CHAPTER 1
CHEMISTRY: THE STUDY OF CHANGE

1.3 **(a)** Quantitative. This statement clearly involves a measurable distance.

(b) Qualitative. This is a value judgment. There is no numerical scale of measurement for artistic excellence.

(c) Qualitative. If the numerical values for the densities of ice and water were given, it would be a quantitative statement.

(d) Qualitative. Another value judgment.

(e) Qualitative. Even though numbers are involved, they are not the result of measurement.

1.4 **(a)** hypothesis **(b)** law **(c)** theory

1.11 **(a)** Chemical property. Oxygen gas is consumed in a combustion reaction; its composition and identity are changed.

(b) Chemical property. The fertilizer is consumed by the growing plants; it is turned into vegetable matter (different composition).

(c) Physical property. The measurement of the boiling point of water does not change its identity or composition.

(d) Physical property. The measurement of the densities of lead and aluminum does not change their composition.

(e) Chemical property. When uranium undergoes nuclear decay, the products are chemically different substances.

1.12 **(a)** Physical change. The helium isn't changed in any way by leaking out of the balloon.

(b) Chemical change in the battery.

(c) Physical change. The orange juice concentrate can be regenerated by evaporation of the water.

(d) Chemical change. Photosynthesis changes water, carbon dioxide, etc., into complex organic matter.

(e) Physical change. The salt can be recovered unchanged by evaporation.

1.13 Li, lithium; F, fluorine; P, phosphorus; Cu, copper; As, arsenic; Zn, zinc; Cl, chlorine; Pt, platinum; Mg, magnesium; U, uranium; Al, aluminum; Si, silicon; Ne, neon.

1.14 **(a)** K **(b)** Sn **(c)** Cr **(d)** B **(e)** Ba
(f) Pu **(g)** S **(h)** Ar **(i)** Hg

1.15 **(a)** element **(b)** compound **(c)** element **(d)** compound

1.16 **(a)** homogeneous mixture **(b)** element **(c)** compound
(d) homogeneous mixture **(e)** heterogeneous mixture **(f)** homogeneous mixture
(g) heterogeneous mixture

1.21 $$\textbf{density} = \frac{\text{mass}}{\text{volume}} = \frac{586\text{ g}}{188\text{ mL}} = \textbf{3.12 g/mL}$$

1.22 **Strategy:** We are given the density and volume of a liquid and asked to calculate the mass of the liquid. Rearrange the density equation, Equation (1.1) of the text, to solve for mass.

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

Solution:

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

$$\textbf{mass of ethanol} = \frac{0.798\text{ g}}{1\text{ mL}} \times 17.4\text{ mL} = \textbf{13.9 g}$$

1.23 $$?\ °\text{C} = (°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}}$$

(a) $$?\ °\text{C} = (95°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}} = \textbf{35°C}$$

(b) $$?\ °\text{C} = (12°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}} = \mathbf{-11°C}$$

(c) $$?\ °\text{C} = (102°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}} = \textbf{39°C}$$

(d) $$?\ °\text{C} = (1852°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}} = \textbf{1011°C}$$

(e) $$?\ °\text{F} = \left(°\text{C} \times \frac{9°\text{F}}{5°\text{C}}\right) + 32°\text{F}$$

$$?\ °\text{F} = \left(-273.15\,°\text{C} \times \frac{9°\text{F}}{5°\text{C}}\right) + 32°\text{F} = \mathbf{-459.67°F}$$

1.24 **Strategy:** Find the appropriate equations for converting between Fahrenheit and Celsius and between Celsius and Fahrenheit given in Section 1.7 of the text. Substitute the temperature values given in the problem into the appropriate equation.

(a) Conversion from Fahrenheit to Celsius.

$$?\ °\text{C} = (°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}}$$

$$\mathbf{?\ °C} = (105°\text{F} - 32°\text{F}) \times \frac{5°\text{C}}{9°\text{F}} = \textbf{41°C}$$

(b) Conversion from Celsius to Fahrenheit.

$$?\ °\text{F} = \left(°\text{C} \times \frac{9°\text{F}}{5°\text{C}}\right) + 32°\text{F}$$

$$\mathbf{?\ °F} = \left(-11.5\,°\text{C} \times \frac{9°\text{F}}{5°\text{C}}\right) + 32°\text{F} = \textbf{11.3°F}$$

(c) Conversion from Celsius to Fahrenheit.

$$? \text{°F} = \left(\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F}$$

$$\mathbf{?\ °F} = \left(6.3 \times 10^3\ \text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F} = \mathbf{1.1 \times 10^4\ °F}$$

(d) Conversion from Fahrenheit to Celsius.

$$? \text{°C} = (\text{°F} - 32\text{°F}) \times \frac{5\text{°C}}{9\text{°F}}$$

$$\mathbf{?\ °C} = (451\text{°F} - 32\text{°F}) \times \frac{5\text{°C}}{9\text{°F}} = \mathbf{233°C}$$

1.25 $\text{K} = (\text{°C} + 273\text{°C})\frac{1\text{ K}}{1\text{°C}}$

(a) $\mathbf{K} = 113\text{°C} + 273\text{°C} = \mathbf{386\ K}$

(b) $\mathbf{K} = 37\text{°C} + 273\text{°C} = \mathbf{3.10 \times 10^2\ K}$

(c) $\mathbf{K} = 357\text{°C} + 273\text{°C} = \mathbf{6.30 \times 10^2\ K}$

1.26 **(a)** $\text{K} = (\text{°C} + 273\text{°C})\frac{1\text{ K}}{1\text{°C}}$

$\mathbf{°C} = \text{K} - 273 = 77\text{ K} - 273 = \mathbf{-196°C}$

(b) $\mathbf{°C} = 4.2\text{ K} - 273 = \mathbf{-269°C}$

(c) $\mathbf{°C} = 601\text{ K} - 273 = \mathbf{328°C}$

1.29 **(a)** 2.7×10^{-8} **(b)** 3.56×10^2 **(c)** 4.7764×10^4 **(d)** 9.6×10^{-2}

1.30 **(a)** 10^{-2} indicates that the decimal point must be moved two places to the left.

$$1.52 \times 10^{-2} = \mathbf{0.0152}$$

(b) 10^{-8} indicates that the decimal point must be moved 8 places to the left.

$$7.78 \times 10^{-8} = \mathbf{0.0000000778}$$

1.31 **(a)** $145.75 + (2.3 \times 10^{-1}) = 145.75 + 0.23 = \mathbf{1.4598 \times 10^2}$

(b) $\frac{79500}{2.5 \times 10^2} = \frac{7.95 \times 10^4}{2.5 \times 10^2} = \mathbf{3.2 \times 10^2}$

(c) $(7.0 \times 10^{-3}) - (8.0 \times 10^{-4}) = (7.0 \times 10^{-3}) - (0.80 \times 10^{-3}) = \mathbf{6.2 \times 10^{-3}}$

(d) $(1.0 \times 10^4) \times (9.9 \times 10^6) = \mathbf{9.9 \times 10^{10}}$

1.32 **(a)** Addition using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When adding numbers using scientific notation, we must write each quantity with the same exponent, n. We can then add the N parts of the numbers, keeping the exponent, n, the same.

Solution: Write each quantity with the same exponent, n.

Let's write 0.0095 in such a way that $n = -3$. We have decreased 10^n by 10^3, so we must increase N by 10^3. Move the decimal point 3 places to the right.

$$0.0095 = 9.5 \times 10^{-3}$$

Add the N parts of the numbers, keeping the exponent, n, the same.

$$\begin{array}{r} 9.5 \times 10^{-3} \\ +\ 8.5 \times 10^{-3} \\ \hline \mathbf{18.0 \times 10^{-3}} \end{array}$$

The usual practice is to express N as a number between 1 and 10. Since we must *decrease* N by a factor of 10 to express N between 1 and 10 (1.8), we must *increase* 10^n by a factor of 10. The exponent, n, is increased by 1 from −3 to −2.

$$18.0 \times 10^{-3} = \mathbf{1.8 \times 10^{-2}}$$

(b) Division using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When dividing numbers using scientific notation, divide the N parts of the numbers in the usual way. To come up with the correct exponent, n, we *subtract* the exponents.

Solution: Make sure that all numbers are expressed in scientific notation.

$$653 = 6.53 \times 10^2$$

Divide the N parts of the numbers in the usual way.

$$6.53 \div 5.75 = 1.14$$

Subtract the exponents, n.

$$1.14 \times 10^{+2-(-8)} = 1.14 \times 10^{+2+8} = \mathbf{1.14 \times 10^{10}}$$

(c) Subtraction using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When subtracting numbers using scientific notation, we must write each quantity with the same exponent, n. We can then subtract the N parts of the numbers, keeping the exponent, n, the same.

Solution: Write each quantity with the same exponent, n.

Let's write 850,000 in such a way that $n = 5$. This means to move the decimal point five places to the left.

$$850{,}000 = 8.5 \times 10^5$$

Subtract the N parts of the numbers, keeping the exponent, n, the same.

$$\begin{array}{r} 8.5 \times 10^5 \\ -\ 9.0 \times 10^5 \\ \hline \mathbf{-0.5 \times 10^5} \end{array}$$

The usual practice is to express N as a number between 1 and 10. Since we must *increase* N by a factor of 10 to express N between 1 and 10 (5), we must *decrease* 10^n by a factor of 10. The exponent, n, is decreased by 1 from 5 to 4.

$$-0.5 \times 10^5 = \mathbf{-5 \times 10^4}$$

(d) Multiplication using scientific notation.

Strategy: Let's express scientific notation as $N \times 10^n$. When multiplying numbers using scientific notation, multiply the N parts of the numbers in the usual way. To come up with the correct exponent, n, we *add* the exponents.

Solution: Multiply the N parts of the numbers in the usual way.

$$3.6 \times 3.6 = 13$$

Add the exponents, n.

$$13 \times 10^{-4+(+6)} = \mathbf{13 \times 10^2}$$

The usual practice is to express N as a number between 1 and 10. Since we must *decrease* N by a factor of 10 to express N between 1 and 10 (1.3), we must *increase* 10^n by a factor of 10. The exponent, n, is increased by 1 from 2 to 3.

$$\mathbf{13 \times 10^2 = 1.3 \times 10^3}$$

1.33 **(a)** four **(b)** two **(c)** five **(d)** two, three, or four
(e) three **(f)** one **(g)** one **(h)** two

1.34 **(a)** one **(b)** three **(c)** three **(d)** four
(e) two or three **(f)** one **(g)** one or two

1.35 **(a)** 10.6 m **(b)** 0.79 g **(c)** 16.5 cm^2

1.36 **(a)** Division

Strategy: The number of significant figures in the answer is determined by the original number having the smallest number of significant figures.

Solution:

$$\frac{7.310 \text{ km}}{5.70 \text{ km}} = 1.28\mathbf{3}$$

The 3 (bolded) is a nonsignificant digit because the original number 5.70 only has three significant digits. Therefore, the answer has only three significant digits.

The correct answer rounded off to the correct number of significant figures is:

1.28 (Why are there no units?)

(b) Subtraction

Strategy: The number of significant figures to the right of the decimal point in the answer is determined by the lowest number of digits to the right of the decimal point in any of the original numbers.

Solution: Writing both numbers in decimal notation, we have

$$\begin{array}{r} 0.00326\text{ mg} \\ -\ \underline{0.0000788\text{ mg}} \\ 0.00318\mathbf{12}\text{ mg} \end{array}$$

The bolded numbers are nonsignificant digits because the number 0.00326 has five digits to the right of the decimal point. Therefore, we carry five digits to the right of the decimal point in our answer.

The correct answer rounded off to the correct number of significant figures is:

$$\mathbf{0.00318\text{ mg} = 3.18 \times 10^{-3}\text{ mg}}$$

(c) Addition

Strategy: The number of significant figures to the right of the decimal point in the answer is determined by the lowest number of digits to the right of the decimal point in any of the original numbers.

Solution: Writing both numbers with exponents = +7, we have

$$(0.402 \times 10^7\text{ dm}) + (7.74 \times 10^7\text{ dm}) = \mathbf{8.14 \times 10^7\text{ dm}}$$

Since 7.74×10^7 has only two digits to the right of the decimal point, two digits are carried to the right of the decimal point in the final answer.

1.37 **(a)** $$\textbf{? dm} = 22.6\text{ m} \times \frac{1\text{ dm}}{0.1\text{ m}} = \mathbf{226\text{ dm}}$$

(b) $$\textbf{? kg} = 25.4\text{ mg} \times \frac{0.001\text{ g}}{1\text{ mg}} \times \frac{1\text{ kg}}{1000\text{ g}} = \mathbf{2.54 \times 10^{-5}\text{ kg}}$$

(c) $$\textbf{? L} = 556\text{ mL} \times \frac{1 \times 10^{-3}\text{ L}}{1\text{ mL}} = \mathbf{0.556\text{ L}}$$

(d) $$?\ \frac{\mathbf{g}}{\mathbf{cm^3}} = \frac{10.6\text{ kg}}{1\text{ m}^3} \times \frac{1000\text{ g}}{1\text{ kg}} \times \left(\frac{1 \times 10^{-2}\text{ m}}{1\text{ cm}}\right)^3 = \mathbf{0.0106\text{ g/cm}^3}$$

1.38 **(a)**

Strategy: The problem may be stated as

$$?\text{ mg} = 242\text{ lb}$$

A relationship between pounds and grams is given on the end sheet of your text (1 lb = 453.6 g). This relationship will allow conversion from pounds to grams. A metric conversion is then needed to convert grams to milligrams ($1\text{ mg} = 1 \times 10^{-3}\text{ g}$). Arrange the appropriate conversion factors so that pounds and grams cancel, and the unit milligrams is obtained in your answer.

Solution: The sequence of conversions is

$$\text{lb} \rightarrow \text{grams} \rightarrow \text{mg}$$

Using the following conversion factors,

$$\frac{453.6\ \text{g}}{1\ \text{lb}} \qquad \frac{1\ \text{mg}}{1 \times 10^{-3}\ \text{g}}$$

we obtain the answer in one step:

$$\textbf{? mg} = 242\ \text{lb} \times \frac{453.6\ \text{g}}{1\ \text{lb}} \times \frac{1\ \text{mg}}{1 \times 10^{-3}\ \text{g}} = \mathbf{1.10 \times 10^{8}\ mg}$$

Check: Does your answer seem reasonable? Should 242 lb be equivalent to 110 million mg? How many mg are in 1 lb? There are 453,600 mg in 1 lb.

(b)
Strategy: The problem may be stated as

$$?\ \text{m}^3 = 68.3\ \text{cm}^3$$

Recall that 1 cm = 1 × 10^{-2} m. We need to set up a conversion factor to convert from cm^3 to m^3.

Solution: We need the following conversion factor so that centimeters cancel and we end up with meters.

$$\frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}}$$

Since this conversion factor deals with length and we want volume, it must therefore be cubed to give

$$\frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}} \times \frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}} \times \frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}} = \left(\frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}}\right)^3$$

We can write

$$\mathbf{?\ m^3} = 68.3\ \text{cm}^3 \times \left(\frac{1 \times 10^{-2}\ \text{m}}{1\ \text{cm}}\right)^3 = \mathbf{6.83 \times 10^{-5}\ m^3}$$

Check: We know that 1 cm^3 = 1 × 10^{-6} m^3. We started with 6.83 × 10^{1} cm^3. Multiplying this quantity by 1 × 10^{-6} gives 6.83 × 10^{-5}.

(c)
Strategy: The problem may be stated as

$$?\ \text{L} = 7.2\ \text{m}^3$$

In Chapter 1 of the text, a conversion is given between liters and cm^3 (1 L = 1000 cm^3). If we can convert m^3 to cm^3, we can then convert to liters. Recall that 1 cm = 1 × 10^{-2} m. We need to set up two conversion factors to convert from m^3 to L. Arrange the appropriate conversion factors so that m^3 and cm^3 cancel, and the unit liters is obtained in your answer.

Solution: The sequence of conversions is

$$m^3 \rightarrow cm^3 \rightarrow L$$

Using the following conversion factors,

$$\left(\frac{1\text{ cm}}{1 \times 10^{-2}\text{ m}}\right)^3 \qquad \frac{1\text{ L}}{1000\text{ cm}^3}$$

the answer is obtained in one step:

$$\textbf{? L} = 7.2\text{ m}^3 \times \left(\frac{1\text{ cm}}{1 \times 10^{-2}\text{ m}}\right)^3 \times \frac{1\text{ L}}{1000\text{ cm}^3} = \mathbf{7.2 \times 10^3\ L}$$

Check: From the above conversion factors you can show that 1 m^3 = 1 × 10^3 L. Therefore, 7 m^3 would equal 7 × 10^3 L, which is close to the answer.

(d)
Strategy: The problem may be stated as

$$?\text{ lb} = 28.3\ \mu\text{g}$$

A relationship between pounds and grams is given on the end sheet of your text (1 lb = 453.6 g). This relationship will allow conversion from grams to pounds. If we can convert from μg to grams, we can then convert from grams to pounds. Recall that 1 μg = 1 × 10^{-6} g. Arrange the appropriate conversion factors so that μg and grams cancel, and the unit pounds is obtained in your answer.

Solution: The sequence of conversions is

$$\mu g \rightarrow g \rightarrow lb$$

Using the following conversion factors,

$$\frac{1 \times 10^{-6}\text{ g}}{1\ \mu\text{g}} \qquad \frac{1\text{ lb}}{453.6\text{ g}}$$

we can write

$$\textbf{? lb} = 28.3\ \mu\text{g} \times \frac{1 \times 10^{-6}\text{ g}}{1\ \mu\text{g}} \times \frac{1\text{ lb}}{453.6\text{ g}} = \mathbf{6.24 \times 10^{-8}\ lb}$$

Check: Does the answer seem reasonable? What number does the prefix μ represent? Should 28.3 μg be a very small mass?

1.39 $\frac{1255\text{ m}}{1\text{ s}} \times \frac{1\text{ mi}}{1609\text{ m}} \times \frac{3600\text{ s}}{1\text{ h}} = \mathbf{2808\ mi/h}$

1.40 **Strategy:** The problem may be stated as

$$?\text{ s} = 365.24\text{ days}$$

You should know conversion factors that will allow you to convert between days and hours, between hours and minutes, and between minutes and seconds. Make sure to arrange the conversion factors so that days, hours, and minutes cancel, leaving units of seconds for the answer.

Solution: The sequence of conversions is

days → hours → minutes → seconds

Using the following conversion factors,

$$\frac{24\ \text{h}}{1\ \text{day}} \qquad \frac{60\ \text{min}}{1\ \text{h}} \qquad \frac{60\ \text{s}}{1\ \text{min}}$$

we can write

$$\textbf{? s} = 365.24\ \text{day} \times \frac{24\ \text{h}}{1\ \text{day}} \times \frac{60\ \text{min}}{1\ \text{h}} \times \frac{60\ \text{s}}{1\ \text{min}} = \mathbf{3.1557 \times 10^{7}\ s}$$

Check: Does your answer seem reasonable? Should there be a very large number of seconds in 1 year?

1.41 $$(93 \times 10^{6}\ \text{mi}) \times \frac{1.609\ \text{km}}{1\ \text{mi}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{s}}{3.00 \times 10^{8}\ \text{m}} \times \frac{1\ \text{min}}{60\ \text{s}} = \mathbf{8.3\ min}$$

1.42 **(a)** $$\textbf{? in/s} = \frac{1\ \text{mi}}{13\ \text{min}} \times \frac{5280\ \text{ft}}{1\ \text{mi}} \times \frac{12\ \text{in}}{1\ \text{ft}} \times \frac{1\ \text{min}}{60\ \text{s}} = \mathbf{81\ in/s}$$

(b) $$\textbf{? m/min} = \frac{1\ \text{mi}}{13\ \text{min}} \times \frac{1609\ \text{m}}{1\ \text{mi}} = \mathbf{1.2 \times 10^{2}\ m/min}$$

(c) $$\textbf{? km/h} = \frac{1\ \text{mi}}{13\ \text{min}} \times \frac{1609\ \text{m}}{1\ \text{mi}} \times \frac{1\ \text{km}}{1000\ \text{m}} \times \frac{60\ \text{min}}{1\ \text{h}} = \mathbf{7.4\ km/h}$$

1.43 $$6.0\ \text{ft} \times \frac{1\ \text{m}}{3.28\ \text{ft}} = \mathbf{1.8\ m}$$

$$168\ \text{lb} \times \frac{453.6\ \text{g}}{1\ \text{lb}} \times \frac{1\ \text{kg}}{1000\ \text{g}} = \mathbf{76.2\ kg}$$

1.44 $$\textbf{? km/h} = \frac{55\ \text{mi}}{1\ \text{h}} \times \frac{1.609\ \text{km}}{1\ \text{mi}} = \mathbf{88\ km/h}$$

1.45 $$\frac{62\ \text{m}}{1\ \text{s}} \times \frac{1\ \text{mi}}{1609\ \text{m}} \times \frac{3600\ \text{s}}{1\ \text{h}} = \mathbf{1.4 \times 10^{2}\ mph}$$

1.46 $$0.62\ \text{ppm Pb} = \frac{0.62\ \text{g Pb}}{1 \times 10^{6}\ \text{g blood}}$$

$$6.0 \times 10^{3}\ \text{g of blood} \times \frac{0.62\ \text{g Pb}}{1 \times 10^{6}\ \text{g blood}} = \mathbf{3.7 \times 10^{-3}\ g\ Pb}$$

1.47 **(a)** $1.42\text{ yr} \times \dfrac{365\text{ day}}{1\text{ yr}} \times \dfrac{24\text{ h}}{1\text{ day}} \times \dfrac{3600\text{ s}}{1\text{ h}} \times \dfrac{3.00 \times 10^8\text{ m}}{1\text{ s}} \times \dfrac{1\text{ mi}}{1609\text{ m}} = \mathbf{8.35 \times 10^{12}\ mi}$

(b) $32.4\text{ yd} \times \dfrac{36\text{ in}}{1\text{ yd}} \times \dfrac{2.54\text{ cm}}{1\text{ in}} = \mathbf{2.96 \times 10^3\ cm}$

(c) $\dfrac{3.0 \times 10^{10}\text{ cm}}{1\text{ s}} \times \dfrac{1\text{ in}}{2.54\text{ cm}} \times \dfrac{1\text{ ft}}{12\text{ in}} = \mathbf{9.8 \times 10^8\ ft/s}$

1.48 **(a)** $?\ \mathbf{m} = 185\text{ nm} \times \dfrac{1 \times 10^{-9}\text{ m}}{1\text{ nm}} = \mathbf{1.85 \times 10^{-7}\ m}$

(b) $?\ \mathbf{s} = (4.5 \times 10^9\text{ yr}) \times \dfrac{365\text{ day}}{1\text{ yr}} \times \dfrac{24\text{ h}}{1\text{ day}} \times \dfrac{3600\text{ s}}{1\text{ h}} = \mathbf{1.4 \times 10^{17}\ s}$

(c) $?\ \mathbf{m^3} = 71.2\text{ cm}^3 \times \left(\dfrac{0.01\text{ m}}{1\text{ cm}}\right)^3 = \mathbf{7.12 \times 10^{-5}\ m^3}$

(d) $?\ \mathbf{L} = 88.6\text{ m}^3 \times \left(\dfrac{1\text{ cm}}{1 \times 10^{-2}\text{ m}}\right)^3 \times \dfrac{1\text{ L}}{1000\text{ cm}^3} = \mathbf{8.86 \times 10^4\ L}$

1.49 **density** $= \dfrac{2.70\text{ g}}{1\text{ cm}^3} \times \dfrac{1\text{ kg}}{1000\text{ g}} \times \left(\dfrac{1\text{ cm}}{0.01\text{ m}}\right)^3 = \mathbf{2.70 \times 10^3\ kg/m^3}$

1.50 **density** $= \dfrac{0.625\text{ g}}{1\text{ L}} \times \dfrac{1\text{ L}}{1000\text{ mL}} \times \dfrac{1\text{ mL}}{1\text{ cm}^3} = \mathbf{6.25 \times 10^{-4}\ g/cm^3}$

1.51

	Substance	Qualitative Statement	Quantitative Statement
(a)	water	colorless liquid	freezes at 0°C
(b)	carbon	black solid (graphite)	density = 2.26 g/cm^3
(c)	iron	rusts easily	density = 7.86 g/cm^3
(d)	hydrogen gas	colorless gas	melts at −255.3°C
(e)	sucrose	tastes sweet	at 0°C, 179 g of sucrose dissolves in 100 g of H_2O
(f)	table salt	tastes salty	melts at 801°C
(g)	mercury	liquid at room temperature	boils at 357°C
(h)	gold	a precious metal	density = 19.3 g/cm^3
(i)	air	a mixture of gases	contains 20% oxygen by volume

1.52 See Section 1.6 of your text for a discussion of these terms.

(a) Chemical property. Iron has changed its composition and identity by chemically combining with oxygen and water.

(b) Chemical property. The water reacts with chemicals in the air (such as sulfur dioxide) to produce acids, thus changing the composition and identity of the water.

(c) Physical property. The color of the hemoglobin can be observed and measured without changing its composition or identity.

(d) Physical property. The evaporation of water does not change its chemical properties. Evaporation is a change in matter from the liquid state to the gaseous state.

(e) Chemical property. The carbon dioxide is chemically converted into other molecules.

1.53 $$(95.0 \times 10^9 \text{ lb of sulfuric acid}) \times \frac{1 \text{ ton}}{2.0 \times 10^3 \text{ lb}} = \mathbf{4.75 \times 10^7 \text{ tons of sulfuric acid}}$$

1.54 Volume of rectangular bar = length × width × height

$$\textbf{density} = \frac{m}{V} = \frac{52.7064 \text{ g}}{(8.53 \text{ cm})(2.4 \text{ cm})(1.0 \text{ cm})} = \mathbf{2.6 \text{ g/cm}^3}$$

1.55 mass = density × volume

(a) $$\textbf{mass} = (19.3 \text{ g/cm}^3) \times [\frac{4}{3}\pi(10.0 \text{ cm})^3] = \mathbf{8.08 \times 10^4 \text{ g}}$$

(b) $$\textbf{mass} = (21.4 \text{ g/cm}^3) \times \left(0.040 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}}\right)^3 = \mathbf{1.4 \times 10^{-6} \text{ g}}$$

(c) $$\textbf{mass} = (0.798 \text{ g/mL})(50.0 \text{ mL}) = \mathbf{39.9 \text{ g}}$$

1.56 You are asked to solve for the inner diameter of the tube. If you can calculate the volume that the mercury occupies, you can calculate the radius of the cylinder, $V_{\text{cylinder}} = \pi r^2 h$ (r is the inner radius of the cylinder, and h is the height of the cylinder). The cylinder diameter is $2r$.

$$\text{volume of Hg filling cylinder} = \frac{\text{mass of Hg}}{\text{density of Hg}}$$

$$\text{volume of Hg filling cylinder} = \frac{105.5 \text{ g}}{13.6 \text{ g/cm}^3} = 7.757 \text{ cm}^3$$

Next, solve for the radius of the cylinder.

$$\text{Volume of cylinder} = \pi r^2 h$$

$$r = \sqrt{\frac{\text{volume}}{\pi \times h}}$$

$$r = \sqrt{\frac{7.757 \text{ cm}^3}{\pi \times 12.7 \text{ cm}}} = 0.4409 \text{ cm}$$

The cylinder diameter equals $2r$.

$$\textbf{Cylinder diameter} = 2r = 2(0.4409 \text{ cm}) = \mathbf{0.882 \text{ cm}}$$

1.57 From the mass of the water and its density, we can calculate the volume that the water occupies. The volume that the water occupies is equal to the volume of the flask.

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

$$\text{Mass of water} = 87.39\text{ g} - 56.12\text{ g} = 31.27\text{ g}$$

$$\textbf{Volume of the flask} = \frac{\text{mass}}{\text{density}} = \frac{31.27\text{ g}}{0.9976\text{ g/cm}^3} = \mathbf{31.35\ cm^3}$$

1.58 $$\frac{343\text{ m}}{1\text{ s}} \times \frac{1\text{ mi}}{1609\text{ m}} \times \frac{3600\text{ s}}{1\text{ h}} = \mathbf{767\ mph}$$

1.59 The volume of silver is equal to the volume of water it displaces.

$$\text{Volume of silver} = 260.5\text{ mL} - 242.0\text{ mL} = 18.5\text{ mL} = 18.5\text{ cm}^3$$

$$\textbf{density} = \frac{194.3\text{ g}}{18.5\text{ cm}^3} = \mathbf{10.5\ g/cm^3}$$

1.60 In order to work this problem, you need to understand the physical principles involved in the experiment in Problem 1.59. The volume of the water displaced must equal the volume of the piece of silver. If the silver did not sink, would you have been able to determine the volume of the piece of silver?

The liquid must be *less dense* than the ice in order for the ice to sink. The temperature of the experiment must be maintained at or below *0°C* to prevent the ice from melting.

1.61 $$\textbf{density} = \frac{\text{mass}}{\text{volume}} = \frac{1.20 \times 10^4\text{ g}}{1.05 \times 10^3\text{ cm}^3} = \mathbf{11.4\ g/cm^3}$$

1.62 $$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$\textbf{Volume occupied by Li} = \frac{1.20 \times 10^3\text{ g}}{0.53\text{ g/cm}^3} = \mathbf{2.3 \times 10^3\ cm^3}$$

1.63 For the Fahrenheit thermometer, we must convert the possible error of 0.1°F to °C.

$$?\ ^\circ\text{C} = 0.1^\circ\text{F} \times \frac{5^\circ\text{C}}{9^\circ\text{F}} = 0.056^\circ\text{C}$$

The percent error is the amount of uncertainty in a measurement divided by the value of the measurement, converted to percent by multiplication by 100.

$$\text{Percent error} = \frac{\text{known error in a measurement}}{\text{value of the measurement}} \times 100\%$$

For the Fahrenheit thermometer, $$\textbf{percent error} = \frac{0.056^\circ\text{C}}{38.9^\circ\text{C}} \times 100\% = \mathbf{0.1\%}$$

For the Celsius thermometer, $$\textbf{percent error} = \frac{0.1^\circ\text{C}}{38.9^\circ\text{C}} \times 100\% = \mathbf{0.3\%}$$

Which thermometer is more accurate?

1.64 To work this problem, we need to convert from cubic feet to L. Some tables will have a conversion factor of 28.3 L = 1 ft^3, but we can also calculate it using the dimensional analysis method described in Section 1.9 of the text.

First, converting from cubic feet to liters:

$$(5.0 \times 10^7 \text{ ft}^3) \times \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \times 10^{-3} \text{ L}}{1 \text{ mL}} = 1.42 \times 10^9 \text{ L}$$

The mass of vanillin (in g) is:

$$\frac{2.0 \times 10^{-11} \text{ g vanillin}}{1 \text{ L}} \times (1.42 \times 10^9 \text{ L}) = 2.84 \times 10^{-2} \text{ g vanillin}$$

The cost is:

$$(2.84 \times 10^{-2} \text{ g vanillin}) \times \frac{\$112}{50 \text{ g vanillin}} = \mathbf{\$0.064} = \mathbf{6.4¢}$$

1.65 $$? \text{°F} = \left(\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F}$$

Let temperature $= t$

$$t = \frac{9}{5}t + 32\text{°F}$$

$$t - \frac{9}{5}t = 32\text{°F}$$

$$-\frac{4}{5}t = 32\text{°F}$$

$$\boldsymbol{t = -40\text{°F} = -40\text{°C}}$$

1.66 There are 78.3 + 117.3 = 195.6 Celsius degrees between 0°S and 100°S. We can write this as a unit factor.

$$\left(\frac{195.6^\circ\text{C}}{100^\circ\text{S}}\right)$$

Set up the equation like a Celsius to Fahrenheit conversion. We need to subtract 117.3°C, because the zero point on the new scale is 117.3°C lower than the zero point on the Celsius scale.

$$? \text{°C} = \left(\frac{195.6\text{°C}}{100\text{°S}}\right)(? \text{°S}) - 117.3\text{°C}$$

Solving for ? °S gives: $$? \text{°S} = (? \text{°C} + 117.3\text{°C})\left(\frac{100\text{°S}}{195.6\text{°C}}\right)$$

For 25°C we have: $$\mathbf{? \text{°S}} = (25\text{°C} + 117.3\text{°C})\left(\frac{100\text{°S}}{195.6\text{°C}}\right) = \mathbf{73\text{°S}}$$

1.67 The key to solving this problem is to realize that all the oxygen needed must come from the 4% difference (20% − 16%) between inhaled and exhaled air.

The 240 mL of pure oxygen/min requirement comes from the 4% of inhaled air that is oxygen.

$$240 \text{ mL of pure oxygen/min} = (0.04)(\text{volume of inhaled air/min})$$

$$\text{Volume of inhaled air/min} = \frac{240 \text{ mL of oxygen/min}}{0.04} = 6000 \text{ mL of inhaled air/min}$$

Since there are 12 breaths per min,

$$\textbf{volume of air/breath} = \frac{6000 \text{ mL of inhaled air}}{1 \text{ min}} \times \frac{1 \text{ min}}{12 \text{ breaths}} = \mathbf{5 \times 10^2 \text{ mL/breath}}$$

1.68 **(a)** $$\frac{6000 \text{ mL of inhaled air}}{1 \text{ min}} \times \frac{0.001 \text{ L}}{1 \text{ mL}} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{24 \text{ h}}{1 \text{ day}} = \mathbf{8.6 \times 10^3 \text{ L of air/day}}$$

(b) $$\frac{8.6 \times 10^3 \text{ L of air}}{1 \text{ day}} \times \frac{2.1 \times 10^{-6} \text{ L CO}}{1 \text{ L of air}} = \mathbf{0.018 \text{ L CO/day}}$$

1.69 The mass of the seawater is:

$$(1.5 \times 10^{21} \text{ L}) \times \frac{1 \text{ mL}}{0.001 \text{ L}} \times \frac{1.03 \text{ g}}{1 \text{ mL}} = 1.55 \times 10^{24} \text{ g} = 1.55 \times 10^{21} \text{ kg seawater}$$

Seawater is 3.1% NaCl by mass. The total mass of NaCl in kilograms is:

$$\textbf{mass NaCl (kg)} = (1.55 \times 10^{21} \text{ kg seawater}) \times \frac{3.1\% \text{ NaCl}}{100\% \text{ seawater}} = \mathbf{4.8 \times 10^{19} \text{ kg NaCl}}$$

$$\textbf{mass NaCl (tons)} = (4.8 \times 10^{19} \text{ kg}) \times \frac{2.205 \text{ lb}}{1 \text{ kg}} \times \frac{1 \text{ ton}}{2000 \text{ lb}} = \mathbf{5.3 \times 10^{16} \text{ tons NaCl}}$$

1.70 First, calculate the volume of 1 kg of seawater from the density and the mass. We chose 1 kg of seawater, because the problem gives the amount of Mg in every kg of seawater. The density of seawater is given in Problem 1.69.

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

$$\text{volume of 1 kg of seawater} = \frac{1000 \text{ g}}{1.03 \text{ g/mL}} = 970.9 \text{ mL} = 0.9709 \text{ L}$$

In other words, there are 1.3 g of Mg in every 0.9709 L of seawater.

Next, let's convert tons of Mg to grams of Mg.

$$(8.0 \times 10^4 \text{ tons Mg}) \times \frac{2000 \text{ lb}}{1 \text{ ton}} \times \frac{453.6 \text{ g}}{1 \text{ lb}} = 7.26 \times 10^{10} \text{ g Mg}$$

Volume of seawater needed to extract 8.0 × 10^4 ton Mg =

$$(7.26 \times 10^{10} \text{ g Mg}) \times \frac{0.9709 \text{ L seawater}}{1.3 \text{ g Mg}} = \mathbf{5.4 \times 10^{10} \text{ L of seawater}}$$

1.71 Assume that the crucible is platinum. Let's calculate the volume of the crucible and then compare that to the volume of water that the crucible displaces.

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

$$\text{Volume of crucible} = \frac{860.2\text{ g}}{21.45\text{ g/cm}^3} = \mathbf{40.10\text{ cm}^3}$$

$$\text{Volume of water displaced} = \frac{(860.2 - 820.2)\text{g}}{0.9986\text{ g/cm}^3} = \mathbf{40.1\text{ cm}^3}$$

The volumes are the same (within experimental error), so the crucible is made of platinum.

1.72 Volume = surface area × depth

Recall that 1 L = 1 dm^3. Let's convert the surface area to units of dm^2 and the depth to units of dm.

$$\text{surface area} = (1.8\times 10^8\text{ km}^2)\times\left(\frac{1000\text{ m}}{1\text{ km}}\right)^2\times\left(\frac{1\text{ dm}}{0.1\text{ m}}\right)^2 = 1.8\times 10^{16}\text{ dm}^2$$

$$\text{depth} = (3.9\times 10^3\text{ m})\times\frac{1\text{ dm}}{0.1\text{ m}} = 3.9\times 10^4\text{ dm}$$

$$\mathbf{Volume} = \text{surface area}\times\text{depth} = (1.8\times 10^{16}\text{ dm}^2)(3.9\times 10^4\text{ dm}) = 7.0\times 10^{20}\text{ dm}^3 = \mathbf{7.0\times 10^{20}\text{ L}}$$

1.73 **(a)** $$2.41\text{ troy oz Au}\times\frac{31.103\text{ g Au}}{1\text{ troy oz Au}} = \mathbf{75.0\text{ g Au}}$$

(b) 1 troy oz = **31.103 g**

$$?\text{ g in 1 oz} = 1\text{ oz}\times\frac{1\text{ lb}}{16\text{ oz}}\times\frac{453.6\text{ g}}{1\text{ lb}} = \mathbf{28.35\text{ g}}$$

A troy ounce is heavier than an ounce.

1.74 $$\text{Volume of sphere} = \frac{4}{3}\pi r^3$$

$$\text{Volume} = \frac{4}{3}\pi\left(\frac{15\text{ cm}}{2}\right)^3 = 1.77\times 10^3\text{ cm}^3$$

$$\text{mass} = \text{volume}\times\text{density} = (1.77\times 10^3\text{ cm}^3)\times\frac{22.57\text{ g Os}}{1\text{ cm}^3}\times\frac{1\text{ kg}}{1000\text{ g}} = \mathbf{4.0\times 10^1\text{ kg Os}}$$

$$4.0\times 10^1\text{ kg Os}\times\frac{2.205\text{ lb}}{1\text{ kg}} = \mathbf{88\text{ lb Os}}$$

1.75 **(a)** $$\frac{|0.798\text{ g/mL} - 0.802\text{ g/mL}|}{0.798\text{ g/mL}}\times 100\% = \mathbf{0.5\%}$$

(b) $\dfrac{|0.864\text{ g} - 0.837\text{ g}|}{0.864\text{ g}} \times 100\% = \mathbf{3.1\%}$

1.76 $62\text{ kg} = 6.2 \times 10^4\text{ g}$

O: $(6.2 \times 10^4\text{ g})(0.65) = \mathbf{4.0 \times 10^4\ g\ O}$

C: $(6.2 \times 10^4\text{ g})(0.18) = \mathbf{1.1 \times 10^4\ g\ C}$

H: $(6.2 \times 10^4\text{ g})(0.10) = \mathbf{6.2 \times 10^3\ g\ H}$

N: $(6.2 \times 10^4\text{ g})(0.03) = \mathbf{2 \times 10^3\ g\ N}$

Ca: $(6.2 \times 10^4\text{ g})(0.016) = \mathbf{9.9 \times 10^2\ g\ Ca}$

P: $(6.2 \times 10^4\text{ g})(0.012) = \mathbf{7.4 \times 10^2\ g\ P}$

1.77 3 minutes 44.39 seconds = 224.39 seconds

Time to run 1500 meters is:

$$1500\text{ m} \times \frac{1\text{ mi}}{1609\text{ m}} \times \frac{224.39\text{ s}}{1\text{ mi}} = \mathbf{209.19\ s = 3\ min\ 29.19\ s}$$

1.78 $\mathbf{?\ °C} = (7.3 \times 10^2 - 273)\text{ K} = \mathbf{4.6 \times 10^2\ °C}$

$$\mathbf{?\ °F} = \left((4.6 \times 10^2\ °\text{C}) \times \frac{9°\text{F}}{5°\text{C}}\right) + 32°\text{F} = \mathbf{8.6 \times 10^2\ °F}$$

1.79 $\mathbf{?\ g\ Cu} = (5.11 \times 10^3\text{ kg ore}) \times \dfrac{34.63\%\text{ Cu}}{100\%\text{ ore}} \times \dfrac{1000\text{ g}}{1\text{ kg}} = \mathbf{1.77 \times 10^6\ g\ Cu}$

1.80 $(8.0 \times 10^4\text{ tons Au}) \times \dfrac{2000\text{ lb Au}}{1\text{ ton Au}} \times \dfrac{16\text{ oz Au}}{1\text{ lb Au}} \times \dfrac{\$350}{1\text{ oz Au}} = \mathbf{\$9.0 \times 10^{11}}$ or **900 billion dollars**

1.81 $\mathbf{?\ g\ Au} = \dfrac{4.0 \times 10^{-12}\text{ g Au}}{1\text{ mL seawater}} \times \dfrac{1\text{ mL}}{0.001\text{ L}} \times (1.5 \times 10^{21}\text{ L seawater}) = \mathbf{6.0 \times 10^{12}\ g\ Au}$

value of gold $= (6.0 \times 10^{12}\text{ g Au}) \times \dfrac{1\text{ lb}}{453.6\text{ g}} \times \dfrac{16\text{ oz}}{1\text{ lb}} \times \dfrac{\$350}{1\text{ oz}} = \mathbf{\$7.4 \times 10^{13}}$

No one has become rich mining gold from the ocean, because the cost of recovering the gold would outweigh the price of the gold.

1.82 $\mathbf{?\ Fe\ atoms} = 4.9\text{ g Fe} \times \dfrac{1.1 \times 10^{22}\text{ Fe atoms}}{1.0\text{ g Fe}} = \mathbf{5.4 \times 10^{22}\ Fe\ atoms}$

1.83 mass of Earth's crust $= (5.9 \times 10^{21}\text{ tons}) \times \dfrac{0.50\%\text{ crust}}{100\%\text{ Earth}} = 2.95 \times 10^{19}\text{ tons}$

mass of silicon in crust $= (2.95 \times 10^{19}\text{ tons crust}) \times \dfrac{27.2\%\text{ Si}}{100\%\text{ crust}} \times \dfrac{2000\text{ lb}}{1\text{ ton}} \times \dfrac{1\text{ kg}}{2.205\text{ lb}} = \mathbf{7.3 \times 10^{21}\ kg\ Si}$

1.84 10 cm = 0.1 m. We need to find the number of times the 0.1 m wire must be cut in half until the piece left is 1.3×10^{-10} m long. Let n be the number of times we can cut the Cu wire in half. We can write:

$$\left(\frac{1}{2}\right)^n \times 0.1\ \text{m} = 1.3 \times 10^{-10}\ \text{m}$$

$$\left(\frac{1}{2}\right)^n = 1.3 \times 10^{-9}\ \text{m}$$

Taking the log of both sides of the equation:

$$n \log\left(\frac{1}{2}\right) = \log(1.3 \times 10^{-9})$$

$$\boldsymbol{n = 30\ \textbf{times}}$$

1.85 $$(40 \times 10^6\ \text{cars}) \times \frac{5000\ \text{mi}}{1\ \text{car}} \times \frac{1\ \text{gal gas}}{20\ \text{mi}} \times \frac{9.5\ \text{kg CO}_2}{1\ \text{gal gas}} = \mathbf{9.5 \times 10^{10}\ kg\ CO_2}$$

1.86 Volume = area × thickness.

From the density, we can calculate the volume of the Al foil.

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{3.636\ \text{g}}{2.699\ \text{g/cm}^3} = 1.3472\ \text{cm}^3$$

Convert the unit of area from ft^2 to cm^2.

$$1.000\ \text{ft}^2 \times \left(\frac{12\ \text{in}}{1\ \text{ft}}\right)^2 \times \left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)^2 = 929.03\ \text{cm}^2$$

$$\textbf{thickness} = \frac{\text{volume}}{\text{area}} = \frac{1.3472\ \text{cm}^3}{929.03\ \text{cm}^2} = 1.450 \times 10^{-3}\ \text{cm} = \mathbf{1.450 \times 10^{-2}\ mm}$$

1.87 **(a)** homogeneous
(b) heterogeneous. The air will contain particulate matter, clouds, etc. This mixture is not homogeneous.

1.88 First, let's calculate the mass (in g) of water in the pool. We perform this conversion because we know there is 1 g of chlorine needed per million grams of water.

$$(2.0 \times 10^4\ \text{gallons H}_2\text{O}) \times \frac{3.79\ \text{L}}{1\ \text{gallon}} \times \frac{1\ \text{mL}}{0.001\ \text{L}} \times \frac{1\ \text{g}}{1\ \text{mL}} = 7.58 \times 10^7\ \text{g H}_2\text{O}$$

Next, let's calculate the mass of chlorine that needs to be added to the pool.

$$(7.58 \times 10^7\ \text{g H}_2\text{O}) \times \frac{1\ \text{g chlorine}}{1 \times 10^6\ \text{g H}_2\text{O}} = 75.8\ \text{g chlorine}$$

The chlorine solution is only 6 percent chlorine by mass. We can now calculate the volume of chlorine solution that must be added to the pool.

$$75.8\text{ g chlorine} \times \frac{100\%\text{ soln}}{6\%\text{ chlorine}} \times \frac{1\text{ mL soln}}{1\text{ g soln}} = \mathbf{1.3 \times 10^3\ mL\ of\ chlorine\ solution}$$

1.89 $(2.0 \times 10^{22}\text{ J}) \times \dfrac{1\text{ yr}}{1.8 \times 10^{20}\text{ J}} = \mathbf{1.1 \times 10^2\ yr}$

1.90 We assume that the thickness of the oil layer is equivalent to the length of one oil molecule. We can calculate the thickness of the oil layer from the volume and surface area.

$$40\text{ m}^2 \times \left(\frac{1\text{ cm}}{0.01\text{ m}}\right)^2 = 4.0 \times 10^5\text{ cm}^2$$

$$0.10\text{ mL} = 0.10\text{ cm}^3$$

$$\text{Volume} = \text{surface area} \times \text{thickness}$$

$$\text{thickness} = \frac{\text{volume}}{\text{surface area}} = \frac{0.10\text{ cm}^3}{4.0 \times 10^5\text{ cm}^2} = 2.5 \times 10^{-7}\text{ cm}$$

Converting to nm:

$$(2.5 \times 10^{-7}\text{ cm}) \times \frac{0.01\text{ m}}{1\text{ cm}} \times \frac{1\text{ nm}}{1 \times 10^{-9}\text{ m}} = \mathbf{2.5\ nm}$$

1.91 The mass of water used by 50,000 people in 1 year is:

$$50{,}000\text{ people} \times \frac{150\text{ gal water}}{1\text{ person each day}} \times \frac{3.79\text{ L}}{1\text{ gal.}} \times \frac{1000\text{ mL}}{1\text{ L}} \times \frac{1.0\text{ g H}_2\text{O}}{1\text{ mL H}_2\text{O}} \times \frac{365\text{ days}}{1\text{ yr}} = 1.04 \times 10^{13}\text{ g H}_2\text{O/yr}$$

A concentration of 1 ppm of fluorine is needed. In other words, 1 g of fluorine is needed per million grams of water. NaF is 45.0% fluorine by mass. The amount of NaF needed per year in kg is:

$$(1.04 \times 10^{13}\text{ g H}_2\text{O}) \times \frac{1\text{ g F}}{10^6\text{ g H}_2\text{O}} \times \frac{100\%\text{ NaF}}{45\%\text{ F}} \times \frac{1\text{ kg}}{1000\text{ g}} = \mathbf{2.3 \times 10^4\ kg\ NaF}$$

An average person uses 150 gallons of water per day. This is equal to 569 L of water. If only 6 L of water is used for drinking and cooking, 563 L of water is used for purposes in which NaF is not necessary. Therefore the amount of NaF wasted is:

$$\frac{563\text{ L}}{569\text{ L}} \times 100\% = \mathbf{99\%}$$

1.92 **(a)** $\dfrac{\$1.30}{15.0\text{ ft}^3} \times \left(\dfrac{1\text{ ft}}{12\text{ in}}\right)^3 \times \left(\dfrac{1\text{ in}}{2.54\text{ cm}}\right)^3 \times \dfrac{1\text{ cm}^3}{1\text{ mL}} \times \dfrac{1\text{ mL}}{0.001\text{ L}} = \mathbf{\$3.06 \times 10^{-3}/L}$

(b) $2.1\text{ L water} \times \dfrac{0.304\text{ ft}^3\text{ gas}}{1\text{ L water}} \times \dfrac{\$1.30}{15.0\text{ ft}^3} = \mathbf{\$0.055} = \mathbf{5.5¢}$

1.93 To calculate the density of the pheromone, you need the mass of the pheromone, and the volume that it occupies. The mass is given in the problem. First, let's calculate the volume of the cylinder. Converting the radius and height to cm gives:

$$0.50\text{ mi} \times \frac{1609\text{ m}}{1\text{ mi}} \times \frac{1\text{ cm}}{0.01\text{ m}} = 8.05 \times 10^{4}\text{ cm}$$

$$40\text{ ft} \times \frac{12\text{ in}}{1\text{ ft}} \times \frac{2.54\text{ cm}}{1\text{ in}} = 1.22 \times 10^{3}\text{ cm}$$

$$\text{volume of a cylinder} = \text{area} \times \text{height} = \pi r^2 \times h$$

$$\text{volume} = \pi(8.05 \times 10^{4}\text{ cm})^2 \times (1.22 \times 10^{3}\text{ cm}) = 2.48 \times 10^{13}\text{ cm}^3$$

Density of gases is usually expressed in g/L. Let's convert the volume to liters.

$$(2.48 \times 10^{13}\text{ cm}^3) \times \frac{1\text{ mL}}{1\text{ cm}^3} \times \frac{1\text{ L}}{1000\text{ mL}} = 2.48 \times 10^{10}\text{ L}$$

$$\textbf{density} = \frac{\text{mass}}{\text{volume}} = \frac{1.0 \times 10^{-8}\text{ g}}{2.48 \times 10^{10}\text{ L}} = \mathbf{4.0 \times 10^{-19}\ g/L}$$

1.94 This problem is similar in concept to a limiting reagent problem. We need sets of coins with 3 quarters, 1 nickel, and 2 dimes. First, we need to find the total number of each type of coin.

$$\text{Number of quarters} = (33.871 \times 10^{3}\text{ g}) \times \frac{1\text{ quarter}}{5.645\text{ g}} = 6000\text{ quarters}$$

$$\text{Number of nickels} = (10.432 \times 10^{3}\text{ g}) \times \frac{1\text{ nickel}}{4.967\text{ g}} = 2100\text{ nickels}$$

$$\text{Number of dimes} = (7.990 \times 10^{3}\text{ g}) \times \frac{1\text{ dime}}{2.316\text{ g}} = 3450\text{ dimes}$$

Next, we need to find which coin limits the number of sets that can be assembled. For each set of coins, we need 2 dimes for every 1 nickel.

$$2100\text{ nickels} \times \frac{2\text{ dimes}}{1\text{ nickel}} = 4200\text{ dimes}$$

We do not have enough dimes.

For each set of coins, we need 2 dimes for every 3 quarters.

$$6000\text{ quarters} \times \frac{2\text{ dimes}}{3\text{ quarters}} = 4000\text{ dimes}$$

Again, we do not have enough dimes, and therefore the number of dimes is our "limiting reagent".

If we need 2 dimes per set, the number of sets that can be assembled is:

$$3450\text{ dimes} \times \frac{1\text{ set}}{2\text{ dimes}} = \mathbf{1725\ sets}$$

The mass of each set is:

$$\left(3\text{ quarters} \times \frac{5.645\text{ g}}{1\text{ quarter}}\right) + \left(1\text{ nickel} \times \frac{4.967\text{ g}}{1\text{ nickel}}\right) + \left(2\text{ dimes} \times \frac{2.316\text{ g}}{1\text{ dime}}\right) = 26.534\text{ g/set}$$

Finally, the total mass of 1725 sets of coins is:

$$1725\text{ sets} \times \frac{26.534\text{ g}}{1\text{ set}} = \mathbf{4.577 \times 10^4\text{ g}}$$

1.95 We wish to calculate the density and radius of the ball bearing. For both calculations, we need the volume of the ball bearing. The data from the first experiment can be used to calculate the density of the mineral oil. In the second experiment, the density of the mineral oil can then be used to determine what part of the 40.00 mL volume is due to the mineral oil and what part is due to the ball bearing. Once the volume of the ball bearing is determined, we can calculate its density and radius.

From experiment one:

$$\text{Mass of oil} = 159.446\text{ g} - 124.966\text{ g} = 34.480\text{ g}$$

$$\text{Density of oil} = \frac{34.480\text{ g}}{40.00\text{ mL}} = 0.8620\text{ g/mL}$$

From the second experiment:

$$\text{Mass of oil} = 50.952\text{ g} - 18.713\text{ g} = 32.239\text{ g}$$

$$\text{Volume of oil} = 32.239\text{ g} \times \frac{1\text{ mL}}{0.8620\text{ g}} = 37.40\text{ mL}$$

The volume of the ball bearing is obtained by difference.

$$\text{Volume of ball bearing} = 40.00\text{ mL} - 37.40\text{ mL} = 2.60\text{ mL} = 2.60\text{ cm}^3$$

Now that we have the volume of the ball bearing, we can calculate its density and radius.

$$\text{Density of ball bearing} = \frac{18.713\text{ g}}{2.60\text{ cm}^3} = \mathbf{7.20\text{ g/cm}^3}$$

Using the formula for the volume of a sphere, we can solve for the radius of the ball bearing.

$$V = \frac{4}{3}\pi r^3$$

$$2.60\text{ cm}^3 = \frac{4}{3}\pi r^3$$

$$r^3 = 0.621\text{ cm}^3$$

$$\boldsymbol{r} = \mathbf{0.853\text{ cm}}$$

1.96 We want to calculate the mass of the cylinder, which can be calculated from its volume and density. The volume of a cylinder is $\pi r^2 l$. The density of the alloy can be calculated using the mass percentages of each element and the given densities of each element.

The volume of the cylinder is:

$$V = \pi r^2 l$$

$$V = \pi(6.44\text{ cm})^2(44.37\text{ cm})$$

$$V = 5781\text{ cm}^3$$

The density of the cylinder is:

$$\text{density} = (0.7942)(8.94\text{ g/cm}^3) + (0.2058)(7.31\text{ g/cm}^3) = 8.605\text{ g/cm}^3$$

Now, we can calculate the mass of the cylinder.

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

$$\textbf{mass} = (8.605\text{ g/cm}^3)(5781\text{ cm}^3) = \mathbf{4.97 \times 10^4\ g}$$

The assumption made in the calculation is that the alloy must be homogeneous in composition.

1.97 It would be more difficult to prove that the unknown substance is an element. Most compounds would decompose on heating, making them easy to identify. For example, see Figure 4.13(a) of the text. On heating, the compound HgO decomposes to elemental mercury (Hg) and oxygen gas (O_2).

1.98 The density of the mixed solution should be based on the percentage of each liquid and its density. Because the solid object is suspended in the mixed solution, it should have the same density as this solution. The density of the mixed solution is:

$$(0.4137)(2.0514\text{ g/mL}) + (0.5863)(2.6678\text{ g/mL}) = 2.413\text{ g/mL}$$

As discussed, the density of the object should have the same density as the mixed solution (**2.413 g/mL**).

Yes, this procedure can be used in general to determine the densities of solids. This procedure is called the flotation method. It is based on the assumptions that the liquids are totally miscible and that the volumes of the liquids are additive.

1.99 Gently heat the liquid to see if any solid remains after the liquid evaporates. Also, collect the vapor and then compare the densities of the condensed liquid with the original liquid. The composition of a mixed liquid would change with evaporation along with its density.

1.100 When the carbon dioxide gas is released, the mass of the solution will decrease. If we know the starting mass of the solution and the mass of solution after the reaction is complete (given in the problem), we can calculate the mass of carbon dioxide produced. Then, using the density of carbon dioxide, we can calculate the volume of carbon dioxide released.

$$\text{Mass of hydrochloric acid} = 40.00\text{ mL} \times \frac{1.140\text{ g}}{1\text{ mL}} = 45.60\text{ g}$$

$$\text{Mass of solution before reaction} = 45.60\text{ g} + 1.328\text{ g} = 46.928\text{ g}$$

We can now calculate the mass of carbon dioxide by difference.

$$\text{Mass of } CO_2 \text{ released} = 46.928 \text{ g} - 46.699 \text{ g} = 0.229 \text{ g}$$

Finally, we use the density of carbon dioxide to convert to liters of CO_2 released.

$$\text{Volume of } CO_2 \text{ released} = 0.229 \text{ g} \times \frac{1 \text{ L}}{1.81 \text{ g}} = \mathbf{0.127\ L}$$

1.101 As water freezes, it expands. First, calculate the mass of the water at 20°C. Then, determine the volume that this mass of water would occupy at −5°C.

$$\text{Mass of water} = 242 \text{ mL} \times \frac{0.998 \text{ g}}{1 \text{ mL}} = 241.5 \text{ g}$$

$$\text{Volume of ice at } -5°\text{C} = 241.5 \text{ g} \times \frac{1 \text{ mL}}{0.916 \text{ g}} = 264 \text{ mL}$$

The volume occupied by the ice is larger than the volume of the glass bottle. **The glass bottle would crack!**