1 Introduction: Matter and Measurement

Visualizing Concepts

1.1 *Pure elements* contain only one kind of atom. Atoms can be present singly or as tightly bound groups called molecules. *Compounds* contain two or more kinds of atoms bound tightly into molecules. *Mixtures* contain more than one kind of atom and/or molecule, not bound into discrete particles.

(a) pure element: i

(b) mixture of elements: v, vi

(c) pure compound: iv

(d) mixture of an element and a compound: ii, iii

1.2 After a *physical change*, the identities of the substances involved are the same as their identities before the change. That is, molecules retain their original composition. During a *chemical change*, at least one new substance is produced; rearrangement of atoms into new molecules occurs.

The diagram represents a chemical change, because the molecules after the change are different than the molecules before the change.

1.3 To brew a cup of coffee, begin with ground coffee beans, a heterogeneous mixture, and water, a pure substance. Hot water contacts the coffee grounds and dissolves components of the coffee bean that are water-soluble. This creates a new heterogeneous mixture of undissolved coffee bean solids and liquid coffee solution; this mixture is separated by filtration. Undissolved grounds are left on the filter paper and liquid coffee, itself a homogeneous mixture, drips into the container below.

Overall, two separations occur. Chemical differences among the components of the coffee bean allow certain compounds to dissolve in water, while other components remain insoluble. This kind of separation based on solubility differences is called *extraction*. The insoluble grounds are then separated from the coffee solution by *filtration*.

1.4 (a) time (b) mass (c) temperature (d) area (e) length

(f) area (g) temperature (h) density (i) volume

1.5 Density is the ratio of mass to volume. For a sphere, size is like volume; both are determined by the radius of the sphere.

(a) For spheres of the same size or volume, the denominator of the density relationship is the same. The denser the sphere, the heavier it is. A list from lightest to heaviest is in order of increasing density and mass. The aluminum sphere (density = 2.70 g/cm^3) is lightest, then nickel (density = 8.90 g/cm^3), then silver (density = 10.409 g/cm^3).

(b) For spheres of equal mass, the numerator of the density relationship is the same. The denser the sphere, the smaller its volume or size. A list from smallest to largest is in order of decreasing density. The platinum sphere (density = 21.45 g/cm^3) is smallest, then gold (density = 19.30 g/cm^3), then lead (density = 11.35 g/cm^3).

1.6 Measurements (darts) that are close to each other are *precise*. Measurements that are close to the "true value" (the bull's eye) are *accurate*.

(a) Figure ii represents data that are both accurate and precise. The darts are close to the bull's eye and each other.

(b) Figure i represents data that are precise but inaccurate. The darts are near each other but their center point (average value) is far from the bull's eye.

(c) Figure iii represents data that are imprecise but their average value is accurate. The darts are far from each other, but their average value, or geometric center point, is close to the bull's eye.

1.7 (a) 7.5 cm. There are two significant figures in this measurement; the number of cm can be read precisely, but there is some estimating (uncertainty) required to read tenths of a centimeter. Listing two significant figures is consistent with the convention that measured quantities are reported so that there is uncertainty in only the last digit.

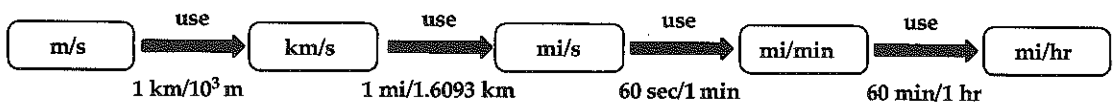
(b) The speed is 72 mi/hr (inner scale, two significant figures) or 115 km/hr (outer scale, three significant figures). Both scales are read with certainty in the "hundreds" and "tens" place, and some uncertainty in the "ones" place. The km/hr speed has one more significant figure because its magnitude is in the hundreds.

1.8 (a) Volume = length × width × height. Because the operation is multiplication, the dimension with fewest significant figures (sig figs) determines the number of sig figs in the result. The dimension "2.5 cm" has 2 sig figs, so the volume is reported with 2 sig figs.

(b) Density = mass/volume. Because the operation is division, again the datum with fewer significant figures determines the number of sig figs in the result. While mass, 104.72 g, has 5 sig figs, volume [from (a)] has 2 sig figs, so density is also reported to 2 sig figs.

1.9 When converting units, arrange the conversion factor so that the given unit cancels and the desired unit is in the correct position. For example, suppose a quantity is expressed in terms of centimeters, but the desired result is expressed in inches. If the given unit has 'cm' in the numerator, then the conversion factor must have 'cm' in its denominator. However, if the original unit has 'cm' in the denominator, the conversion factor must have 'cm' in the numerator. Ideally, this will lead to the desired units in the appropriate location, numerator or denominator. However, the inverse of the answer can be taken when necessary.

1.10 Given: m/s Find: mi/hr. Both the given and desired units have distance in the numerator and time in the denominator. Use appropriate conversion factors to change 'm' to 'mi' in the numerator and 's' to 'hr' in the denominator.



Classification and Properties of Matter (sections 1.2 and 1.3)

1.11 (a) heterogeneous mixture

(b) homogeneous mixture (If there are undissolved particles, such as sand or decaying plants, the mixture is heterogeneous.)

(c) pure substance

(d) pure substance

1.12 (a) homogeneous mixture

(b) heterogeneous mixture (particles in liquid)

(c) pure substance

(d) heterogeneous mixture

1.13 (a) S (b) Au (c) K (d) Cl (e) Cu (f) uranium

(g) nickel (h) sodium (i) aluminum (j) silicon

1.14 (a) C (b) N (c) Ti (d) Zn (e) Fe (f) phosphorus

(g) calcium (h) helium (i) lead (j) silver

1.15 A(s) $\rightarrow$ B(s) + C(g)

When solid carbon is burned in excess oxygen gas, the two elements combine to form a gaseous compound, carbon dioxide. Clearly substance C is this compound. Since C is produced when A is heated in the absence of oxygen (from air), both the carbon and oxygen in C must have been present in A originally. A is, therefore, a compound composed of two or more elements chemically combined. Without more information on the chemical or physical properties of B, we cannot determine absolutely whether it is an element or a compound. However, few if any elements exist as white solids, so B is probably also a compound.

1.16 Gold, Au, is an element and "fool's gold", FeS_2, is a compound; both are solids and pure substances. Take advantage of differences in physical and or chemical properties between the two substances. Density and melting point measurements are often used to identify solids. For these two substances, melting points are very high, but densities are easy to measure. Gold is much denser than "fool's gold". Gold is much less chemically reactive than FeS_2, so relative reactivity with acids and bases can be observed. Of these experiments, density measurement is the most definitive and does not destroy the sample. (Note that neither substance is attracted to a magnet, so this test will not identify the gold.)

1.17 *Physical properties*: silvery white (color); lustrous; melting point = 649°C; boiling point = 1105°C; density at 20°C = 1.738 g/cm^3; pounded into sheets (malleable); drawn into wires (ductile); good conductor. *Chemical properties*: burns in air to give intense white light; reacts with Cl_2 to produce brittle white solid.

1.18 *Physical properties*: silver-gray (color); melting point = 420°C; hardness = 2.5 Mohs; density = 7.13 g/cm^3 at 25°C. *Chemical properties*: metal; reacts with sulfuric acid to produce hydrogen gas; reacts slowly with oxygen at elevated temperatures to produce ZnO.

1.19 (a) chemical (b) physical (c) physical (d) chemical (e) chemical

1.20 (a) chemical

(b) physical

(c) physical (The production of H_2O is a chemical change, but its *condensation* is a physical change.)

(d) physical (The production of soot is a chemical change, but its *deposition* is a physical change.)

1.21 (a) Take advantage of the different water solubilities of the two solids. Add water to dissolve the sugar; filter this mixture, collecting the sand on the filter paper and the sugar water in the flask. Evaporate water from the flask to recover solid sugar.

(b) Take advantage of the different solubilities and densities of the two liquids. Allow the mixture to settle so that there are two distinct layers. Vinegar (a water solution) is denser and on the bottom; oil (the organic layer) is less dense and on top. Carefully pour off most of the top layer. After the layers reform, use a dropper to remove any remaining oil. Vinegar is in the original vessel and oil is in a second container.

1.22 First heat the liquid in each beaker to 100°C to evaporate the water. The beaker with no residue contained pure water. The other two beakers have a solid, white residue. Measure the melting point of each solid. Sugar has a much lower melting point than salt, so the beaker with the lower-melting residue contained sugar water and that with the higher-melting residue contained salt water. (If confirmation is required, measure the densities of the two white residues.)

Units and Measurement (section 1.4)

1.23 (a) 1×10^{-1} (b) 1×10^{-2} (c) 1×10^{-15} (d) 1×10^{-6} (e) 1×10^{6}

(f) 1×10^{3} (g) 1×10^{-9} (h) 1×10^{-3} (i) 1×10^{-12}

1.24 (a) $$2.3 \times 10^{-10}\,\text{L} \times \frac{1\,\text{nL}}{1 \times 10^{-9}\,\text{L}} = 0.23\,\text{nL}$$

(b) $4.7 \times 10^{-6}\,\text{g} \times \dfrac{1\,\mu\text{g}}{1\times10^{-6}\,\text{g}} = 4.7\,\mu\text{g}$

(c) $1.85 \times 10^{-12}\,\text{m} \times \dfrac{1\,\text{pm}}{1\times10^{-12}\,\text{m}} = 1.85\,\text{pm}$

(d) $16.7 \times 10^{6}\,\text{s} \times \dfrac{1\,\text{Ms}}{1\times10^{6}\,\text{s}} = 16.7\,\text{Ms}$

(e) $15.7 \times 10^{3}\,\text{g} \times \dfrac{1\,\text{kg}}{1\times10^{3}\,\text{g}} = 15.7\,\text{kg}$

(f) $1.34 \times 10^{-3}\,\text{m} \times \dfrac{1\,\text{mm}}{1\times10^{-3}\,\text{m}} = 1.34\,\text{mm}$

(g) $1.84 \times 10^{2}\,\text{cm} \times \dfrac{1\,\text{m}}{1\times10^{2}\,\text{cm}} = 1.84\,\text{m}$

1.25 (a) °C = 5/9 (°F – 32°); 5/9 (72 – 32) = 22°C

(b) °F = 9/5 (°C) + 32°; 9/5 (216.7) + 32 = 422.1°F

(c) K = °C + 273.15; 233°C + 273.15 = 506 K

(d) °C = 315 K – 273.15 = 41.85 = 42°C; °F = 9/5 (41.85°C) + 32 = 107°F

(e) °C = 5/9 (°F – 32°); 5/9 (2500 – 32) = 1371°C; K = 1371°C + 273.15 = 1644 K (assuming 2500 °F has 4 sig figs)

(f) °C = 0 K – 273.15 = –273.15°C; °F = 9/5 (–273.15°C) + 32 = –459.67°F (assuming 0 K has infinite sig figs)

1.26 (a) °C = 5/9 (87°F – 32°) = 31°C

(b) K = 25°C + 273.15 = 298 K; °F = 9/5 (25°C) + 32 = 77°F

(c) °C = 5/9 (400°F – 32°) = 204.444 = 204°C

K = °C + 273.15 = 204.444°C + 273.15 = 478 K

(d) °C = 77 K – 273.15 = –196.15 = –196°C; °F = 9/5 (–196.15°C) + 32 = –321°F

1.27 (a) $\text{density} = \dfrac{\text{mass}}{\text{volume}} = \dfrac{40.55\,\text{g}}{25.0\,\text{mL}} = 1.62\,\text{g/mL} \text{ or } 1.62\,\text{g/cm}^3$

(The units cm^3 and mL will be used interchangeably in this manual.)

Tetrachloroethylene, 1.62 g/mL, is more dense than water, 1.00 g/mL; tetrachloroethylene will sink rather than float on water.

(b) $25.0\,\text{cm}^3 \times 0.469\,\dfrac{\text{g}}{\text{cm}^3} = 11.7\,\text{g}$

1.28 (a) volume = length^3 (cm^3); density = mass/volume (g/cm^3)

volume = $(1.500)^3\,\text{cm}^3 = 3.375\,\text{cm}^3$

$\text{density} = \dfrac{76.31\,\text{g}}{3.375\,\text{cm}^3} = 22.61\,\text{g/cm}^3$ osmium

(b) $125.0 \text{ mL} \times \frac{1 \text{ cm}^3}{1 \text{ mL}} \times \frac{4.51 \text{ g}}{1 \text{ cm}^3} = 563.75 = 564 \text{ g}$ titanium

(c) $0.1500 \text{ L} \times \frac{1 \text{ mL}}{1 \times 10^{-3} \text{ L}} \times \frac{0.8787 \text{ g}}{1 \text{ mL}} = 131.8 \text{ g}$ benzene

1.29 (a) $\text{density} = \frac{38.5 \text{ g}}{45 \text{ mL}} = 0.86 \text{ g/mL}$

The substance is probably toluene, density = 0.866 g/mL.

(b) $45.0 \text{ g} \times \frac{1 \text{ mL}}{1.114 \text{ g}} = 40.4 \text{ mL}$ ethylene glycol

(c) $(5.00)^3 \text{ cm}^3 \times \frac{8.90 \text{ g}}{1 \text{ cm}^3} = 1.11 \times 10^3 \text{ g}$ (1.11 kg) nickel

1.30 (a) $\frac{21.95 \text{ g}}{25.0 \text{ mL}} = 0.878 \text{ g/mL}$

The tabulated value has four significant figures, while the experimental value has three. The tabulated value rounded to three figures is 0.879. The values agree within one in the last significant figure of the experimental value; the two results agree. The liquid could be benzene.

(b) $15.0 \text{ g} \times \frac{1 \text{ mL}}{0.7781 \text{ g}} = 19.3 \text{ mL}$ cyclohexane

(c) $r = d/2 = 5.0 \text{ cm}/2 = 2.5 \text{ cm}$

$V = 4/3 \, \pi r^3 = 4/3 \times \pi \times (2.5)^3 \text{ cm}^3 = 65.4498 = 65 \text{ cm}^3$

$65.4498 \text{ cm}^3 \times \frac{11.34 \text{ g}}{\text{cm}^3} = 7.4 \times 10^2 \text{ g}$

(The answer has two significant figures because the diameter had only two significant figures.)

Note: This is the first exercise where "intermediate rounding" occurs. In this manual, when a solution is given in steps, the intermediate result will be rounded to the correct number of significant figures. However, the **unrounded** number will be used in subsequent calculations. The final answer will appear with the correct number of significant figures. That is, calculators need not be cleared and new numbers entered in the middle of a calculation sequence. This may result in a small discrepancy in the last significant digit between student-calculated answers and those given in the manual. These variations occur in any analysis of numerical data.

For example, in this exercise the volume of the sphere, 65.4498 cm^3, is rounded to 65 cm^3, but 65.4498 is retained in the subsequent calculation of mass, 7.4×10^2 g. In this case, 65 $\text{cm}^3 \times 11.34 \text{ g/cm}^3$ also yields 7.4×10^2 g. In other exercises, the correctly rounded results of the two methods may not be identical.

1.31 $31 \text{ billion tons} \times \frac{1 \times 10^9 \text{ tons}}{1 \text{ billion tons}} \times \frac{2000 \text{ lb}}{1 \text{ ton}} \times \frac{453.59 \text{ g}}{1 \text{ lb}} = 2.8 \times 10^{16} \text{ g}$

The metric prefix for 1×10^{15} is peta, abbreviated P.

$$2.8 \times 10^{16} \text{ g} \times \frac{1 \text{ Pg}}{1 \times 10^{15} \text{ g}} = 28 \text{ Pg}$$

1.32 (a) The wafers have the same diameter as the boule, so the question becomes 'how many 0.75 mm wafers can be cut from the 2 m boule?'

$$\frac{2.0 \text{ m}}{\text{boule}} \times \frac{1 \text{ mm}}{1 \times 10^{-3} \text{ m}} \times \frac{1 \text{ wafer}}{0.75\text{mm}} = 2667 = 2.7 \times 10^3 \text{ wafers}$$

(b) Calculate the volume of the wafer in cm^3. $V = \pi r^2 h$

$$r = \frac{d}{2} = \frac{300 \text{ mm}}{2} \times \frac{1 \text{ cm}}{10 \text{ mm}} = 15 \text{ cm}; \quad h = 0.75 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} = 7.5 \times 10^{-2} \text{ cm}$$

$$V = \pi r^2 h = \pi (15 \text{ cm})^2 (7.5 \times 10^{-2} \text{ cm}) = 53.0144 = 53 \text{ cm}^3$$

Density = mass / V; mass = density × V

$$\frac{2.33 \text{ g}}{\text{cm}^3} \times 53.0144 \text{ cm}^3 = 123.52 = 1.2 \times 10^2 \text{ g}$$

Uncertainty in Measurement (section 1.5)

1.33 Exact: (c), (d), and (f) (All others depend on measurements and standards that have margins of error, e.g., the length of a week as defined by the earth's rotation.)

1.34 Exact: (b), (e) (The number of students is exact on any given day.)

1.35 (a) 3 (b) 2 (c) 5 (d) 3 (e) 5 (f) 1 [See Sample Exercise 1.6 (c)]

1.36 (a) 4 (b) 3 (c) 4 (d) 5 (e) 6 (f) 2

1.37 (a) 1.025×10^2 (b) 6.570×10^5 (c) 8.543×10^{-3}

(d) 2.579×10^{-4} (e) -3.572×10^{-2}

1.38 (a) 7.93×10^3 mi (b) 4.001×10^4 km

1.39 (a) $14.3505 + 2.65 = 17.0005 = 17.00$ (For addition and subtraction, the minimum number of decimal places, here two, determines decimal places in the result.)

(b) $952.7 - 140.7389 = 812.0$

(c) $(3.29 \times 10^4)(0.2501) = 8.23 \times 10^3$ (For multiplication and division, the minimum number of significant figures, here three, determines sig figs in the result.)

(d) $0.0588/0.677 = 8.69 \times 10^{-2}$

1.40 (a) [320.5 – 6104.5/2.3] = –2.3 × 10^3 (The intermediate result has two significant figures, so only the thousand and hundred places in the answer are significant.)

(b) [285.3 × 10^5 – 0.01200 × 10^5] × 2.8954 = 8.260 × 10^7 (Since subtraction depends on decimal places, both numbers must have the same exponent to determine decimal places/sig figs. The intermediate result has 1 decimal place and 4 sig figs, so the answer has 4 sig figs.)

(c) (0.0045 × 20,000.0) + (2813 × 12) = 3.4 × 10^4
2 sig figs /0 dec pl   2 sig figs /first 2 digits

(d) 863 × [1255 – (3.45 × 108)] = 7.62 × 10^5
(3 sig figs /0 dec pl)
3 sig figs × [0 dec pl/3 sig figs] = 3 sig figs

1.41 The mass 21.427 g has 5 significant figures.

1.42 The volume in the graduated cylinder is 19.5 mL. Liquid volumes are read at the bottom of the meniscus, so the volume is slightly less than 20 mL. Volumes in this cylinder can be read with certainty to 1 mL, and with some uncertainty to 0.1 mL, so this measurement has 3 sig figs.

Dimensional Analysis (section 1.6)

1.43 In each conversion factor, the old unit appears in the denominator, so it cancels, and the new unit appears in the numerator.

(a) $\text{mm} \rightarrow \text{nm}: \dfrac{1 \times 10^{-3}\ \text{m}}{1\ \text{mm}} \times \dfrac{1\ \text{nm}}{1 \times 10^{-9}\ \text{m}} = 1 \times 10^{6}\ \text{nm/mm}$

(b) $\text{mg} \rightarrow \text{kg}: \dfrac{1 \times 10^{-3}\ \text{g}}{1\ \text{mg}} \times \dfrac{1\ \text{kg}}{1000\ \text{g}} = 1 \times 10^{-6}\ \text{kg/mg}$

(c) $\text{km} \rightarrow \text{ft}: \dfrac{1000\ \text{m}}{1\ \text{km}} \times \dfrac{1\ \text{cm}}{1 \times 10^{-2}\ \text{m}} \times \dfrac{1\ \text{in}}{2.54\ \text{cm}} \times \dfrac{1\ \text{ft}}{12\ \text{in}} = 3.28 \times 10^{3}\ \text{km/ft}$

(d) $\text{in}^3 \rightarrow \text{cm}^3: \dfrac{(2.54)^3\ \text{cm}^3}{1^3\ \text{in}^3} = 16.4\ \text{cm}^3/\text{in}^3$

1.44 In each conversion factor, the old unit appears in the denominator, so it cancels, and the new unit appears in the numerator.

(a) $\mu\text{m} \rightarrow \text{mm}: \dfrac{1 \times 10^{-6}\ \text{m}}{1\ \mu\text{m}} \times \dfrac{1\ \text{mm}}{1 \times 10^{-3}\ \text{m}} = 1 \times 10^{-3}\ \text{mm}/\mu\text{m}$

(b) $\text{ms} \rightarrow \text{ns}: \dfrac{1 \times 10^{-3}\ \text{s}}{1\ \text{ms}} \times \dfrac{1\ \text{ns}}{1 \times 10^{-9}\ \text{s}} = 1 \times 10^{6}\ \text{ns/ms}$

(c) mi → km: 1.6093 km/mi

(d) $\text{ft}^3 \rightarrow \text{L}: \dfrac{(12)^3\ \text{in}^3}{1\ \text{ft}^3} \times \dfrac{(2.54)^3\ \text{cm}^3}{1\ \text{in}^3} \times \dfrac{1\ \text{L}}{1000\ \text{cm}^3} = 28.3\ \text{L/ft}^3$

1.45 (a) $\frac{15.2\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} = 54.7\text{ km/hr}$

(b) $5.0 \times 10^3\text{ L} \times \frac{1\text{ gal}}{3.7854\text{ L}} = 1.3 \times 10^3\text{ gal}$

(c) $151\text{ ft} \times \frac{1\text{ yd}}{3\text{ ft}} \times \frac{1\text{ m}}{1.0936\text{ yd}} = 46.025 = 46.0\text{ m}$

(d) $\frac{60.0\text{ cm}}{\text{d}} \times \frac{1\text{ in}}{2.54\text{ cm}} \times \frac{1\text{ d}}{24\text{ hr}} = 0.984\text{ in/hr}$

1.46 (a) $\frac{2.998 \times 10^8\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{1\text{ mi}}{1.6093\text{ km}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} = 6.707 \times 10^8\text{ mi/hr}$

(b) $1454\text{ ft} \times \frac{1\text{ yd}}{3\text{ ft}} \times \frac{1\text{ m}}{1.0936\text{ yd}} = 443.18 = 443.2\text{ m}$

(c) $3{,}666{,}500\text{ m}^3 \times \frac{1^3\text{ dm}^3}{(1 \times 10^{-1})^3\text{ m}^3} \times \frac{1\text{ L}}{1\text{ dm}^3} = 3.6665 \times 10^9\text{ L}$

(d) $\frac{242\text{ mg cholesterol}}{100\text{ mL blood}} \times \frac{1\text{ mL}}{1 \times 10^{-3}\text{ L}} \times 5.2\text{ L} \times \frac{1 \times 10^{-3}\text{ g}}{1\text{ mg}} = 12.58 = 13\text{ g cholesterol}$

1.47 (a) $5.00\text{ days} \times \frac{24\text{ hr}}{1\text{ day}} \times \frac{60\text{ min}}{1\text{ hr}} \times \frac{60\text{ s}}{1\text{ min}} = 4.32 \times 10^5\text{ s}$

(b) $0.0550\text{ mi} \times \frac{1.6093\text{ km}}{\text{mi}} \times \frac{1000\text{ m}}{1\text{ km}} = 88.5\text{ m}$

(c) $\frac{\$1.89}{\text{gal}} \times \frac{1\text{ gal}}{3.7854\text{ L}} = \frac{\$0.499}{\text{L}}$

(d) $\frac{0.510\text{ in}}{\text{ms}} \times \frac{2.54\text{ cm}}{1\text{ in}} \times \frac{1 \times 10^{-2}\text{ m}}{1\text{ cm}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{1\text{ ms}}{1 \times 10^{-3}\text{ s}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} = 46.6\ \frac{\text{km}}{\text{hr}}$

Estimate: $0.5 \times 2.5 = 1.25$; $1.25 \times 0.01 \approx 0.01$; $0.01 \times 60 \times 60 \approx 36$ km/hr

(e) $\frac{22.50\text{ gal}}{\text{min}} \times \frac{3.7854\text{ L}}{\text{gal}} \times \frac{1\text{ min}}{60\text{ s}} = 1.41953 = 1.420\text{ L/s}$

Estimate: $20 \times 4 = 80$; $80/60 \approx 1.3$ L/s

(f) $0.02500\text{ ft}^3 \times \frac{12^3\text{ in}^3}{1\text{ ft}^3} \times \frac{2.54^3\text{ cm}^3}{1\text{ in}^3} = 707.9\text{ cm}^3$

Estimate: $10^3 = 1000$; $3^3 = 27$; $1000 \times 27 = 27{,}000$; $27{,}000/0.04 \approx 700\text{ cm}^3$

1.48 (a) $0.105\text{ in} \times \frac{2.54\text{ cm}}{\text{in}} \times \frac{1 \times 10^{-2}\text{ m}}{\text{cm}} \times \frac{1\text{ mm}}{1 \times 10^{-3}\text{ m}} = 2.667 = 2.67\text{ mm}$

(b) $0.650\text{ qt} \times \frac{1\text{ L}}{1.057\text{ qt}} \times \frac{1\text{ mL}}{1 \times 10^{-3}\text{ L}} = 614.94 = 615\text{ mL}$

(c) $\frac{8.75\ \mu\text{m}}{\text{s}} \times \frac{1 \times 10^{-6}\text{ m}}{1\ \mu\text{m}} \times \frac{1\text{ km}}{1 \times 10^3\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} = 3.15 \times 10^{-5}\text{ km/hr}$

(d) $1.955\ m^3 \times \frac{(1.0936)^3\ yd^3}{1\ m^3} = 2.55695 = 2.557\ yd^3$

(e) $\frac{\$3.99}{lb} \times \frac{2.205\ lb}{1\ kg} = 8.798 = \$8.80/kg$

(f) $\frac{8.75\ lb}{ft^3} \times \frac{453.59\ g}{1\ lb} \times \frac{1\ ft^3}{12^3\ in^3} \times \frac{1\ in^3}{2.54^3\ cm^3} \times \frac{1\ cm^3}{1\ mL} = 0.140\ g/mL$

1.49 (a) $31\ gal \times \frac{4\ qt}{1\ gal} \times \frac{1\ L}{1.057\ qt} = 1.2 \times 10^2\ L$

Estimate: $(30 \times 4)/1 \approx 120$ L

(b) $\frac{6\ mg}{kg\ (body)} \times \frac{1\ kg}{2.205\ lb} \times 185\ lb = 5 \times 10^2\ mg$

Estimate: $6/2 = 3$; $3 \times 180 = 540$ mg

(c) $\frac{400\ km}{47.3\ L} \times \frac{1\ mi}{1.6093\ km} \times \frac{1\ L}{1.057\ qt} \times \frac{4\ qt}{1\ gal} = \frac{19.9\ mi}{gal}$

(2×10^1 mi/gal for 1 sig fig)

Estimate: $400/50 = 8$; $8/1.6 = 5$; $5/1 = 5$;$.5 \times 4 \approx 20$ mi/gal

(d) $\frac{50\ cups}{1\ lb} \times \frac{1\ qt}{4\ cups} \times \frac{1\ L}{1.057\ qt} \times \frac{1000\ mL}{1\ L} \times \frac{1\ lb}{453.6\ g} = \frac{26\ mL}{g}$

(3×10^1 mL/L for 1 sig fig)

Estimate: $50/4 = 12$; $1000/500 = 2$; $(12 \times 2)/1 \approx 24$ mL/g

1.50 (a) $1257\ mi \times \frac{1\ km}{0.62137\ mi} \times \frac{charge}{225\ km} = 8.99$ charges

Since charges are integral events, 9 total charges are required. The trip begins with a full charge, so 8 additional charges during the trip are needed.

(b) $\frac{14\ m}{s} \times \frac{1\ km}{1 \times 10^3\ m} \times \frac{1\ mi}{1.6093\ km} \times \frac{60\ s}{1\ min} \times \frac{60\ min}{1\ hr} = 31\ mi/hr$

(c) $450\ in^3 \times \frac{(2.54)^3\ cm^3}{1\ in^3} \times \frac{1\ mL}{1\ cm^3} \times \frac{1 \times 10^{-3}\ L}{1\ mL} = 7.37\ L$

(d) $2.4 \times 10^5\ barrels \times \frac{42\ gal}{1\ barrel} \times \frac{4\ qt}{1\ gal} \times \frac{1\ L}{1.057\ qt} = 3.8 \times 10^7\ L$

1.51 $14.5\ ft \times 16.5\ ft \times 8.0\ ft = 1914 = 1.9 \times 10^3\ ft^3$ (2 sig figs)

$$1914\ ft^3 \times \frac{(1\ yd)^3}{(3\ ft)^3} \times \frac{(1\ m)^3}{(1.0936)^3\ yd^3} \times \frac{10^3\ dm^3}{1\ m^3} \times \frac{1\ L}{1\ dm^3} \times \frac{1.19\ g}{L} \times \frac{1\ kg}{1000\ g} = 64.4985 = 64\ kg\ air$$

Estimate: $1900/27 \approx 60$; $(60 \times 1)/1 \approx 60$ kg

1.52 $11.0 \text{ ft} \times 11.5 \text{ ft} \times 20.5 \text{ ft} = 2593.25 = 2.59 \times 10^3 \text{ ft}^3$

$$2593.25 \text{ ft}^3 \times \frac{(1 \text{ yd})^3}{(3 \text{ ft})^3} \times \frac{(1 \text{ m})^3}{(1.0936 \text{ yd})^3} \times \frac{48 \, \mu\text{g CO}}{1 \text{ m}^3} \times \frac{1 \times 10^{-6} \text{ g}}{1 \, \mu\text{g}} = 3.5 \times 10^{-3} \text{ g CO}$$

1.53 Select a common unit for comparison, in this case the cm.

1 in ≈ 2.5 cm, 1 m = 100 cm

57 cm = 57 cm

14 in ≈ 35 cm

1.1 m = 110 cm

The order of length from shortest to longest is 14-in shoe < 57-cm string < 1.1-m pipe.

1.54 Select a common unit for comparison, in this case the kg.

1 kg > 2 lb, 1 L ≈ 1 qt

5 lb potatoes < 2.5 kg

5 kg sugar = 5 kg

1 gal = 4 qt ≈ 4 L; 1 mL H_2O = 1 g H_2O; 1 L = 1000 g, 4 L = 4000 g = 4 kg

The order of mass from lightest to heaviest is 5 lb potatoes < 1 gal water < 5 kg sugar.

1.55 Strategy: 1) Calculate volume of gold (Au) in cm^3 in the sheet

2) Mass = density × volume

3) Change g → troy oz and $

$$100 \text{ ft} \times 82 \text{ ft} \times \frac{(12)^2 \text{ in}^2}{1 \text{ ft}^2} \times 5 \times 10^{-6} \text{ in} \times \frac{(2.54)^3 \text{ cm}^3}{1 \text{ in}^3} = 96.75 = 1 \times 10^2 \text{ cm}^3 \text{ Au}$$

$$96.75 \text{ cm}^3 \text{ Au} \times \frac{19.32 \text{ g}}{1 \text{ cm}^3} \times \frac{1 \text{ troy oz}}{31.1034768 \text{ g}} \times \frac{\$953}{\text{troy oz}} = \$57{,}272 = \$6 \times 10^4$$

(Strictly speaking, the datum 100 ft has 1 sig fig, so the result has 1 sig fig.)

1.56 A wire is a very long, thin cylinder of volume, $V = \pi r^2 h$, where h is the length of the wire and πr^2 is the cross-sectional area of the wire.

Strategy: 1) Calculate total volume of copper in cm^3 from mass and density

2) $h \text{ (length in cm)} = \dfrac{V}{\pi r^2}$

3) Change cm → ft

$$150 \text{ lb Cu} \times \frac{453.6 \text{ g}}{1 \text{ lb Cu}} \times \frac{1 \text{ cm}^3}{8.94 \text{ g}} = 7610.7 = 7.61 \times 10^3 \text{ cm}^3$$

$$r = d/2 = 7.50 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} \times \frac{1}{2} = 0.375 \text{ cm}$$

$$h = \frac{V}{\pi r^2} = \frac{7610.7 \text{ cm}^3}{\pi(0.375)^2 \text{ cm}^2} = 1.7227 \times 10^4 = 1.72 \times 10^4 \text{ cm}$$

$$1.7227 \times 10^4 \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}} = 565 \text{ ft}$$

(too difficult to estimate)

Additional Exercises

1.57 (a) A gold coin is probably a *solid solution*. Pure gold (element 79) is too soft and too valuable to be used for coinage, so other metals are added. However, the simple term "gold coin" does not give a specific indication of the other metals in the mixture.

A cup of coffee is a *solution* if there are no suspended solids (coffee grounds). It is a heterogeneous mixture if there are grounds. If cream or sugar is added, the homogeneity of the mixture depends on how thoroughly the components are mixed.

A wood plank is a *heterogeneous mixture* of various cellulose components. The different domains in the mixture are visible as wood grain or knots.

(b) The ambiguity in each of these examples is that the name of the substance does not provide a complete description of the material. We must rely on mental images, and these vary from person to person.

1.58 (a) A *hypothesis* is a possible explanation for certain phenomena based on preliminary experimental data. A *theory* may be more general, and has a significant body of experimental evidence to support it; a theory has withstood the test of experimentation.

(b) A scientific *law* is a summary or statement of natural behavior; it tells how matter behaves. A *theory* is an explanation of natural behavior; it attempts to explain why matter behaves the way it does.

1.59 Any sample of vitamin C has the same relative amount of carbon and oxygen; the ratio of oxygen to carbon in the isolated sample is the same as the ratio in synthesized vitamin C.

$$\frac{2.00 \text{ g O}}{1.50 \text{ g C}} = \frac{x \text{ g O}}{6.35 \text{ g C}}; \quad x = \frac{(2.00 \text{ g O})(6.35 \text{ g C})}{1.50 \text{ g C}} = 8.47 \text{ g O}$$

This calculation assumes the law of constant composition.

1.60 (a) I. (22.52 + 22.48 + 22.54)/3 = 22.51

II. (22.64 + 22.58 + 22.62)/3 = 22.61

Based on the average, set I is more accurate. That is, it is closer to the true value of 22.52%.