CHAPTER 1
CHEMISTRY: THE STUDY OF CHANGE

Problem Categories
Biological: 1.24, 1.48, 1.69, 1.70, 1.78, 1.84, 1.94, 1.95, 1.103, 1.112.
Conceptual: 1.3, 1.4, 1.11, 1.12, 1.15, 1.16, 1.54, 1.62, 1.89, 1.92, 1.99, 1.101, 1,115.
Environmental: 1.70, 1.87, 1.89, 1.96, 1.107, 1.110.
Industrial: 1.51, 1.55, 1.81.

Difficulty Level
Easy: 1.3, 1.11, 1.13, 1.14, 1.15, 1.16, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 1.29, 1.30, 1.31, 1.32, 1.33, 1.34, 1.54, 1.55, 1.64, 1.77, 1.80, 1.84, 1.89.
Medium: 1.4, 1.12, 1.35, 1.36, 1.37, 1.38, 1.39, 1.40, 1.41, 1.42, 1.43, 1.44, 1.45, 1.46, 1.47, 1.48, 1.49, 1.50, 1.51, 1.52, 1.53, 1.56, 1.57, 1.58, 1.59, 1.60, 1.61, 1.62, 1.63, 1.70, 1.71, 1.72, 1.73, 1.74, 1.75, 1.76, 1.78, 1.79, 1.81, 1.82, 1.83, 1.85, 1.91, 1.94, 1.95, 1.96.
Difficult: 1.65, 1.66, 1.67, 1.68, 1.69, 1.86, 1.87, 1.88, 1.90, 1.92, 1.93, 1.97, 1.98, 1.99, 1.100, 1.101, 1.102, 1.103, 1.104.

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)** Cs **(b)** Ge **(c)** Ga **(d)** Sr
(e) U **(f)** Se **(g)** Ne **(h)** Cd

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)** heterogeneous mixture
(g) element

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

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:

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

$$\textbf{mass of methanol} = \frac{0.7918\text{ g}}{1\ \cancel{\text{mL}}} \times 89.9\ \cancel{\text{mL}} = \mathbf{71.2\ g}$$

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

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

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

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

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

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

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

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.

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

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

(b) Conversion from Celsius to Fahrenheit.

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

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

(c) Conversion from Celsius to Fahrenheit.

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

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

(d) Conversion from Fahrenheit to Celsius.

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

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

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

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

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

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

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

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

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

(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 **(d)** 1×10^6 g/cm^3

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:

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

(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

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

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.

(d) Subtraction, addition, and division

Strategy: For subtraction and addition, the number of significant figures to the right of the decimal point in that part of the calculation is determined by the lowest number of digits to the right of the decimal point in any of the original numbers. For the division part of the calculation, the number of significant figures in the answer is determined by the number having the smallest number of significant figures. First, perform the subtraction and addition parts to the correct number of significant figures, and then perform the division.

Solution:

$$\frac{(7.8\text{ m} - 0.34\text{ m})}{(1.15\text{ s} + 0.82\text{ s})} = \frac{7.5\text{ m}}{1.97\text{ s}} = \mathbf{3.8\ m/s}$$

1.37 Calculating the mean for each set of date, we find:

Student A: 87.6 mL
Student B: 87.1 mL
Student C: 87.8 mL

From these calculations, we can conclude that the volume measurements made by Student B were the most accurate of the three students. The precision in the measurements made by both students B and C are fairly high, while the measurements made by student A are less precise. In summary:

Student A: neither accurate nor precise
Student B: both accurate and precise
Student C: precise, but not accurate

1.38 Calculating the mean for each set of date, we find:

Tailor X: 31.5 in
Tailor Y: 32.6 in
Tailor Z: 32.1 in

From these calculations, we can conclude that the seam measurements made by Tailor Z were the most accurate of the three tailors. The precision in the measurements made by both tailors X and Z are fairly high, while the measurements made by tailor Y are less precise. In summary:

Tailor X: most precise
Tailor Y: least accurate and least precise
Tailor Z: most accurate

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

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

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

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

1.40 **(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 mg = 1×10^{-3} 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:

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

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

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

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

$$\text{m}^3 \rightarrow \text{cm}^3 \rightarrow \text{L}$$

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:

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

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 $1\ \mu\text{g} = 1 \times 10^{-6}$ 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

$$\mu\text{g} \rightarrow \text{g} \rightarrow \text{lb}$$

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

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

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

1.41 $$\frac{1255\ \cancel{\text{m}}}{1\ \cancel{\text{s}}} \times \frac{1\text{ mi}}{1609\ \cancel{\text{m}}} \times \frac{3600\ \cancel{\text{s}}}{1\text{ h}} = \mathbf{2808\ mi/h}$$

1.42 **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

$$\text{days} \rightarrow \text{hours} \rightarrow \text{minutes} \rightarrow \text{seconds}$$

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

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

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

1.43 $$(93 \times 10^{6}\ \cancel{\text{mi}}) \times \frac{1.609\ \cancel{\text{km}}}{1\ \cancel{\text{mi}}} \times \frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{s}}}{3.00 \times 10^{8}\ \cancel{\text{m}}} \times \frac{1\text{ min}}{60\ \cancel{\text{s}}} = \mathbf{8.3\ min}$$

1.44 (a) $? \textbf{ in/s} = \dfrac{1\ \cancel{\text{mi}}}{8.92\ \cancel{\text{min}}} \times \dfrac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}} \times \dfrac{12\ \text{in}}{1\ \cancel{\text{ft}}} \times \dfrac{1\ \cancel{\text{min}}}{60\ \text{s}} = \mathbf{118\ in/s}$

(b) $? \textbf{ m/min} = \dfrac{1\ \cancel{\text{mi}}}{8.92\ \text{min}} \times \dfrac{1609\ \text{m}}{1\ \cancel{\text{mi}}} = \mathbf{1.80 \times 10^2\ m/min}$

(c) $? \textbf{ km/h} = \dfrac{1\ \cancel{\text{mi}}}{8.92\ \cancel{\text{min}}} \times \dfrac{1609\ \cancel{\text{m}}}{1\ \cancel{\text{mi}}} \times \dfrac{1\ \text{km}}{1000\ \cancel{\text{m}}} \times \dfrac{60\ \cancel{\text{min}}}{1\ \text{h}} = \mathbf{10.8\ km/h}$

1.45 $6.0\ \cancel{\text{ft}} \times \dfrac{1\ \text{m}}{3.28\ \cancel{\text{ft}}} = \mathbf{1.8\ m}$

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

1.46 $? \textbf{ mph} = \dfrac{286\ \cancel{\text{km}}}{1\ \text{h}} \times \dfrac{1\ \text{mi}}{1.609\ \cancel{\text{km}}} = \mathbf{178\ mph}$

1.47 $\dfrac{62\ \cancel{\text{m}}}{1\ \cancel{\text{s}}} \times \dfrac{1\ \text{mi}}{1609\ \cancel{\text{m}}} \times \dfrac{3600\ \cancel{\text{s}}}{1\ \text{h}} = \mathbf{1.4 \times 10^2\ mph}$

1.48 $0.62\ \text{ppm Pb} = \dfrac{0.62\ \text{g Pb}}{1 \times 10^6\ \text{g blood}}$

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

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

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

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

1.50 (a) $? \textbf{ lbs} = 70\ \cancel{\text{kg}} \times \dfrac{1\ \text{lb}}{0.4536\ \cancel{\text{kg}}} = \mathbf{1.5 \times 10^2\ lbs}$

(b) $? \textbf{ s} = 14 \times 10^9\ \cancel{\text{yr}} \times \dfrac{365\ \cancel{\text{d}}}{1\ \cancel{\text{yr}}} \times \dfrac{24\ \cancel{\text{h}}}{1\ \cancel{\text{d}}} \times \dfrac{3600\ \text{s}}{1\ \cancel{\text{h}}} = \mathbf{4.4 \times 10^{17}\ s}$

(c) $? \textbf{ m} = 90\ \cancel{\text{in}} \times \dfrac{2.54\ \cancel{\text{cm}}}{1\ \cancel{\text{in}}} \times \dfrac{1 \times 10^{-2}\ \text{m}}{1\ \cancel{\text{cm}}} = \mathbf{2.3\ m}$

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

1.51 $\textbf{density} = \dfrac{2.70\ \cancel{g}}{1\ \cancel{cm^3}} \times \dfrac{1\ kg}{1000\ \cancel{g}} \times \left(\dfrac{1\ \cancel{cm}}{0.01\ m}\right)^3 = \mathbf{2.70 \times 10^3\ kg/m^3}$

1.52 $\textbf{density} = \dfrac{0.625\ g}{1\ \cancel{L}} \times \dfrac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \dfrac{1\ \cancel{mL}}{1\ cm^3} = \mathbf{6.25 \times 10^{-4}\ g/cm^3}$

1.53

<u>**Substance**</u>	<u>**Qualitative Statement**</u>	<u>**Quantitative Statement**</u>
(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

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

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

(b) <u>Chemical property</u>. 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) <u>Physical property</u>. The color of the hemoglobin can be observed and measured without changing its composition or identity.

(d) <u>Physical property</u>. 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) <u>Chemical property</u>. The carbon dioxide is chemically converted into other molecules.

1.55 $(95.0 \times 10^9\ \cancel{lb}\text{ of sulfuric acid}) \times \dfrac{1\ \text{ton}}{2.0 \times 10^3\ \cancel{lb}} = \mathbf{4.75 \times 10^7\ tons\ of\ sulfuric\ acid}$

1.56 Volume of rectangular bar = length × width × height

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

1.57 mass = density × volume

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

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

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

1.58 You are asked to solve for the inner diameter of the bottle. If we can calculate the volume that the cooking oil occupies, we can calculate the radius of the cylinder. The volume of the cylinder is, $V_{cylinder} = \pi r^2 h$ (r is the inner radius of the cylinder, and h is the height of the cylinder). The cylinder diameter is $2r$.

$$\text{volume of oil filling bottle} = \frac{\text{mass of oil}}{\text{density of oil}}$$

$$\text{volume of oil filling bottle} = \frac{1360\ \cancel{\text{g}}}{0.953\ \cancel{\text{g}}/\text{mL}} = 1.43 \times 10^3\ \text{mL} = 1.43 \times 10^3\ \text{cm}^3$$

Next, solve for the radius of the cylinder.

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

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

$$r = \sqrt{\frac{1.43 \times 10^3\ \text{cm}^3}{\pi \times 21.5\ \text{cm}}} = 4.60\ \text{cm}$$

The inner diameter of the bottle equals $2r$.

Bottle diameter $= 2r = 2(4.60\text{ cm}) =$ **9.20 cm**

1.59 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.

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

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

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

1.60 $$\frac{343\ \cancel{\text{m}}}{1\ \cancel{\text{s}}} \times \frac{1\ \text{mi}}{1609\ \cancel{\text{m}}} \times \frac{3600\ \cancel{\text{s}}}{1\ \text{h}} = \mathbf{767\ mph}$$

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

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

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

1.62 In order to work this problem, you need to understand the physical principles involved in the experiment in Problem 1.61. 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.

1.63 The volume of a sphere is:

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{48.6\ \text{cm}}{2}\right)^3 = 6.01 \times 10^4\ \text{cm}^3$$

$$\textbf{density} = \frac{\text{mass}}{\text{volume}} = \frac{6.852 \times 10^5\ \text{g}}{6.01 \times 10^4\ \text{cm}^3} = \mathbf{11.4\ g/cm^3}$$

1.64 $\text{Volume} = \dfrac{\text{mass}}{\text{density}}$

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

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

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

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, $\quad \textbf{percent error} = \dfrac{0.056°\text{C}}{38.9°\text{C}} \times 100\% = \mathbf{0.1\%}$

For the Celsius thermometer, $\quad \textbf{percent error} = \dfrac{0.1°\text{C}}{38.9°\text{C}} \times 100\% = \mathbf{0.3\%}$

Which thermometer is more accurate?

1.66 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:

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

The mass of vanillin (in g) is:

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

The cost is:

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

1.67 $? \text{°F} = \left(\text{°C} \times \frac{9\text{°F}}{5\text{°C}}\right) + 32\text{°F}$

Let temperature $= t$

$$t = \frac{9}{5}t + 32\text{°F}$$

$$t - \frac{9}{5}t = 32\text{°F}$$

$$-\frac{4}{5}t = 32\text{°F}$$

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

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

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

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

1.69 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,

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

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

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

1.71 Twenty-five grams of the least dense metal (solid A) will occupy the greatest volume of the three metals, and 25.0 g of the most dense metal (solid B) will occupy the least volume.

We can calculate the volume occupied by each metal and then add the volume of water (20.0 mL) to find the total volume occupied by the metal and water.

Solid A:

$$25.0\ \cancel{g}\ A \times \frac{1\ mL}{2.9\ \cancel{g}\ A} = 8.6\ mL$$

$$\text{Total volume} = 8.6\ mL + 20.0\ mL = 28.6\ mL$$

Solid B:

$$25.0\ \cancel{g}\ B \times \frac{1\ mL}{8.3\ \cancel{g}\ B} = 3.0\ mL$$

$$\text{Total volume} = 3.0\ mL + 20.0\ mL = 23.0\ mL$$

Solid C:

$$25.0\ \cancel{g}\ C \times \frac{1\ mL}{3.3\ \cancel{g}\ C} = 7.6\ mL$$

$$\text{Total volume} = 7.6\ mL + 20.0\ mL = 27.6\ mL$$

Therefore, we have: (a) **solid C**, (b) **solid B**, and (c) **solid A**.

1.72 The diameter of the basketball can be calculated from its circumference. We can then use the diameter of a ball as a conversion factor to determine the number of basketballs needed to circle the equator.

Circumference $= 2\pi r$

$$d = 2r = \frac{\text{circumference}}{\pi} = \frac{29.6\ \text{in}}{\pi} = 9.42\ \text{in}$$

$$6400\ \cancel{km} \times \frac{1000\ \cancel{m}}{1\ \cancel{km}} \times \frac{1\ \cancel{cm}}{1 \times 10^{-2}\ \cancel{m}} \times \frac{1\ \cancel{in}}{2.54\ \cancel{cm}} \times \frac{1\ \text{ball}}{9.42\ \cancel{in}} = \mathbf{26{,}700{,}000\ basketballs}$$

We round up to an integer number of basketballs with 3 significant figures.

1.73 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.

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

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

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

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

1.74 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.

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

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

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

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

(b) $1 \text{ troy oz} = \mathbf{31.103 \text{ g}}$

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

A troy ounce is heavier than an ounce.

1.76 $\text{Volume of sphere} = \dfrac{4}{3}\pi r^3$

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

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

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

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

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

1.78 $62 \text{ kg} = 6.2 \times 10^4 \text{ g}$

O: $(6.2 \times 10^4 \text{ g})(0.65) = \mathbf{4.0 \times 10^4 \text{ g O}}$
C: $(6.2 \times 10^4 \text{ g})(0.18) = \mathbf{1.1 \times 10^4 \text{ g C}}$
H: $(6.2 \times 10^4 \text{ g})(0.10) = \mathbf{6.2 \times 10^3 \text{ g H}}$
N: $(6.2 \times 10^4 \text{ g})(0.03) = \mathbf{2 \times 10^3 \text{ g N}}$
Ca: $(6.2 \times 10^4 \text{ g})(0.016) = \mathbf{9.9 \times 10^2 \text{ g Ca}}$
P: $(6.2 \times 10^4 \text{ g})(0.012) = \mathbf{7.4 \times 10^2 \text{ g P}}$

1.79 3 minutes 43.13 seconds = 223.13 seconds

Time to run 1500 meters is:

$$1500 \cancel{\text{m}} \times \frac{1 \cancel{\text{mi}}}{1609 \cancel{\text{m}}} \times \frac{223.13 \text{ s}}{1 \cancel{\text{mi}}} = \mathbf{208.01 \text{ s} = 3 \text{ min } 28.01 \text{ s}}$$

1.80 $\mathbf{? \text{ °C}} = (7.3 \times 10^2 - 273) \text{ K} = \mathbf{4.6 \times 10^2 \text{°C}}$

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

1.81 $\mathbf{? \text{ g Cu}} = (5.11 \times 10^3 \cancel{\text{kg}} \text{ ore}) \times \dfrac{34.63\% \text{ Cu}}{100\% \text{ ore}} \times \dfrac{1000 \text{ g}}{1 \cancel{\text{kg}}} = \mathbf{1.77 \times 10^6 \text{ g Cu}}$

1.82 $(8.0 \times 10^4 \cancel{\text{tons}} \text{ Au}) \times \dfrac{2000 \cancel{\text{lb}} \text{ Au}}{1 \cancel{\text{ton}} \text{ Au}} \times \dfrac{16 \cancel{\text{oz}} \text{ Au}}{1 \cancel{\text{lb}} \text{ Au}} \times \dfrac{\$948}{1 \cancel{\text{oz}} \text{ Au}} = \mathbf{\$2.4 \times 10^{12}}$ or **2.4 trillion dollars**

1.83 $$\textbf{? g Au} = \frac{4.0\times10^{-12}\text{ g Au}}{1\ \cancel{\text{mL}}\text{ seawater}}\times\frac{1\ \cancel{\text{mL}}}{0.001\ \cancel{\text{L}}}\times(1.5\times10^{21}\ \cancel{\text{L}}\text{ seawater}) = \mathbf{6.0\times10^{12}\ g\ Au}$$

$$\textbf{value of gold} = (6.0\times10^{12}\ \cancel{\text{g}}\text{ Au})\times\frac{1\ \cancel{\text{lb}}}{453.6\ \cancel{\text{g}}}\times\frac{16\ \cancel{\text{oz}}}{1\ \cancel{\text{lb}}}\times\frac{\$948}{1\ \cancel{\text{oz}}} = \mathbf{\$2.0\times10^{14}}$$

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

1.84 $$\textbf{? Fe atoms} = 4.9\ \cancel{\text{g}}\text{ Fe}\times\frac{1.1\times10^{22}\text{ Fe atoms}}{1.0\ \cancel{\text{g}}\text{ Fe}} = \mathbf{5.4\times10^{22}\ Fe\ atoms}$$

1.85 $$\text{mass of Earth's crust} = (5.9\times10^{21}\text{ tons})\times\frac{0.50\%\text{ crust}}{100\%\text{ Earth}} = 2.95\times10^{19}\text{ tons}$$

$$\textbf{mass of silicon in crust} = (2.95\times10^{19}\ \cancel{\text{tons}}\text{ crust})\times\frac{27.2\%\text{ Si}}{100\%\text{ crust}}\times\frac{2000\ \cancel{\text{lb}}}{1\ \cancel{\text{ton}}}\times\frac{1\text{ kg}}{2.205\ \cancel{\text{lb}}} = \mathbf{7.3\times10^{21}\ kg\ Si}$$

1.86 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 equal to the diameter of a Cu atom, which is $(2)(1.3\times10^{-10}\text{ m})$. Let n be the number of times we can cut the Cu wire in half. We can write:

$$\left(\frac{1}{2}\right)^n\times0.1\text{ m} = 2.6\times10^{-10}\text{ m}$$

$$\left(\frac{1}{2}\right)^n = 2.6\times10^{-9}\text{ m}$$

Taking the log of both sides of the equation:

$$n\log\left(\frac{1}{2}\right) = \log(2.6\times10^{-9})$$

$$\boldsymbol{n} = \mathbf{29\ times}$$

1.87 $$(250\times10^6\ \cancel{\text{cars}})\times\frac{5000\ \cancel{\text{mi}}}{1\ \cancel{\text{car}}}\times\frac{1\ \cancel{\text{gal}}\text{ gas}}{20\ \cancel{\text{mi}}}\times\frac{9.5\text{ kg }CO_2}{1\ \cancel{\text{gal}}\text{ gas}} = \mathbf{5.9\times10^{11}\ kg\ CO_2}$$

1.88 Volume = area × thickness.

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

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

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

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

$$\textbf{thickness} = \frac{\text{volume}}{\text{area}} = \frac{1.3472\text{ cm}^3}{929.03\text{ cm}^2} = 1.450\times10^{-3}\text{ cm} = \mathbf{1.450\times10^{-2}\ mm}$$

1.89 **(a)** homogeneous

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

1.90 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.

$$(2.0 \times 10^4 \cancel{\text{gallons}}\ H_2O) \times \frac{3.79\ \cancel{\text{L}}}{1\ \cancel{\text{gallon}}} \times \frac{1\ \cancel{\text{mL}}}{0.001\ \cancel{\text{L}}} \times \frac{1\ \text{g}}{1\ \cancel{\text{mL}}} = 7.58 \times 10^7\ \text{g}\ H_2O$$

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

$$(7.58 \times 10^7\ \cancel{\text{g}\ H_2O}) \times \frac{1\ \text{g chlorine}}{1 \times 10^6\ \cancel{\text{g}\ H_2O}} = 75.8\ \text{g chlorine}$$

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.

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

1.91 The volume of the cylinder is:

$$V = \pi r^2 h = \pi(0.25\ \text{cm})^2(10\ \text{cm}) = 2.0\ \text{cm}^3$$

The number of Al atoms in the cylinder is:

$$2.0\ \cancel{\text{cm}^3} \times \frac{2.70\ \cancel{\text{g}}}{1\ \cancel{\text{cm}^3}} \times \frac{1\ \text{Al atom}}{4.48 \times 10^{-23}\ \cancel{\text{g}}} = \mathbf{1.2 \times 10^{23}\ Al\ atoms}$$

1.92 **(a)** The volume of the pycnometer can be calculated by determining the mass of water that the pycnometer holds and then using the density to convert to volume.

$$(43.1195 - 32.0764)\cancel{\text{g}} \times \frac{1\ \text{mL}}{0.99820\ \cancel{\text{g}}} = \mathbf{11.063\ mL}$$

(b) Using the volume of the pycnometer from part (a), we can calculate the density of ethanol.

$$\frac{(40.8051 - 32.0764)\ \text{g}}{11.063\ \text{mL}} = \mathbf{0.78900\ g/mL}$$

(c) From the volume of water added and the volume of the pycnometer, we can calculate the volume of the zinc granules by difference. Then, we can calculate the density of zinc.

$$\text{volume of water} = (62.7728 - 32.0764 - 22.8476)\cancel{\text{g}} \times \frac{1\ \text{mL}}{0.99820\ \cancel{\text{g}}} = \mathbf{7.8630\ mL}$$

$$\text{volume of zinc granules} = 11.063\ \text{mL} - 7.8630\ \text{mL} = \mathbf{3.200\ mL}$$

$$\mathbf{density\ of\ zinc} = \frac{22.8476\ \text{g}}{3.200\ \text{mL}} = \mathbf{7.140\ g/mL}$$

1.93 Let the fraction of gold = x, and the fraction of sand = $(1 - x)$. We set up an equation to solve for x.

$$(x)(19.3\ \text{g/cm}^3) + (1 - x)(2.95\ \text{g/cm}^3) = 4.17\ \text{g/cm}^3$$

$$19.3x - 2.95x + 2.95 = 4.17$$

$$x = 0.0746$$

Converting to a percentage, the mixture contains **7.46%** gold.

1.94 First, convert 10 μm to units of cm.

$$10\ \cancel{\mu\text{m}} \times \frac{1 \times 10^{-4}\ \text{cm}}{1\ \cancel{\mu\text{m}}} = 1.0 \times 10^{-3}\ \text{cm}$$

Now, substitute into the given equation to solve for time.

$$\boldsymbol{t} = \frac{x^2}{2D} = \frac{(1.0 \times 10^{-3}\ \cancel{\text{cm}})^{\cancel{2}}}{2(5.7 \times 10^{-7}\ \cancel{\text{cm}^2}/\text{s})} = \mathbf{0.88\ s}$$

It takes **0.88 seconds** for a glucose molecule to diffuse 10 μm.

1.95 The mass of a human brain is about 1 kg (1000 g) and contains about 10^{11} cells. The mass of a brain cell is:

$$\frac{1000\ \text{g}}{1 \times 10^{11}\ \text{cells}} = 1 \times 10^{-8}\ \text{g/cell}$$

Assuming that each cell is completely filled with water (density = 1 g/mL), we can calculate the volume of each cell. Then, assuming the cell to be cubic, we can solve for the length of one side of such a cell.

$$\frac{1 \times 10^{-8}\ \cancel{\text{g}}}{1\ \text{cell}} \times \frac{1\ \cancel{\text{mL}}}{1\ \cancel{\text{g}}} \times \frac{1\ \text{cm}^3}{1\ \cancel{\text{mL}}} = 1 \times 10^{-8}\ \text{cm}^3/\text{cell}$$

$$V_{\text{cube}} = a^3$$

$$\boldsymbol{a} = (V)^{1/3} = (1 \times 10^{-8}\ \text{cm}^3)^{1/3} = \mathbf{0.002\ cm}$$

Next, the height of a single cell is a, 0.002 cm. If 10^{11} cells are spread out in a thin layer a single cell thick, the surface area can be calculated from the volume of 10^{11} cells and the height of a single cell.

$$V = \text{surface area} \times \text{height}$$

The volume of 10^{11} brain cells is:

$$1000\ \cancel{\text{g}} \times \frac{1\ \cancel{\text{mL}}}{1\ \cancel{\text{g}}} \times \frac{1\ \text{cm}^3}{1\ \cancel{\text{mL}}} = 1000\ \text{cm}^3$$

The surface area is:

$$\textbf{Surface area} = \frac{V}{\text{height}} = \frac{1000\ \text{cm}^3}{0.002\ \text{cm}} = 5 \times 10^5\ \cancel{\text{cm}^2} \times \left(\frac{1 \times 10^{-2}\ \text{m}}{1\ \cancel{\text{cm}}}\right)^2 = \mathbf{5 \times 10^1\ m^2}$$

1.96 **(a)** A concentration of CO of 800 ppm in air would mean that there are 800 parts by volume of CO per 1 million parts by volume of air. Using a volume unit of liters, 800 ppm CO means that there are 800 L of CO per 1 million liters of air. The volume in liters occupied by CO in the room is:

$$17.6\text{ m} \times 8.80\text{ m} \times 2.64\text{ m} = 409\ \cancel{\text{m}^3} \times \left(\frac{1\ \cancel{\text{cm}}}{1 \times 10^{-2}\ \cancel{\text{m}}}\right)^{\cancel{3}} \times \frac{1\text{ L}}{1000\ \cancel{\text{cm}^3}} = 4.09 \times 10^5\text{ L air}$$

$$4.09 \times 10^5\ \cancel{\text{L}}\text{ air} \times \frac{8.00 \times 10^2\text{ L CO}}{1 \times 10^6\ \cancel{\text{L}}\text{ air}} = \mathbf{327\ L\ CO}$$

(b) 1 mg = 1 × 10^{-3} g and 1 L = 1000 cm^3. We convert mg/m^3 to g/L:

$$\frac{0.050\ \cancel{\text{mg}}}{1\ \cancel{\text{m}^3}} \times \frac{1 \times 10^{-3}\text{ g}}{1\ \cancel{\text{mg}}} \times \left(\frac{1 \times 10^{-2}\ \cancel{\text{m}}}{1\ \cancel{\text{cm}}}\right)^{\cancel{3}} \times \frac{1000\ \cancel{\text{cm}^3}}{1\text{ L}} = \mathbf{5.0 \times 10^{-8}\ g / L}$$

(c) 1 μg = 1 × 10^{-3} mg and 1 mL = 1 × 10^{-2} dL. We convert mg/dL to μg/mL:

$$\frac{120\ \cancel{\text{mg}}}{1\ \cancel{\text{dL}}} \times \frac{1\ \mu\text{g}}{1 \times 10^{-3}\ \cancel{\text{mg}}} \times \frac{1 \times 10^{-2}\ \cancel{\text{dL}}}{1\text{ mL}} = \mathbf{1.20 \times 10^3\ \mu g / mL}$$

1.97 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.

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

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

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

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.

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

We do not have enough dimes.

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

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

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:

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

The mass of each set is:

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

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

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

1.98 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:

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

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

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.

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

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

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

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

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

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

1.99 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).

1.100 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.

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

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

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

1.101 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.

1.102 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.

1.103 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.

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

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

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.

$$\text{Volume of CO}_2\text{ released} = 0.229\ \cancel{\text{g}} \times \frac{1\text{ L}}{1.81\ \cancel{\text{g}}} = \mathbf{0.127\ L}$$

1.104 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.

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

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

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

1.105 **Basic approach:**
- Estimate the mass of one ant. In this problem a reasonable estimate is provided, but in future problems of this type you will need to provide such estimates and look up certain constants. See page 24 of your textbook for some general advice on looking up chemical information.
- Multiply by 6×10^{23} to obtain the mass of one mole of ants, and convert mg to kg.

The mass of one mole of ants in kilograms is

$$6\times10^{23} \times\ 3\ \text{mg}\times\frac{1\times10^{-3}\ \text{g}}{1\ \text{mg}}\times\frac{1\ \text{kg}}{1000\ \text{g}}\ \approx\ 2\times10^{18}\ \text{kg}$$

It is interesting to compare this mass with the total mass of Earth's human population. The world population is very close to 6.9 billion people. Assuming an average body mass of 150 lb, we write

$$6.9\times10^{9}\ \times150\ \text{lb}\ \times\frac{453.6\ \text{g}}{1\ \text{lb}}\times\frac{1\ \text{kg}}{1000\ \text{g}}\ \approx\ 5\times10^{11}\ \text{kg}$$

Thus, one mole of ants outweigh all humans by 4 million times!

1.106 **Basic approach:**
- Assume an average amount of time that a person sleeps in one night.
- Multiple that value by the number of nights in 80 years.

We assume that an average person sleeps eight hours a night. Although an infant or a young child sleeps more than eight hours a day, as one grows older, one tends to sleep less and less. Thus, the time spent sleeping in 80 years is

$$\frac{8\ \text{h sleep}}{1\ \text{day}}\times\frac{365\ \text{day}}{1\ \text{yr}}\times80\ \text{yr}\times\frac{1\ \text{day}}{24\ \text{h}}\times\frac{1\ \text{yr}}{365\ \text{day}}\ \approx\ 27\ \text{yr}$$

So regardless of an adult's age, on average, a third of his/her life is spent sleeping!

1.107 **Basic approach:**
- List the major ways water is used indoors by a typical family.
- Estimate the volume of water used according to the activity and the number of times that activity occurs in one day.
- Calculate total volume of water used in one day.

We can estimate the usage of water in the following categories:

Showers Each person takes one shower per day; each shower lasts for 8 minutes; 2 gallons of water used per minute.

4 people × 1 shower/person × 8 minutes/shower × 2 gallons/minute = 64 gallons

Washing Hands Each person washes hands six times a day; each washing uses 0.5 gallons of water.

4 people × 6 washings/person × 0.5 gallon/washing = 12 gallons

Brushing Teeth Each person brushes teeth twice a day; each brushing uses 0.5 gallon of water.

4 people × 2 brushings/person × 0.5 gallon/brushing = 4 gallons

Flushing Toilets Each person uses the toilet four times a day; each flushing uses 1.5 gallons of water.

4 people × 4 flushes/person × 1.5 gallons/flush = 24 gallons

Dishwasher It is used twice a day; for newer dishwashers, each wash uses 6 gallons of water.

2 dishwashing × 6 galloons/dishwashing = 12 gallons

Laundry Seven loads of laundry per week; each load uses 40 gallons of water.

$$\frac{1}{7}\text{ week} \times 7\text{ loads/week} \times 40\text{ gallons/load} = 40\text{ gallons}$$

Other Miscellaneous Uses (washing dishes by hand, watering plants, drinking, etc.)

20 gallons

Summing all of the activities gives 176 gallons. Obviously this is a very rough estimate, and the amount of water used by a family of four in one day will vary considerably depending on the habits of that family; however, this estimate is almost certainly within a factor of two, and it is noteworthy that the daily water consumption of a typical US family is considerable and rather extravagant by international standards.

1.108 **Basic approach:**

- Calculate the volume of a bowling ball in cm^3.
- Convert the mass of the ball to grams.
- Calculate the density of the bowling ball and compare to the density of water (1 g/cm^3).

The volume of the bowling ball is given by

$$\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{8.6\text{ in}}{2}\right)^3 \times \left(\frac{2.54\text{ cm}}{1\text{ in}}\right)^3 = 5.5\times10^3\text{ cm}^3$$

Starting with an 8 lb bowling ball and assuming two significant figures in the mass, converting pounds to grams gives

$$8\text{ lb}\times\frac{453.6\text{ g}}{1\text{ lb}} = 3.6\times10^3\text{ g}$$

So the density of an 8 lb bowling ball would be

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{3.6\times10^3\text{ g}}{5.5\times10^3\text{ cm}^3} = 0.65\text{ g/cm}^3$$

Carrying out analogous calculations for the higher-weight bowling balls gives

ball weight (lb)	mass (g)	density (g/cm^3)
9	4.1×10^3	0.75
10	4.5×10^3	0.82
11	5.0×10^3	0.91
12	5.4×10^3	0.98
13	5.9×10^3	1.1

Therefore we would expect bowling balls that are 11 lb or lighter to float since they are less dense than water. Bowling balls that are 13 lb or heavier would be expected to sink since they are denser than water. The 12 lb bowling ball is borderline, but it would probably float.

Note that the above calculations were carried out by rounding off the intermediate answers, as discussed in Section 1.8. If we carry an additional digit past the number of significant figures to minimize errors from rounding, the following densities are obtained:

ball weight (lb)	density (g/cm^3)
10	0.83
11	0.91
12	1.01

The differences in the densities obtained are slight, but the value obtained for the 12 lb ball now suggests that it might sink. This problem illustrates the difference rounding off intermediate answers can make in the final answers for some calculations.

1.109 **Basic approach:**

- Approximate the shape of the juncture.
- Estimate the dimensions in nm and calculate the volume, converting to L.

The volume could be approximated in several ways. One approach would be to model the junction as a cylinder with an internal diameter of 200 nm and a height of 200 nm. The volume of the cylinder would be

$$\pi r^2 h = \pi\left(\frac{200\text{ nm}}{2}\right)^2 \times 200\text{ nm} \times \left(\frac{10^2\text{ cm}}{10^9\text{ nm}}\right)^3 \times \frac{1\text{ mL}}{1\text{ cm}^3} \times \frac{1\text{ L}}{1000\text{ mL}} = 6\times10^{-18}\text{ L}$$

To get a sense of that volume relative to a molecule, consider that the volume of a water molecule in liquid water is roughly 3×10^{-26} L. Therefore a volume of 6×10^{-18} L could still potentially contain (6×10^{-18} L)/(3×10^{-26} L) $\approx 2 \times 10^8$ water molecules! Water molecules are very small, and they pack tightly in the liquid state due to strong intermolecular forces (Chapter 11). For larger molecules such as those involved in biological processes, it might be possible to trap a much smaller number in a nanofiber juncture.

1.110 **Basic approach:**

- Look up or estimate the number of car currently operating in the United States.
- Estimate the average fuel efficiency (miles per gallon) and average miles driven by a car in one year.

The information from the web shows there are about 250 million passenger cars in the US. Assume on average each car covers 10,000 miles at the gas consumption rate of 20 mpg (miles per gallon). The total number of gallons of gasoline consumed in a year is

$$250\times10^6\text{ cars}\times\frac{10000\text{ mi}}{1\text{ car}}\times\frac{1\text{ gal}}{20\text{ mi}} \approx 1\times10^{11}\text{ gal}$$

1.111 Basic approach:

- Look up the percentage Earth's surface covered by oceans and the average depth of the ocean.
- Calculate volume based on the surface area of the oceans and the average depth.

About 70 percent of Earth is covered with water. Useful information from the web: Average depth of ocean is 4000 m; radius of Earth = 6400 km or 6.4×10^8 cm. Using the formula for the surface area of a sphere of radius r as $(4\pi r^2)$, we calculate the area of ocean water as follows:

$$4\pi r^2 \times 0.7 = 4\pi(6.4 \times 10^8 \text{ cm})^2 \times 0.7 = 3.6 \times 10^{18} \text{ cm}^2$$

Volume is area × depth so the volume of ocean water is

$$(3.6 \times 10^{18} \text{ cm}^2) \times (4 \times 10^5 \text{ cm}) \approx 1 \times 10^{24} \text{ cm}^3 = 1 \times 10^{21} \text{ L}$$

1.112 Basic approach:

- Model the shape and approximate the dimensions of an average human body, and calculate volume.
- Look up the percent water in the body, and estimate the fraction of that water contained in the blood stream.

One way to proceed is to assume that the human body can be treated as a cylinder of height h and diameter d. The volume of the body is then given by $\pi r^2 \times h$ where r is the radius. For a 6 ft tall person with an average width of 15 in, the volume in cubic inches is

$$\pi(15 \text{ in}/2)^2 \times 6 \text{ ft} \times 12 \text{ in/ft} = 1.3 \times 10^4 \text{ in}^3$$

Expressed in liters,

$$1.3\times10^4 \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \times \frac{1 \text{ L}}{1000 \text{ cm}^3} = 210 \text{ L}$$

About 60 percent of a human body is water, so the volume of water is

$$0.6 \times 210 \text{ L} = 130 \text{ L}$$

Assuming that one-tenth of the water is blood, the volume of blood would be 13 L. This calculation turns out to be a rather rough estimate, where most of our error probably comes from our assumption that 10% of the water in our bodies is contained in the blood stream. In reality, the volume of blood in an adult is around 5 L.

1.113 Basic approach:

- Look up the speed of light and calculate the distance traveled in one nanosecond.

The speed of light is 3×10^8 m/s and a nanosecond is 1×10^{-9} s. The distance covered by light in this time period is

$$3\times10^8 \text{ m/s}\times\frac{100 \text{ cm}}{1 \text{ m}}\times\frac{1 \text{ in}}{2.54 \text{ cm}}\times\frac{1 \text{ ft}}{12 \text{ in}}\times\frac{1\times10^{-9} \text{ s}}{1 \text{ ns}} = 1 \text{ ft}$$

Our senses tell us that objects are instantly illuminated by light, but this calculation shows that while the speed of light is very fast, it travels finite and measurable distances in very short periods of time.

1.114 Basic approach:

- Break up period of time over which a professional basketball game is played according to the level of activity of the players.
- Estimate the time spend engaged in that activity and the average running speed.
- Calculate the total distance traveled.

An NBA game lasts 48 minutes. We can divide this time period into three parts: (1) dashing, (2) running, and (3) movement during offense and defense under the basket. Reasonable estimates for time and speed during these activities are: dashing (3 min at 10 m/s); running (5 min at 7 m/s); movement under basket (40 min at 3 m/s). (Note that both the 10 m/s and 7 m/s estimates are near world track records.) Summing up, we calculate the average distance covered by the player as

$$(3 \text{ min} \times 60 \text{ s/min} \times 10 \text{ m/s}) + (5 \text{ min} \times 60 \text{ s/min} \times 7 \text{ m/s}) + (40 \text{ min} \times 60 \text{ s/min} \times 3 \text{ m/s}) \approx 1 \times 10^4 \text{ m}$$

Expressed in miles,

$$1 \times 10^4 \text{ m} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{1 \text{ mi}}{1.61 \text{ km}} \approx 7 \text{ mi}$$

Alternatively, one can make a quicker (and cruder) estimate by assuming that the players traverse the length of the court (94 ft) every 24 seconds based on the shot clock. Over 48 minutes, the distance traveled would be

$$48 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{94 \text{ ft}}{24 \text{ s}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} \approx 2 \text{ mi}$$

Taking the higher estimate, this distance would correspond to quite a bit of running, with an average speed of roughly 1 mile every 7 minutes. Keep in mind, however, that hardly any player is on the court for a full 48 minutes of a game, and all players get a break during the timeouts.

1.115 **Basic approach:**

• Calculate the thickness of the oil layer from the volume and surface area, and assume that to be the length of one molecule.

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.

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

Given that 0.10 mL = 0.10 cm^3, we write

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

and rearranging that equation gives

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

Converting to nm:

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

ANSWERS TO REVIEW OF CONCEPTS

Section 1.3 (p. 5)	**(c)**
Section 1.4 (p. 8)	Elements: **(b)** and **(d)**. Compounds: **(a)** and **(c)**.
Section 1.5 (p. 10)	**(a)**
Section 1.6 (p. 11)	Chemical change: **(b)** and **(c)**. Physical change: **(d)**.
Section 1.7 (p. 18)	**(a)**
Section 1.8 (p. 23)	Top ruler, **4.6 in**. Bottom ruler, **4.57 in**.
Section 1.9 (p. 27)	**0.14 g**