

96. The average heart rate is 75 beats/min. How many times does the average person's heart beat in a week? *(Obj 15)*

$$? \text{ beats} = 1 \text{ week}\left(\frac{7\text{ day}}{1\text{ week}}\right)\left(\frac{24\text{ hr}}{1\text{ day}}\right)\left(\frac{60\text{ min}}{1\text{ hr}}\right)\left(\frac{75\text{ beats}}{1\text{ min}}\right) = \mathbf{7.6 \times 10^5\ beats}$$

98. In optimum conditions, one molecule of the enzyme carbonic anhydrase can convert 3.6×10^5 molecules per minute of carbonic acid, H_2CO_3, into carbon dioxide, CO_2, and water, H_2O. How many molecules could be converted by one of these enzyme molecules in 1 week? *(Obj 15)*

$$? \text{ molecules} = 1 \text{ week}\left(\frac{7\text{ day}}{1\text{ week}}\right)\left(\frac{24\text{ hr}}{1\text{ day}}\right)\left(\frac{60\text{ min}}{1\text{ hr}}\right)\left(\frac{3.6\times10^5\text{ molecules}}{1\text{ min}}\right)$$

$$= \mathbf{3.6 \times 10^9\ molecules}$$

100. In optimum conditions, one molecule of the enzyme amylase can convert 1.0×10^5 molecules per minute of starch into the sugar maltose. How many days would it take one of these enzyme molecules to convert a billion (1.0×10^9) starch molecules? *(Obj 15)*

$$? \text{ days} = 1.0\times10^9 \text{ molecules}\left(\frac{1\text{ min}}{1.0\times10^5\text{ molecules}}\right)\left(\frac{1\text{ hr}}{60\text{ min}}\right)\left(\frac{1\text{ day}}{24\text{ hr}}\right) = \mathbf{6.9\ days}$$

102. When you sneeze, you close your eyes for about 1.00 second. If you are driving 65 miles per hour on the freeway and you sneeze, how many feet do you travel with your eyes closed? *(Obj 15)*

$$? \text{ ft} = 1.00 \text{ s}\left(\frac{1\text{ min}}{60\text{ s}}\right)\left(\frac{1\text{ hr}}{60\text{ min}}\right)\left(\frac{65\text{ mi}}{1\text{ hr}}\right)\left(\frac{5280\text{ ft}}{1\text{ mi}}\right) = \mathbf{95\ ft}$$

Section 2.6 Temperature Conversions

103. Butter melts at 31 °C. What is this temperature in °F? in K? *(Obj 16)*

$$°F = 31\,°C\left(\frac{1.8\,°F}{1\,°C}\right) + 32\,°F \;\mathbf{= 88\ °F} \qquad K = 31\ °C + 273.15\ \mathbf{= 304\ K}$$

105. A saturated salt solution boils at 226 °F. What is this temperature in °C? in K? *(Obj 16)*

$$°C = \left(226\,°F - 32\,°F\right)\left(\frac{1\,°C}{1.8\,°F}\right) \;\mathbf{= 108\ °C} \qquad K = 108\ °C + 273.15\ \mathbf{= 381\ K}$$

107. Iron boils at 3023 K. What is this temperature in °C? in °F ? *(Obj 16)*

$°C = 3023\ K - 273.15\ \mathbf{= 2.750 \times 10^3\ °C}$

$$°F = 2.750 \times 10^3\,°C\left(\frac{1.8\,°F}{1\,°C}\right) + 32\,°F \;\mathbf{= 4982\ °F}$$

109. The surface of the sun is 1.0×10^4 °F. What is this temperature in °C? in K? *(Obj 16)*

$$°C = \left(1.0 \times 10^4\,°F - 32\,°F\right)\left(\frac{1\,°C}{1.8\,°F}\right) \;\mathbf{= 5.5 \times 10^3\ °C}$$

$K = 5.5 \times 10^3\ °C + 273.15\ \mathbf{= 5.8 \times 10^3\ K}$