Chapter 1 – Matter and Energy

1.1 (a) mass; (b) chemical property; (c) mixture; (d) element; (e) energy; (f) physical property; (g) liquid; (h) density; (i) homogeneous mixture; (j) solid state

1.2 (a) atom; (b) chemical change; (c) matter; (d) compound; (e) molecule; (f) physical change; (g) gas; (h) potential energy; (i) hypothesis; (j) kinetic energy

1.3 When converting to scientific notation, count the number of places you need to move the decimal point. Zeros to the left of the number are always dropped. For example, the number 0.002030 becomes 2.030×10^{-3} and the zeros to the left of 2030 are dropped. The zero to the right is only kept if it is significant (covered later in this chapter). If the decimal point moves right, the exponent decreases. If the decimal moves left the exponent increases.
(a) 2.95×10^{4}; (b) 8.2×10^{-5}; (c) 6.5×10^{8}; (d) 1.00×10^{-2}

1.4 When converting to scientific notation, count the number of places you need to move the decimal point. Zeros to the left of the number are always dropped. For example, the number 0.002030 becomes 2.030×10^{-3} and the zeros to the left of 2030 are dropped. The zero to the right is only kept if it is significant (covered later in this chapter). If the decimal point moves right, the exponent decreases. If the decimal moves left the exponent increases.
(a) 1.0×10^{-4}; (b) 4.5×10^{3}; (c) 9.01×10^{7}; (d) 7.9×10^{-6}

1.5 When converting from scientific notation to standard notation you may need to add place-holder zeros so that the magnitude of the number is correct. For example, to get 1.86×10^{-5} into standard notation, you need to increase the power by five, so the decimal moves to the left. In addition, you'll need four placeholder zeros after the decimal to show the magnitude of the number, 0.0000186.
(a) 0.0000186; (b) 10,000,000; (c) 453,000; (d) 0.0061

1.6 When converting from scientific notation to standard notation you may need to add place-holder zeros so that the magnitude of the number is correct. For example, to get 1.86×10^{-5} into standard notation, you need to increase the power by five, so the decimal moves to the left. In addition, you'll need four placeholder zeros after the decimal to show the magnitude of the number, 0.0000186.
(a) 8200; (b) 0.000002025; (c) 0.07; (d) 300,000,000

1.7 (a) 6.2×10^{3}; (b) 3.5×10^{7}; (c) 2.9×10^{-3}; (d) 2.5×10^{-7}; (e) 8.20×10^{5}; (f) 1.6×10^{-6}

1.8 (a) 2.0×10^{8}; (b) 1.5×10^{14}; (c) 3.0×10^{-10}; (d) 8.5×10^{-6}; (e) 8.56×10^{5}; (f) 1.26×10^{8}

1.9 Nonzero digits and zeros between nonzero digits are significant. Zeros at the end of a number and to the right of the decimal are significant. Zeros to the left of the first nonzero digit and in exponentials (i.e. $\times 10^{3}$) are not significant. The number 0.0950 has three significant digits. The digits "950" are all significant because (1) the 9 and 5 are nonzero, and (2) the zero is significant because it is at the end of the number and to the right of the decimal.
(a) 3; (b) 2; (c) 4; (d) 2; (e) 3

1.10 Nonzero digits and zeros between nonzero digits are significant. Zeros at the end of a number and to the right of the decimal are significant. Zeros to the left of the first nonzero digit and in exponentials (i.e. $\times 10^{3}$) are not significant. The number 0.04350 has four significant digits. The digits "4350" are all significant because (1) the 4, 3, and 5 are nonzero, and (2) the zero is significant because it is at the end of the number and to the right of the decimal.
(a) 3; (b) 4; (c) 4; (d) 4; (e) 2

1.11 For operations involving multiplication, division, and powers, the answer will have the same number of significant figures as the number with the fewest significant figures. For example, in part (c) the number 1.201×10^3 has four significant figures and the number 1.2×10^{-2} has two significant figures. The calculated value is 14.412 which will be rounded to two significant figures, 14.
(a) 1.5; (b) 1.5; (c) 14; (d) 1.20

1.12 For operations involving multiplication, division, and powers, the answer will have the same number of significant figures as the number with the fewest significant figures. For example, in part (a) the number 1.600×10^{-7} has four significant figures and the number 2.1×10^3 has two significant figures. The calculated value is 3.36×10^3 which will be rounded to two significant figures, 3.4×10^{-4}.
(a) 3.4×10^{-4}; (b) 2.35; (c) 5.12; (d) 2.0

1.13 For operations involving addition and subtraction, the answer can only be as precise as the least precise number. A number that has its last significant digit in the tenths place (one place past the decimal) has less precision than a number that ends in the hundredths place (two places past the decimal). If you add these two numbers together, you would have to round the answer to the tenths place. For example, in part (a) 1.6 + 1.15 gives a value of 2.75. This number will have to be rounded to the tenths place, 2.8.
(a) 2.8; (b) 0.28; (c) 2.8; (d) 0.049

1.14 For operations involving addition and subtraction, the answer can only be as precise as the least precise number. A number that has its last significant digit in the tenths place (one place past the decimal) has less precision than a number that ends in the ten thousandths place (four places past the decimal). If you add these two numbers together, you would have to round the answer to the tenths place. For example, in part (a) 87.5 + 1.3218 gives a value of 88.8218. This number will have to be rounded to the tenths place, 88.8.
(a) 88.8; (b) 12; (c) 0.22; (d) 1.80

1.15 When calculations involve multiple steps, the number of significant figures in subsequent steps requires us to know the number of significant figures in the answers from the previous steps. We must keep track of the last significant figure in the answer to each step. For example, in part (c) 0.35 m × 0.55 m gives a value of 0.1925 m^2. Following the rules of multiplication/division, this value should only be expressed to two significant figures. However, to prevent rounding errors, we don't round yet. We'll make note that the first step only has two significant figures by underlining the last significant digit, $0.1\underline{9}25\ m^2$. In the second step of the calculation we add this number to 25.2 m^2. The value 25.3925 is obtained from the calculation. Following the rules of addition/subtraction, the answer can only be as precise as the least precise number. For this calculation, the number will have to be rounded to the tenths place, 25.4 m^2.

(a) $$\frac{(20.90\text{ kg} - 12.90\text{ kg})}{10.00\text{ L}} = \frac{(8.00\text{ kg})}{10.00\text{ L}} = 0.800\text{ kg/L}$$

(b) $$\left[\frac{45.82\text{ g}}{(3.0\text{ cm})^3} - \frac{0.64\text{ g}}{(0.859\text{ cm})^3}\right] \div 2 = \left[\frac{45.82\text{ g}}{(2\underline{7}\text{ cm}^3)} - \frac{0.64\text{ g}}{(0.63\underline{3}8498\text{ cm}^3)}\right] \div 2$$

$$= \left[1.\underline{6}9704\text{ g/cm}^3 - 1.\underline{0}0972\text{ g/cm}^3\right] \div 2 = \left[0.\underline{6}8732\text{ g/cm}^3\right] \div 2 = 0.\underline{3}4366\text{ g/cm}^3 = 0.3\text{ g/cm}^3$$

(c) $(0.35\text{ m} \times 0.55\text{ m}) + 25.2\text{ m}^2 = (0.1\underline{9}25\text{ m}^2) + 25.2\text{ m}^2 = 25.\underline{3}925\text{ m}^2 = 25.4\text{ m}^2$

1.16 When calculations involve multiple steps, the number of significant figures in subsequent steps requires us to know the number of significant figures in the answers from the previous steps. We must keep track of the last significant figure in the answer to each step. For example, in part (a) 0.25 m/s × 45.77 s gives a value of 11.4425 m. Following the rules of multiplication/division, this value should only be expressed to two significant figures. However, to prevent rounding errors, we don't round yet. We'll make note that the first step only has two significant figures by underlining the last significant digit, $1\underline{1}.4425$ m. In the second step of the calculation we add this number to 5.0 m. The value 16.4425 is obtained from the calculation. Following the rules of addition/subtraction, the answer can only be as precise as the least precise number. For this calculation, the number will have to be rounded to the ones place, 16 m.

(a) $(0.25 \text{ m/s} \times 45.77 \text{ s}) + 5.0 \text{ m} = (1\underline{1}.4425 \text{ m}) + 5.0 \text{ m} = 1\underline{6}.4425 \text{ m} = 16 \text{ m}$

(b) $$\frac{2.523 \text{ lb}}{(62.9 \text{ gal} - 58.9 \text{ gal})} = \frac{2.523 \text{ lb}}{(4.0 \text{ gal})} = 0.6\underline{3}075 \text{ lb/gal} = 0.63 \text{ lb/gal}$$

(c) $(9.0 \text{ cm} \times 15.1 \text{ cm} \times 10.5 \text{ cm}) + 75.7 \text{ cm}^3 = (1\underline{4}26.95 \text{ cm}^3) + 75.7 \text{ cm}^3 = 1\underline{5}02.65 \text{ cm}^3 = 1.5 \times 10^3 \text{ cm}^3$

1.17 (a) 1.21; (b) 0.204; (c) 1.84; (d) 42.2; (e) 0.00710

1.18 (a) 0.0205; (b) 1.36×10^4; (c) 13.5; (d) 16.2; (e) 1.00

1.19 When you are converting between a unit and the same base unit with a prefix (e.g. mm to m or vice versa) you can find the conversion factors in Math Toolbox 1.3. Suppose you want to convert between millimeters and meters. There are several ways you can do this. First, by definition milli is = 10^{-3}, so 1 mm = 10^{-3} m. You might also already know that there are one thousand millimeters in a meter, 1000 mm = 1 m. Either conversion factor is correct. Next, you set up your calculation so that the appropriate units cancel. The English-Metric conversions are also found in Math Toolbox 1.3.

(a) Map: $\text{Length in mm} \xrightarrow{1 \text{ mm} = 10^{-3} \text{ m}} \text{Length in m}$

Problem solution:

$$\text{Length in m} = 36 \cancel{\text{mm}} \times \frac{10^{-3} \text{ m}}{1 \cancel{\text{mm}}} = 0.036 \text{ m}$$

(b) Map: $\text{Mass in kg} \xrightarrow{1 \text{ kg} = 10^{3} \text{ g}} \text{Mass in g}$

Problem solution:

$$\text{Mass in g} = 357 \cancel{\text{kg}} \times \frac{10^{3} \text{ g}}{1 \cancel{\text{kg}}} = 3.57 \times 10^5 \text{ g}$$

(c) Map: $\text{Volume in mL} \xrightarrow{1 \text{ mL} = 10^{-3} \text{ L}} \text{Volume in L}$

Problem solution:

$$\text{Volume in L} = 76.50 \cancel{\text{mL}} \times \frac{10^{-3} \text{ L}}{1 \cancel{\text{mL}}} = 0.07650 \text{ L}$$

(d) Map: $\text{Length in m} \xrightarrow{1 \text{ cm} = 10^{-2} \text{ m}} \text{Length in cm}$

Problem solution:

$$\text{Length in cm} = 0.0084670 \cancel{\text{m}} \times \frac{\text{cm}}{10^{-2} \cancel{\text{m}}} = 0.84670 \text{ cm}$$

(e) Map: $\text{Length in nm} \xrightarrow{1 \text{ nm} = 10^{-9} \text{ m}} \text{Length in m}$

Problem solution:

$$\text{Length in m} = 597 \cancel{\text{nm}} \times \frac{10^{-9} \text{m}}{1 \cancel{\text{nm}}} = 5.97 \times 10^{-7} \text{m}$$

(f) This is the first metric-English conversion, but the process is exactly the same. Note that the in-cm conversion factor is exact, so it is not a factor in determining significant figures:

Map: Length in in $\xrightarrow{1\text{ in} = 2.54\text{ cm (exact)}}$ Length in cm

Problem solution:

$$\text{Length in cm} = 36.5\,\cancel{\text{in}} \times \frac{2.54\text{ cm}}{1\,\cancel{\text{in}}} = 92.7\text{ cm}$$

(g) Map: Mass in lb $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ Mass in g

Problem solution:

$$\text{Mass in g} = 168\,\cancel{\text{lb}} \times \frac{453.6\text{ g}}{1\,\cancel{\text{lb}}} = 7.62 \times 10^4\text{ g}$$

(h) Map: Volume in qt $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ Volume in L

Problem solution:

$$\text{Volume in L} = 914\,\cancel{\text{qt}} \times \frac{0.9464\text{ L}}{1\,\cancel{\text{qt}}} = 865\text{ L}$$

(i) Map: Length in cm $\xrightarrow{1\text{ in} = 2.54\text{ cm (exact)}}$ Length in in

Problem solution:

$$\text{Length in in} = 44.5\,\cancel{\text{cm}} \times \frac{\text{in}}{2.54\,\cancel{\text{cm}}} = 17.5\text{ in}$$

(j) Map: Mass in g $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ Mass in lb

Problem solution:

$$\text{Mass in lb} = 236.504\,\cancel{\text{g}} \times \frac{\text{lb}}{453.6\,\cancel{\text{g}}} = 0.5214\text{ lb}$$

(k) Map: Volume in L $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ Volume in qt

Problem solution:

$$\text{Volume in qt} = 2.0\,\cancel{\text{L}} \times \frac{1\text{ qt}}{0.9464\,\cancel{\text{L}}} = 2.1\text{ qt}$$

1.20 When you are converting between a unit and the same base unit with a prefix (i.e. mm to m or vice versa) you can find the conversion factors in Math Toolbox 1.3. Suppose you want to convert between millimeters and meters. There are several ways you can do this. First, by definition milli is = 10^{-3}, so 1 mm = 10^{-3} m. You might also already know that there are one thousand millimeters in a meter, 1000 mm = 1 m. Either conversion factor is correct. Next you set up your calculation so that the appropriate units cancel. The English-Metric conversions are also found in Math Toolbox 1.3.

(a) Map: Length in km $\xrightarrow{1\text{ km} = 10^3\text{ m}}$ Length in m

Problem solution:

$$\text{Length in m} = 75.5\,\cancel{\text{km}} \times \frac{10^3\text{ m}}{1\,\cancel{\text{km}}} = 7.55 \times 10^4\text{ m}$$

(b) Map: Mass in g $\xrightarrow{1\text{ mg} = 10^{-3}\text{ g}}$ Mass in mg

Problem solution:

$$\text{Mass in mg} = 25.7\,\cancel{\text{g}} \times \frac{1\text{ mg}}{10^{-3}\,\cancel{\text{g}}} = 2.57 \times 10^4\text{ mg}$$

(c) Map: Volume in L $\xrightarrow{1\text{ dL} = 10^{-1}\text{ L}}$ Volume in dL

Problem solution:

$$\text{Volume in dL} = 0.516\,\cancel{\text{L}} \times \frac{1\text{ dL}}{10^{-1}\,\cancel{\text{L}}} = 5.16\text{ dL}$$

(d) Map: Length in cm $\xrightarrow{1\text{ cm} = 10^{-2}\text{ m}}$ Length in m

Problem solution:

$$\text{Length in m} = 5.2\,\cancel{\text{cm}} \times \frac{10^{-2}\text{ m}}{1\,\cancel{\text{cm}}} = 0.052\text{ m}$$

(e) Map: Length in m $\xrightarrow{1\text{ nm} = 10^{-9}\text{ m}}$ Length in nm

Problem solution:

$$\text{Length in nm} = 0.000000450\,\cancel{\text{m}} \times \frac{1\text{ nm}}{10^{-9}\,\cancel{\text{m}}} = 4.50 \times 10^{2}\text{ m}$$

(f) Map: Length in in $\xrightarrow{1\text{ in} = 2.54\text{ cm (exact)}}$ Length in cm

Problem solution:

$$\text{Length in cm} = 12\,\cancel{\text{in}} \times \frac{2.54\text{ cm}}{1\,\cancel{\text{in}}} = 3.0 \times 10^{1}\text{ cm}$$

(g) Map: Mass in lb $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ Mass in g

Problem solution:

$$\text{Mass in g} = 25.6\,\cancel{\text{lb}} \times \frac{453.6\text{ g}}{1\,\cancel{\text{lb}}} = 1.16 \times 10^{4}\text{ g}$$

(h) Map: Volume in qt $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ Volume in L

Problem solution:

$$\text{Volume in L} = 4.005\,\cancel{\text{qt}} \times \frac{0.9464\text{ L}}{1\,\cancel{\text{qt}}} = 3.790\text{ L}$$

(i) Map: Length in cm $\xrightarrow{1\text{ in} = 2.54\text{ cm (exact)}}$ Length in in

Problem solution:

$$\text{Length in in} = 934\,\cancel{\text{cm}} \times \frac{1\text{ in}}{2.54\,\cancel{\text{cm}}} = 368\text{ in}$$

(j) Map: Mass in g $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ Mass in lb

Problem solution:

$$\text{Mass in lb} = 155\,\cancel{\text{g}} \times \frac{\text{lb}}{453.6\,\cancel{\text{g}}} = 0.342\text{ lb}$$

(k) Map: Volume in L $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ Volume in qt

Problem solution:

$$\text{Volume in qt} = 22.4\,\cancel{\text{L}} \times \frac{1\text{ qt}}{0.9464\,\cancel{\text{L}}} = 23.7\text{ qt}$$

1.21 For all conversion problems, you need to identify the conversion factors which connect the starting units to the final units. In (a) for example, we need to convert from meters to miles. In Math Toolbox 1.3, we find that 1 mile is 1.609 km and we also know that 1 km is 1000 m. Once you establish these relationships – miles to kilometers to meters – you have the necessary information to do the calculation. *It is very important to recognize that there are often many different paths in unit conversion problems. The paths sometimes depend on which conversion factors you have handy, but they will all lead to the same answer.*

(a) Map: length in m $\xrightarrow{1\text{ km} = 10^{3}\text{m}}$ length in km $\xrightarrow{1\text{ mi} = 1.609\text{ km}}$ length in mi

Problem solution:

$$\text{length in mi} = 947\,\cancel{\text{m}} \times \frac{1\,\cancel{\text{km}}}{10^{3}\,\cancel{\text{m}}} \times \frac{1\text{ mi}}{1.609\,\cancel{\text{km}}} = 0.589\text{ mi}$$

(b) Map: mass in kg $\xrightarrow{1\text{ kg} = 10^3\text{g}}$ mass in g $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in lb

Problem solution:

$$\text{mass in lb} = 6.74\,\cancel{\text{kg}} \times \frac{10^3\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \frac{1\text{ lb}}{453.6\ \cancel{\text{g}}} = 14.9\text{ lb}$$

(c) Map: volume in mL $\xrightarrow{1\text{ mL} = 10^{-3}\text{L}}$ volume in L $\xrightarrow{1\text{ gal} = 3.785\text{ L}}$ volume in gal

Problem solution:

$$\text{volume in gal} = 250.4\,\cancel{\text{mL}} \times \frac{10^{-3}\ \cancel{\text{L}}}{1\ \cancel{\text{mL}}} \times \frac{1\text{ gal}}{3.785\ \cancel{\text{L}}} = 0.06616\text{ gal}$$

(d) Map: volume in dL $\xrightarrow{1\text{ dL} = 10^{-1}\text{ L}}$ volume in L $\xrightarrow{1\text{ mL} = 10^{-3}\text{ L}}$ volume in mL

Problem solution:

$$\text{Volume in mL} = 2.30\,\cancel{\text{dL}} \times \frac{10^{-1}\ \cancel{\text{L}}}{1\ \cancel{\text{dL}}} \times \frac{1\text{ mL}}{10^{-3}\ \cancel{\text{L}}} = 2.30 \times 10^2\text{ mL}$$

(e) Map: length in cm $\xrightarrow{1\text{ cm} = 10^{-2}\text{ m}}$ length in m $\xrightarrow{1\text{ nm} = 10^{-9}\text{ m}}$ length in nm

Problem solution:

$$\text{length in nm} = 0.000450\,\cancel{\text{cm}} \times \frac{10^{-2}\ \cancel{\text{m}}}{1\ \cancel{\text{cm}}} \times \frac{1\text{ nm}}{10^{-9}\ \cancel{\text{m}}} = 4.50 \times 10^3\text{ nm}$$

(f) Map: length in in $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ length in cm $\xrightarrow{1\text{ cm} = 10^{-2}\text{ m}}$ length in m

Problem solution:

$$\text{length in m} = 37.5\,\cancel{\text{in}} \times \frac{2.54\ \cancel{\text{cm}}}{1\ \cancel{\text{in}}} \times \frac{10^{-2}\text{ m}}{1\ \cancel{\text{cm}}} = 0.952\text{ m}$$

(g) Map: mass in lb $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in g $\xrightarrow{1\text{ kg} = 10^3\text{ g}}$ mass in kg

Problem solution:

$$\text{mass in kg} = 689\,\cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\text{ kg}}{10^3\ \cancel{\text{g}}} = 312\text{ kg}$$

(h) Map: volume in qt $\xrightarrow{1\text{ qt} = 0.9464\text{L}}$ volume in L $\xrightarrow{1\text{ mL} = 10^{-3}\text{ L}}$ volume in mL

Problem solution:

$$\text{volume in mL} = 0.5\,\cancel{\text{qt}} \times \frac{0.9464\ \cancel{\text{L}}}{1\ \cancel{\text{qt}}} \times \frac{1\text{ mL}}{10^{-2}\ \cancel{\text{L}}} = 5 \times 10^2\text{ mL}$$

(i) Map: length in cm $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ length in in $\xrightarrow{1\text{ ft} = 12\text{ in}}$ length in ft

Problem solution:

$$\text{length in ft} = 125\,\cancel{\text{cm}} \times \frac{1\ \cancel{\text{in}}}{2.54\ \cancel{\text{cm}}} \times \frac{1\text{ ft}}{12\ \cancel{\text{in}}} = 4.10\text{ ft}$$

(j) Map: mass in mg $\xrightarrow{1\text{ mg} = 10^{-3}\text{g}}$ mass in g $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in lb

Problem solution:

$$\text{mass in lb} = 542\,\cancel{\text{mg}} \times \frac{10^{-3}\ \cancel{\text{g}}}{1\ \cancel{\text{mg}}} \times \frac{1\text{ lb}}{453.6\ \cancel{\text{g}}} = 1.19 \times 10^{-3}\text{ lb}$$

(k) Map: volume in nL $\xrightarrow{1\text{ nL} = 10^{-9}\text{ L}}$ volume in L $\xrightarrow{1\text{ gal} = 3.785\text{ L}}$ volume in gal

Problem solution:

$$\text{volume in gal} = 25\,\cancel{\text{nL}} \times \frac{10^{-3}\ \cancel{\text{L}}}{1\ \cancel{\text{nL}}} \times \frac{1\text{ gal}}{3.785\ \cancel{\text{L}}} = 6.6 \times 10^{-9}\text{ gal}$$

1.22 For all conversion problems, you need to identify the conversion factors which connect the starting units to the final units. In (a) for example, we need to convert from centimeters to feet. In Math Toolbox 1.3, we find that 1 in is 2.54 cm (exactly) and we also know that there are 12 inches in 1 foot. Once you establish these relationships – cm to in to feet – you have the necessary information to do the calculation. *It is very important to recognize that there are often many different paths in unit conversion problems. The paths sometimes depend on which conversion factors you have handy, but they will all lead to the same answer.*

(a) Map: length in cm $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ length in in $\xrightarrow{1\text{ ft} = 12\text{ in}}$ length in ft

Problem solution:

$$\text{length in ft} = 32\,\cancel{\text{cm}} \times \frac{1\ \cancel{\text{in}}}{2.54\ \cancel{\text{cm}}} \times \frac{1\text{ ft}}{12\ \cancel{\text{in}}} = 1.0\text{ ft}$$

(b) Map: mass in kg $\xrightarrow{1\text{ kg} = 10^3\text{g}}$ mass in g $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in lb

Problem solution:

$$\text{mass in lb} = 0.579\,\cancel{\text{kg}} \times \frac{10^3\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \frac{1\text{ lb}}{453.6\ \cancel{\text{g}}} = 1.28\text{ lb}$$

(c) Map: volume in μL $\xrightarrow{1\ \mu\text{L} = 10^{-6}\text{ L}}$ volume in L $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ volume in qt

Problem solution:

$$\text{volume in qy} = 22.70\,\cancel{\mu\text{L}} \times \frac{10^{-6}\ \cancel{\text{L}}}{\cancel{\mu\text{L}}} \times \frac{1\text{ qt}}{0.9464\ \cancel{\text{L}}} = 2.399 \times 10^{-5}\text{ qt}$$

(d) Map: length in mm $\xrightarrow{1\text{ mm} = 10^{-3}\text{m}}$ length in m $\xrightarrow{1\text{ km} = 10^3\text{ m}}$ length in km

Problem solution:

$$\text{length in km} = 9212\,\cancel{\text{mm}} \times \frac{10^{-3}\ \cancel{\text{m}}}{1\ \cancel{\text{mm}}} \times \frac{1\text{ km}}{10^3\ \cancel{\text{m}}} = 9.212 \times 10^{-3}\text{ km}$$

(e) Map: length in nm $\xrightarrow{1\text{ nm} = 10^{-9}\text{ m}}$ length in m $\xrightarrow{1\text{ mm} = 10^{-3}\text{ m}}$ length in mm

Problem solution:

$$\text{length in mm} = 465\,\cancel{\text{nm}} \times \frac{10^{-9}\ \cancel{\text{m}}}{1\ \cancel{\text{nm}}} \times \frac{1\text{ mm}}{10^{-3}\ \cancel{\text{m}}} = 4.65 \times 10^{-4}\text{ mm}$$

(f) Map: length in ft $\xrightarrow{1\text{ ft} = 12\text{ in}}$ length in in $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ length in cm

Problem solution:

$$\text{length in cm} = 4\,\cancel{\text{ft}} \times \frac{12\ \cancel{\text{in}}}{1\ \cancel{\text{ft}}} \times \frac{2.54\text{ cm}}{1\ \cancel{\text{in}}} = 1 \times 10^2\text{ cm}$$

(g) Map: mass in lb $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in g $\xrightarrow{1\text{ kg} = 10^3\text{ g}}$ mass in kg

Problem solution:

$$\text{mass in kg} = 2.7\,\cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\text{ kg}}{10^3\ \cancel{\text{g}}} = 1.2\text{ kg}$$

(h) Map: volume in qt $\xrightarrow{1\text{ qt} = 0.9464\text{ L}}$ volume in L $\xrightarrow{1\text{ mL} = 10^{-3}\text{ L}}$ volume in mL

Problem solution:

$$\text{volume in mL} = 8.320\,\cancel{\text{qt}} \times \frac{0.9464\ \cancel{\text{L}}}{1\ \cancel{\text{qt}}} \times \frac{1\text{ mL}}{10^{-3}\ \cancel{\text{L}}} = 787.4\text{ mL}$$

(i) Map: length in km $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ length in cm $\xrightarrow{1\text{ ft} = 12\text{ in}}$ length in ft

Problem solution:

$$\text{length in ft} = 375\,\cancel{\text{km}} \times \frac{1\ \cancel{\text{mi}}}{1.609\,\cancel{\text{km}}} \times \frac{5280\text{ ft}}{1\ \cancel{\text{mi}}} = 1.23 \times 10^{6}\text{ ft}$$

(j) There is a bit of a short cut in this problem. If you know that a pound equals 16 oz and 453.6 g, you can use the conversion 16 oz = 453.6 g. Also, be aware that in English units an ounce is a measure for both mass and volume. For volume we usually designate a "fluid ounce" to distinguish it from the mass measurement.

Map: mass in g $\xrightarrow{16\text{ oz} = 453.6\text{ g}}$ mass in oz

Problem solution:

$$\text{mass in oz} = 62\,\cancel{\text{g}} \times \frac{16\text{ oz}}{453.6\ \cancel{\text{g}}} = 2.2\text{ oz}$$

(k) Map: volume in mL $\xrightarrow{1\text{ nL} =\ 10^{-3}\text{ L}}$ volume in L $\xrightarrow{1\text{ gal} = 3.785\text{ L}}$ volume in gal

Problem solution:

$$\text{volume in gal} = 752\,\cancel{\text{mL}} \times \frac{10^{-3}\ \cancel{\text{L}}}{1\ \cancel{\text{mL}}} \times \frac{1\text{ gal}}{3.785\ \cancel{\text{L}}} = 0.199\text{ gal}$$

1.23 (a) There are actually two different conversions associated with this problem. It helps to consider these separately before setting up the problem. The two conversions are meters to feet and seconds to minutes. As with other conversions, the conversion factors are set up so that units cancel properly. Whether you do the meters to feet or the seconds to minutes conversion first, the answer will be the same.

Map: $\frac{\text{m}}{\text{s}} \xrightarrow{1\text{ min} = 60\text{ s}} \frac{\text{m}}{\text{min}} \xrightarrow{1\text{ yd} = 0.9144\text{ m}} \frac{\text{yd}}{\text{min}} \xrightarrow{1\text{ yd} = 3\text{ ft}} \frac{\text{ft}}{\text{min}}$

Problem solution:

$$\frac{\text{ft}}{\text{min}} = 375\frac{\cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{60\ \cancel{\text{s}}}{1\ \text{min}} \times \frac{1\ \cancel{\text{yd}}}{0.9144\ \cancel{\text{m}}} \times \frac{3\text{ ft}}{1\ \cancel{\text{yd}}} = 7.38 \times 10^{4}\ \frac{\text{ft}}{\text{min}}$$

(b) For conversions of units with exponents, you will have to apply the conversion factor the same number of times as the magnitude of the exponent. It helps if you remind yourself that cm^3 is actually cm × cm × cm. When you convert cm^3 to in^3, the conversion factor is applied three times so that each cm factor in the unit is cancelled.

Map: $\text{cm}^3 \xrightarrow{1\text{ in} = 2.54\text{ cm}} \xrightarrow{1\text{ in} = 2.54\text{ cm}} \xrightarrow{1\text{ in} = 2.54\text{ cm}} \text{in}^3$

Problem solution:

$$\text{Volume in}^3 = 24.5\ \cancel{\text{cm}} \times \cancel{\text{cm}} \times \cancel{\text{cm}} \times \frac{1\text{ in}}{2.54\ \cancel{\text{cm}}} \times \frac{1\text{ in}}{2.54\ \cancel{\text{cm}}} \times \frac{1\text{ in}}{2.54\ \cancel{\text{cm}}} = 1.50\text{ in}^3$$

Most likely when you get accustomed to this process you will find it easier to write:

$$\text{Volume in}^3 = 24.5\ \cancel{\text{cm}^3} \times \left(\frac{1\text{ in}}{2.54\ \cancel{\text{cm}}}\right)^3 = 1.50\text{ in}^3$$

(c) Make sure that you understand conversions with exponents given in part (b) of the problem. You also need to recall that 1 mL = 1 cm^3.

Map: $\frac{g}{mL} \xrightarrow{1\ lb = 453.6\ g} \frac{lb}{mL} \xrightarrow{1\ mL = cm^3} \frac{lb}{cm^3} \xrightarrow{(1\ in = 2.54\ cm)^3} \frac{lb}{in^3}$

Problem solution:

$$\frac{lb}{in^3} = 19.3\ \frac{\cancel{g}}{\cancel{mL}} \times \frac{1\ lb}{453.6\ \cancel{g}} \times \frac{1\ \cancel{mL}}{1\ \cancel{cm^3}} \times \frac{2.54\ \cancel{cm}}{1\ in} \times \frac{2.54\ \cancel{cm}}{1\ in} \times \frac{2.54\ \cancel{cm}}{1\ in} = 0.697\ \frac{lb}{in^3}$$

1.24 (a) There are actually two different conversions associated with this problem. It helps to consider these separately before setting up the problem. The two conversions are feet to centimeters and seconds to minutes. As with other conversions, the conversion factors are set up so that units cancel properly. Whether you do the feet to centimeters or the seconds to minutes conversion first, the answer will be the same. Map:

$\frac{ft}{s} \xrightarrow{1\ min = 60\ s} \frac{ft}{min} \xrightarrow{1\ ft = 12\ in} \frac{in}{min} \xrightarrow{1\ in = 2.54\ cm} \frac{cm}{min}$

Problem solution:

$$\frac{ft}{min} = 27\frac{\cancel{ft}}{\cancel{s}} \times \frac{60\ \cancel{s}}{1\ min} \times \frac{12\ \cancel{in}}{1\ \cancel{ft}} \times \frac{2.54\ cm}{1\ \cancel{in}} = 4.9 \times 10^4\ \frac{cm}{min}$$

(b) For conversions of units with exponents, you will have to apply the conversion factor the same number of times as the magnitude of the exponent. It helps if you remind yourself that ft^3 is actually ft × ft × ft. You can also find that there are 3 ft in a yard and that one yard is 0.9144 m (Math Toolbox 1.3). This means you can apply the conversion 3 ft = 0.9144 m.

Map: $ft^3 \xrightarrow{3\ ft = 0.9144\ m} \xrightarrow{3\ ft = 0.9144\ m} \xrightarrow{3\ ft = 0.9144\ m} m^3$

Problem solution:

$$\text{Volume } m^3 = 2764\ \cancel{ft} \times \cancel{ft} \times \cancel{ft} \times \frac{0.9144\ m}{3\ \cancel{ft}} \times \frac{0.9144\ m}{3\ \cancel{ft}} \times \frac{0.9144\ m}{3\ \cancel{ft}} = 78.27\ m^3$$

Most likely when you get accustom to this process you will find it easier to write:

$$\text{Volume } m^3 = 2764\ \cancel{ft^3} \times \left(\frac{0.9144\ m}{3\ \cancel{ft}}\right)^3 = 78.27\ m^3$$

(c)

Map: $\frac{g}{mL} \xrightarrow{1\ lb = 453.6\ g} \frac{lb}{mL} \xrightarrow{1\ mL = 10^{-3} L} \frac{lb}{L} \xrightarrow{1\ gal = 3.785\ L} \frac{lb}{gal}$

Problem solution:

$$\frac{lb}{gal} = 0.927\ \frac{\cancel{g}}{\cancel{mL}} \times \frac{1\ lb}{453.6\ \cancel{g}} \times \frac{1\ \cancel{mL}}{10^{-3}\ \cancel{L}} \times \frac{3.785\ \cancel{L}}{1\ gal} = 7.74\ \frac{lb}{gal}$$

1.25 When you are trying to classify matter, it helps to carefully read the description. If it contains two or more pure substances, it is some type of mixture. If it only contains one type of substance, you have to consider that it might be an element or compound. Remember, compounds are also called pure substances since each unit of the compound is the same. Water (H_2O) is a pure substance.

(a) Water and dye is a mixture. It is a homogeneous mixture if the dye is evenly mixed into the water.

(b) The pipe is made of copper and nothing else is mentioned. That makes it a pure substance. Since it only contains one type of atom, it is an element.

(c) Air is made up of several different kinds of gases. That means it is a mixture. Also, if you blow up a balloon, you might be adding moisture (water vapor) to the mixture. Because the composition is most likely uniform throughout (gases mix quickly), it is a homogenous mixture.

(d) Pizza is not an element even though you might think it is essential to life. Pizza is made (at the very least) of cheese, bread, and anchovies. That makes it a mixture. Since each slice is not the same, it is a heterogeneous mixture.

1.26 When you are trying to classify matter, it helps to carefully read the description. If it contains two or more pure substances, it is some type of mixture. If it only contains one type of substance, you have to consider that it might be an element or compound. Remember, compounds are also called pure substances since each unit of the compound is the same. Water (H_2O) is a pure substance.

If you look closely at sand, it is made up of grains with different sizes and colors. In addition, the colored grains are not evenly distributed. That makes it a heterogeneous mixture.

(a) The bat is made only of aluminum. That makes it a pure substance. Since it only contains one type of atom, it is an element.

(b) A helium balloon contains only helium, a pure substance. Like the aluminum bat, there is only one type of atom, so it is an element.

(c) The soft drink is a heterogeneous mixture since the bubbles are not distributed evenly. A glass and a soft drink also compose a heterogeneous mixture.

1.27 Matter has mass and occupies space. Any object or substance is matter. It might also be helpful to remember that if a substance has a smell or taste, it is a form of matter because your body has to interact with it for you to sense it. If something makes you hot or cold, it may be some form of energy (for example sunlight). Only (a) is not a form of matter. Any type of light or heat, although it occupies space, does not have mass.

(a) Not matter. Light or heat are forms of energy and do not have mass. They still occupy space.

(b) Gasoline occupies space and has mass. Also, you can smell it so it is some form of matter.

(c) Even though you might not be able to see it, automobile exhaust has mass and occupies space. Also, since you can feel the pressure of the exhaust as it leaves the engine, you can assume it has mass.

(d) Oxygen gas occupies space and is made of oxygen molecules that have mass.

(e) Any object is matter.

1.28 Matter has mass and occupies space. Any object or substance is matter. It might also be helpful to remember that if a substance has a smell or taste, it is a form of matter because your body has to interact with it for you to sense it. If something makes you hot or cold, it may be some form of energy (for example sunlight). Only (a) and (e) are not forms of matter. Any type of light or heat, although it occupies space, does not have mass.

(a) Not matter. Light or heat are forms of energy and do not have mass. They still occupy space.

(b) Sand occupies space and has mass.

(c) Any object, moving or not, is matter.

(d) Balloons occupy space and have mass even though they may be less dense than air.

(e) Not matter. Light or heat are forms of energy and do not have mass. They still occupy space.

1.29 Elements are composed of only one type of atom. Compounds are made up of two or more different elements in some fixed proportion. Natural gas, CH_4, also called methane is an example of a compound. Any sample of methane is composed of one part carbon and four parts hydrogen.

1.30 If you sample any part of a homogenous mixture, you always get the same proportions of substances. Samples taken from a heterogeneous mixture have differing amounts of each substance. For example, every scoop of beans and rice has a different proportion of beans and rice in it. That makes it a heterogeneous mixture.

1.31 Metals are lustrous (shiny) and conduct heat and electricity. In addition, you can form wires with metals (ductile) and you can make foil out of them by hitting them with a hammer (malleable).

1.32 Nonmetals tend to be brittle and do not easily form wires or foils. In addition, they are not usually good conductors of electricity or heat.

1.33 (a) titanium; (b) tantalum; (c) thorium; (d) technetium; (e) thallium

1.34 (a) carbon; (b) calcium; (c) chromium; (d) cobalt; (e) copper; (f) chlorine; (g) cesium

1.35 (a) boron; (b) barium; (c) beryllium; (d) bromine; (e) bismuth

1.36 (a) sulfur; (b) silicon; (c) selenium; (d) strontium; (e) tin

1.37 (a) nitrogen; (b) iron; (c) manganese; (d) magnesium; (e) aluminum; (f) chlorine

1.38 (a) beryllium; (b) rubidium; (c) nickel; (d) scandium; (e) titanium; (f) neon

1.39 (a) Fe; (b) Pb; (c) Ag; (d) Au; (e) Sb

1.40 (a) Cu; (b) Hg; (c) Sn; (d) Na; (e) W

1.41 Ir is the symbol for the element iridium. While many elements have symbols that start with the same letter as the name of the element, some do not. Iron's symbol is Fe which comes from the Latin word for iron, ferrum.

1.42 Only the first letter of an element symbol is capitalized. Si is the correct way to write the element symbol for silicon. SI indicates a compound formed from sulfur and iodine.

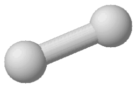
1.43 Only the first letter of an element symbol is capitalized. No is the correct way to write the element symbol for nobelium. NO is a compound formed from nitrogen and oxygen.

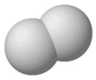
1.44 Only the first letter of an element symbol is capitalized. Co is the correct way to write the element symbol for cobalt. CO is compound formed from carbon and oxygen.

1.45 The hamburger is a heterogeneous mixture. The salt is a pure substance (NaCl). The soft drink is a heterogeneous mixture until it goes flat. The ketchup is also a heterogeneous mixture; after sitting for awhile, liquid collects on the top.

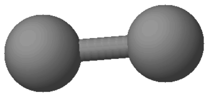
1.46 The sand, boardwalk, and roller coaster are heterogeneous mixtures. The sand is heterogeneous because its composition is not exactly the same everywhere you sample it. The ocean as a whole is heterogeneous as well, but the salt water in the surface of the ocean has a fairly constant composition (i.e. it's a homogeneous mixture).

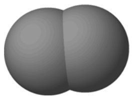
1.47 The chemical formula for hydrogen gas would be H_2. Hydrogen is normally represented by white colored spheres. There are different ways to draw H_2. The spheres represent the atoms and the line or "stick" represents the bond that holds the atoms together.


Ball and Stick


Space Filled

1.48 The chemical formula for chlorine gas is Cl_2. Chlorine is usually represented by green colored spheres. There are different ways to draw Cl_2. The spheres represent the atoms and the line or "stick" represents the bond that holds the atoms together.


Ball and Stick


Space Filled

1.49 There are four oxygen atoms (drawn as red spheres) and the two nitrogen atoms (colored blue). We write the chemical formula as N_2O_4. Subscripts following each atom type are used to indicate the number of each type of atom.

1.50 The phosphorus atom is drawn as a tan sphere and the chlorine atoms are colored green. You should be able to see one phosphorus atom connected to three oxygen atoms. The chemical formula is written as PCl_3.

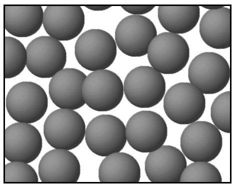
1.51 Elements and compounds are types of pure substances. A mixture of elements and compounds would contain two different substances. Image A represents a compound; each molecule is composed of two types of atoms. B represents an element; each molecule is exactly the same and only one kind of atom is present in each. What about C? The substances in C represent a mixture of elements. Compounds are not present. In D you have a compound and an element mixed together. E represents a mixture of two compounds.

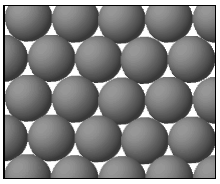
1.52 Image A contains only one type of molecule (pure) and each molecule of the substance has two different atoms (a compound).

1.53 The term *element* can refer to species of atoms all of one type (N or O) or pure substances composed of only one type of atom (N_2 or O_2). O_2 is what is called an elementary substance or elemental form and is one way we would find the element in nature. This means that O_2, P_4, and He are elements. Fe_2O_3, NaCl, and H_2O are compounds.

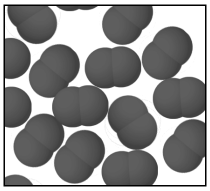
1.54 The term *element* can refer to species of atoms all of one type (N or O) or pure substances composed of only one type of atom (N_2 or O_2). O_2 is what is called an elementary substance or elemental form and is one way we would find the element in nature. Hydrogen gas (H_2) and neon (Ne) are the only two substances that can be called elements. Water (H_2O), salt (NaCl), nitrogen dioxide (NO_2), and aluminum chloride ($AlCl_3$) are compounds.

1.55 The atoms or molecules in the liquid state are close together but do not have a rigid form. In the solid state, the atoms or molecules are close together and are not free to move. This often means they will take on some sort of ordered structure (which we call the crystal lattice).

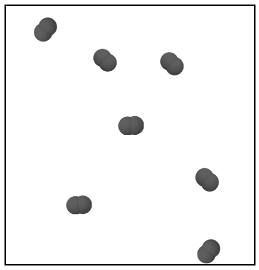

Liquid State


Solid State

1.56 The atoms or molecules in the liquid state are close together but do not have a rigid form. In the gas state, the molecules are very far apart from each other and have very high velocity.



Liquid State



Gas State

1.57 Gas. In the gas state, molecules are spaced far apart. As a result, they can easily be compressed. The molecular attractions of gas molecules tend to be weak compared to the amount of kinetic energy they have. If the attractions were strong, the molecules would prefer to be in a liquid or solid state. Since the attractive forces are weak, the molecules easily separate from each other (expand).

1.58 Solid. In the solid state, molecules have high attractions for each other in comparison to their kinetic energy. As a result, the solid state tends to be very rigid.

1.59 There are three states of matter; solid (*s*), liquid (*l*), and gas (*g*). (a) gas; (b) liquid; (c) solid

1.60 There are three states of matter; solid (*s*), liquid (*l*), and gas (*g*). (a) solid; (b) liquid; (c) gas

1.61 The diagram is an illustration of the solid state. You can make this conclusion since there is very little space between the atoms, and the atoms are in a very organized arrangement. If the distances between the atoms were large, you would conclude that it represents the gas state. Liquids do not show long range organized structure like that seen in solids.

1.62 In the gas state, you would expect that the atoms (or molecules) would be spaced far apart and would be moving very quickly.

1.63 When a substance is dissolved in water we say that it is an aqueous solution. This is abbreviated by the notation (*aq*). Oxygen gas can be dissolved in water to make a homogenous mixture (which is why fish can survive in water). This solution is represented as $O_2(aq)$.

1.64 The term aqueous means dissolved in water. The notation $H_2O(aq)$ would mean water dissolved in water.

1.65 These are physical properties. You can observe physical properties without changing the substance. Chemical properties are only observed when new substances are formed.

1.66 These are chemical changes. When new substances are formed (e.g., exhaust from the truck, or the smoke from the welder) these are chemical changes. Physical changes take place without a change in the substance.

1.67 When you are converting a unit with a prefix to the same base unit but with a different prefix (e.g., milligrams to micrograms) you can find the conversion factors in Math Toolbox 1.3. Suppose you want to convert between grams and micrograms (µg). There are several ways you can do this. First, by definition micro = 10^{-6}, so 10^{-6} g = 1 µg. This equation says, "one millionth of a gram is one microgram". We could also use 1 g = 10^{6} µg =1,000,000 µg. This equation says, "1 gram is one million micrograms". In question 69 part (b), you can see both ways of doing this conversion.

(a) Map: Sodium mass in mg $\xrightarrow{1000 \text{ mg} = 1 \text{ g}}$ Sodium mass in g

Problem solution:

$$\text{Mass in g} = 45\,\cancel{\text{mg}} \times \frac{1 \text{ g}}{1000\,\cancel{\text{mg}}} = 0.045 \text{ g}$$

(b) Map: Sodium mass in g $\xrightarrow{16 \text{ oz} = 453.6 \text{ g}}$ Sodium mass in oz

Problem solution:

$$\text{Mass in oz} = 0.045\,\cancel{\text{g}} \times \frac{16 \text{ oz}}{453.6\,\cancel{\text{g}}} = 1.6 \times 10^{-3} \text{ oz}$$

(c) Map: Sodium mass in g $\xrightarrow{1 \text{ lb} = 453.6 \text{ g}}$ Sodium mass in lb

$$\text{Mass in lb} = 0.045\,\cancel{\text{g}} \times \frac{1 \text{ lb}}{453.6\,\cancel{\text{g}}} = 9.9 \times 10^{-5} \text{ lb}$$

1.68 When you are converting a unit with a prefix to the same base unit but with a different prefix (e.g. milligrams to micrograms) you can find the conversion factors in Math Toolbox 1.3. Suppose you want to convert between grams and micrograms (µg). There are several ways you can do this. First, by definition micro = 10^{-6}, so 10^{-6} g = 1 µg. This equation says, "one millionth of a gram is one microgram". We could also use 1 g = 10^{6} µg =1,000,000 µg. This equation says, "1 gram is one million micrograms". In question 69 part (b), you can see both ways of doing this conversion.

(a) Map: Cheese mass in g $\xrightarrow{1000 \text{ g} = 1 \text{ kg}}$ Cheese mass in kg

Problem solution:

$$\text{Mass in g} = 0.340\,\cancel{\text{kg}} \times \frac{1000 \text{ g}}{1\,\cancel{\text{kg}}} = 340.\text{ g or } 3.40 \times 10^{2} \text{ g}$$

(b) Map: Cheese mass in g $\xrightarrow{16 \text{ oz} = 453.6 \text{ g}}$ Cheese mass in oz

Problem solution:

$$\text{Mass in oz} = 340.\,\cancel{\text{g}} \times \frac{16 \text{ oz}}{453.6\,\cancel{\text{g}}} = 12.0 \text{ oz}$$

(c) Map: Cheese mass in g $\xrightarrow{1 \text{ lb} = 453.6 \text{ g}}$ Cheese mass in lb

Problem solution:

$$\text{Mass in lb} = 340.\,\cancel{\text{g}} \times \frac{1 \text{ lb}}{453.6\,\cancel{\text{g}}} = 0.750 \text{ lb}$$

1.69 (a) Map: Salt mass in g $\xrightarrow{1 \text{ g} = 1000 \text{ mg}}$ Salt mass in mg

Problem solution:

$$\text{Mass in mg} = 1.0 \times 10^{-6}\,\cancel{\text{g}} \times \frac{1000 \text{ mg}}{1\,\cancel{\text{g}}} = 0.10 \text{ mg}$$

(b) Map: Salt mass in g $\xrightarrow{10^{-6}\text{ g} = 1\ \mu\text{g}}$ Salt mass in μg

Problem solution:

$$\text{Mass in }\mu\text{g} = 1.0\times10^{-4}\ \cancel{\text{g}}\times\frac{1\ \mu\text{g}}{10^{-6}\ \cancel{\text{g}}} = 1.0\times10^{2}\ \mu\text{g}$$

Alternate

Map: Salt mass in g $\xrightarrow{1\text{ g} = 1{,}000{,}000\ \mu\text{g}}$ Salt mass in μg

Problem solution:

$$\text{Mass in }\mu\text{g} = 1.0\times10^{-4}\ \cancel{\text{g}}\times\frac{1{,}000{,}000\ \mu\text{g}}{1\cancel{\text{g}}} = 1.0\times10^{2}\ \mu\text{g}$$

(c) Map: Salt mass in g $\xrightarrow{1\text{ kg} = 1000\text{ g}}$ Salt mass in kg

Problem solution:

$$\text{Mass in kg} = 1.0\times10^{-4}\ \cancel{\text{g}}\times\frac{1\text{ kg}}{1000\ \cancel{\text{g}}} = 1.0\times10^{-7}\ \text{kg}$$

1.70 (a) Map: Dog mass in kg $\xrightarrow{1\text{ kg} = 1000\text{ g}}$ Dog mass in g

Problem solution:

$$\text{Mass in g} = 15.2\ \cancel{\text{kg}}\times\frac{1000\text{ g}}{1\ \cancel{\text{kg}}} = 1.52\times10^{4}\ \text{g}$$

(b) Map: Dog mass in g $\xrightarrow{1\text{ g} = 1000\text{ mg}}$ Dog mass in mg

Problem solution:

$$\text{Mass in g} = 1.52\times10^{4}\ \cancel{\text{g}}\times\frac{1000\text{ mg}}{1\cancel{\text{g}}} = 1.52\times10^{7}\ \text{mg}$$

(c) Map: Dog mass in g $\xrightarrow{10^{-6}\text{ g} = 1\ \mu\text{g}}$ Dog mass in μg

Problem solution:

$$\text{Mass in g} = 1.52\times10^{4}\ \cancel{\text{g}}\times\frac{1\ \mu\text{g}}{10^{-6}\ \cancel{\text{g}}} = 1.52\times10^{10}\ \mu\text{g}$$

Alternate

Map: Dog mass in g $\xrightarrow{1\text{ g} = 1{,}000{,}000\ \mu\text{g}}$ Dog mass in μg

Problem solution:

$$\text{Mass in g} = 1.52\times10^{4}\ \cancel{\text{g}}\times\frac{1{,}000{,}000\ \mu\text{g}}{1\cancel{\text{g}}} = 1.52\times10^{10}\ \mu\text{g}$$

1.71 (a) Map: Drink volume in L $\xrightarrow{1000\text{ mL} = 1\text{ L}}$ Drink volume in mL

Problem solution:

$$\text{Volume in mL} = 1.2\cancel{\text{L}}\times\frac{1000\text{ mL}}{1\cancel{\text{L}}} = 1.2\times10^{3}\ \text{mL}$$

(b) Map: Drink volume in L $\xrightarrow{1000\text{ cm}^3 = 1\text{ L}}$ Drink volume in cm^3

Problem solution:

$$\text{Volume in cm}^3 = 1.2\ \cancel{\text{L}}\times\frac{1000\text{ cm}^3}{1\cancel{\text{L}}} = 1.2\times10^{3}\ \text{cm}^3$$

(c) Map: Drink volume in L $\xrightarrow{1000\text{ L} = 1\text{ m}^3}$ Drink volume in m^3

Problem solution:

$$\text{Volume in m}^3 = 1.2\ \cancel{\text{L}} \times \frac{1\text{ m}^3}{1000\ \cancel{\text{L}}} = 1.2 \times 10^{-3}\text{ m}^3$$

1.72 (a) Map: Balloon volume in cm^3 $\xrightarrow{1\text{ mL} = 1\text{ cm}^3}$ Balloon volume in mL

Problem solution:

$$\text{Volume in mL} = 145\ \cancel{\text{cm}^3} \times \frac{1\text{ mL}}{1\cancel{\text{cm}^3}} = 145\text{ mL}$$

(b) Map: Balloon volume in cm^3 $\xrightarrow{1\text{ L} = 1000\text{ cm}^3}$ Balloon volume in L

Problem solution:

$$\text{Volume in cm}^3 = 145\ \cancel{\text{cm}^3} \times \frac{1\text{ L}}{1000\ \cancel{\text{cm}^3}} = 0.145\text{ L}$$

(c) Map:

Balloon volume in cm^3 $\xrightarrow{1000\text{ cm}^3 = 1\text{ L}}$ Volume in L $\xrightarrow{1000\text{ L} = 1\text{ m}^3}$ Balloon volume in m^3

Problem solution:

$$\text{Volume in m}^3 = 145\ \cancel{\text{cm}^3} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{cm}^3}} \times \frac{1\text{ m}^3}{1000\ \cancel{\text{L}}} = 1.45 \times 10^{-4}\text{ m}^3$$

1.73 You are given the length, width, and height of the box and asked to calculate the volume in milliliters and liters. Notice that length and volume are *different types of units*. When the type of unit given and the unit in the answer are different (e.g., length and volume units), this often means you will need to use an equation. The key equation is the volume equation:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

$$\text{Volume in cm}^3 = 8.0\text{ cm} \times 5.0\text{ cm} \times 4.0\text{ cm} = 1.6 \times 10^2\text{ cm}^3$$

Notice that this answer is a volume unit, but not the units you want (mL or L)! You can solve this problem through two separate unit conversions:

Problem map: Volume in cm^3 $\xrightarrow{1\text{ mL} = 1\text{ cm}^3}$ Volume in mL

Problem solution:

$$\text{Volume in mL} = 1.6 \times 10^2\ \cancel{\text{cm}^3} \times \frac{1\text{ mL}}{1\ \cancel{\text{cm}^3}} = 1.6 \times 10^2\text{ mL}$$

Problem map: Volume in cm^3 $\xrightarrow{1\text{ L} = 1000\text{ cm}^3}$ Volume in L

Problem solution:

$$\text{Volume in mL} = 1.6 \times 10^2\ \cancel{\text{cm}^3} \times \frac{1\text{ L}}{1000\ \cancel{\text{cm}^3}} = 0.16\text{ L}$$

1.74 Volume and length are different types of units. This doesn't mean that they are unrelated. It is important to understand that volume can also be expressed in terms of length units. For example 1000 cm^3 = 1 L. However, when you are converting from one type of unit to another (i.e. volume to length), usually you need to use an equation. The volume of a cube can be calculated from the following equation:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height} = \text{length}^3$$

This is true because the length, width, and height of a cube are all equal. This means that the length of a cube's side is calculated as:

$$\text{length} = \sqrt[3]{\text{Volume}}$$

Here is the problem solving map:

$$\text{Volume in L} \xrightarrow{1\text{ L} = 1000\text{cm}^3} \text{Volume in cm}^3 \xrightarrow{\text{volume equation}} \text{Length in cm}$$

Here's the solution:

$$\text{Volume in cm}^3 = 1.0\ \cancel{\text{L}} \times \frac{1000\text{ cm}^3}{1\ \cancel{\text{L}}} = 1.0 \times 10^3\ \text{cm}^3$$

$$\text{Length in cm} = \sqrt[3]{1.0 \times 10^3\ \text{cm}^3} = 1.0 \times 10^1\ \text{cm}$$

1.75 The density is defined as $\text{density} = \dfrac{\text{mass}}{\text{volume}}$.

$$\text{Density} = \frac{28\text{ g}}{21\text{ cm}^3} = 1.\underline{3}33\text{ g/cm}^3 = 1.3\text{ g/cm}^3$$

Since 1 mL = 1 cm^3, we find that 21 cm^3 = 21 mL

$$\text{Density} = \frac{28\text{ g}}{21\text{ mL}} = 1.3\text{ g/mL}$$

Alternately, we can convert the density as follows (using the conversion 1 mL = 1 cm^3):

$$\text{Density in } \frac{\text{g}}{\text{mL}} = \frac{28\text{ g}}{21\ \cancel{\text{cm}^3}} \times \frac{1\ \cancel{\text{cm}^3}}{1\ \cancel{\text{mL}}} = 1.3\text{ g/mL}$$

Note that density units of g/cm^3 and g/mL are equivalent.

1.76 Density is a property that depends only on the substance and not the amount of substance. If the density of one of the two stones is not the same as diamond, it is very likely that that substance is not diamond. The stone densities are calculated as follows:

Stone A	Stone B
$\text{Density} = \dfrac{0.52\text{g}}{0.15\text{cm}^3} = 3.5\text{g/cm}^3$	$\text{Density} = \dfrac{0.42\text{g}}{0.15\text{cm}^3} = 2.8\text{ g / cm}^3$

Since the density of stone A is the same as diamond, 3.5 g/cm^3, there is a chance that this stone is diamond. Since the density of stone B is 2.8 g/cm^3, it is not diamond.

1.77 You are given the mass and density and asked to calculate the volume. These are related by the density equation: Density = mass/volume. The equation can be rearranged to solve for volume.

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{50.0\ \cancel{\text{g}}}{1.30\dfrac{\cancel{\text{g}}}{\text{mL}}} = 38.5\text{mL}$$

1.78 Here is a problem solving map:

$$\text{l, w, h} \xrightarrow{\text{volume equation}} \text{Volume} \xrightarrow{\text{density}} \text{Mass}$$

Since the density is given in units of g/cm^3, it is easiest to calculate the volume in units of cm^3. This means all the length, width, and height measurements must first be converted to cm.

$$\text{Length in cm} = 10.0\ \cancel{\text{m}} \times \frac{100\ \text{cm}}{\cancel{\text{m}}} = 1000\ \text{cm}$$

$$\text{Width in cm} = 1.0\ \cancel{\text{m}} \times \frac{100\ \text{cm}}{\cancel{\text{m}}} = 100\ \text{cm}$$

$$\text{Volume} = \text{l} \times \text{w} \times \text{h} = (1000\ \text{cm}) \times (100\ \text{cm}) \times (1\ \text{cm}) = 1 \times 10^5\ \text{cm}^3$$

Rearranging the density equation (Density = mass/volume) to solve for mass gives

$$\text{Mass} = \text{d} \times \text{V} = 0.75\ \frac{\text{g}}{\cancel{\text{cm}^3}} \times \left(1 \times 10^5\ \cancel{\text{cm}^3}\right) = 8 \times 10^4\ \text{g}$$

1.79 Molecules in the liquid state are closer together than molecules in the gas state. This means that when a liquid or gas occupies the same size container, there will be more molecules of the liquid than the gas. Since density is $d = m/V$, the density of the liquid is higher than the density of the gas.

1.80 The density decreases. When you are answering conceptual questions, it often helps to think about the equation relating the different parts of the concept. In this case we are asked what happens to density when the volume changes. Density is given by $d = m/V$. This means that density is inversely proportional to volume. If the volume goes up, the equation tells us the density must go down. This makes sense since the amount of matter in the balloon does not change when the temperature changes. The same amount of mass in a larger volume means lower density.

1.81 When the plastic is placed in the water, it floats. This means that its density is lower than that of water. However, it sinks when placed in the oil. From this information, we can order the substances according to increasing density.

oil (least density) < plastic < water (greatest density)

What happens when oil is placed in water? Based on our order, oil should float on water. If you make your own oil and vinegar (which is mostly water) salad dressing, you may have already noticed this yourself.

1.82 The pictures both show the same volume of water. However, the space between the molecules in liquid water is smaller than the space between the water molecules in the solid. This means that there are more molecules in the same volume of liquid water. Since the mass is less in the solid, but the volume is the same, the density of the solid is less than that of the liquid.

1.83 Temperature conversions are always done using equations. The following equation is used to convert between Celsius and Kelvin scales: $T_{\text{K}} = T_{^\circ\text{C}} + 273.15$

$$T_{\text{K}} = 56\,^\circ\text{C} + 273.15 = 329\ \text{K}$$

1.84 Temperature conversions are done using equations. When you are solving for temperature in °C, first solve the equation and then calculate the temperature. Rearranging $T_{\text{K}} = T_{^\circ\text{C}} + 273.15$ to solve for degrees Celsius gives $T_{^\circ\text{C}} = T_{\text{K}} - 273.15$.

$$T_{^\circ\text{C}} = 77\ \text{K} - 273.15 = -196\,^\circ\text{C}$$

1.85 In the Celsius scale, water freezes at 0°C and boils at 100°C. There are 100 degrees between the boiling and freezing temperature of water.

The freezing and boiling points of water from these values in Celsius using the equation:

$T_K = T_{^\circ C} + 273.15$

$$\text{Freezing point in K} = 0\,^\circ\text{C} + 273.15 = 273.15\text{ K}$$

$$\text{Boiling point in K} = 100\,^\circ\text{C} + 273.15 = 373.15\text{ K}$$

In Fahrenheit we calculate the freezing and boiling points using the equation: $T_{^\circ F} = 1.8\left(T_{^\circ C}\right) + 32$

$$\text{Freezing point in }^\circ\text{F} = 1.8 \times (0\,^\circ\text{C}) + 32 = 32\,^\circ\text{F}$$

$$\text{Boiling point in }^\circ\text{F} = 1.8 \times (100\,^\circ\text{C}) + 32 = 212\,^\circ\text{F}$$

	Freezing Point	**Boiling Point**	**Difference**
Celsius	0°C	100°C	100°C
Kelvin	273.15 K	373.15 K	100 K
Fahrenheit	32°F	212°F	180°F

1.86 The temperature increments in the Kelvin scale are the same as those in the Celsius scale. From the problem, we know that the temperature dropped from 60.0°C to 25.0°C. The temperature difference is:

$$\text{Temperature difference in }^\circ\text{C} = 60.0\,^\circ\text{C} - 25.0\,^\circ\text{C} = 35.0\,^\circ\text{C}$$

The difference in K is the same, 35.0 K.

1.87 No. Boiling point is a property that depends on what the substance is, not how much is present. In a microwave oven, you can boil half a cup of water much faster than two cups of water. However, the temperature at which both boil is the same (100°C).

1.88 No. Melting point is a property that depends on what the substance is, not how much is present. A small ice cube melts in less time than a large block of ice. However, the temperature at which they melt is still the same (0°C).

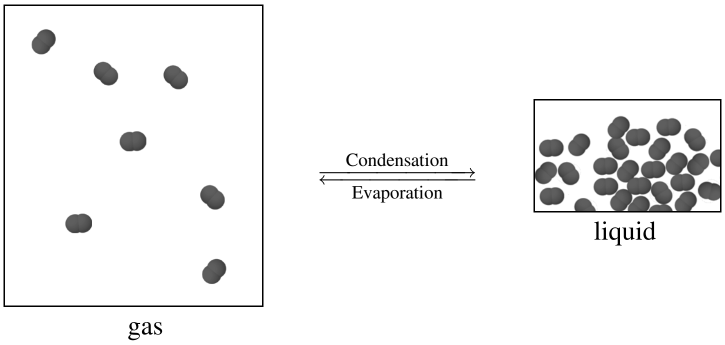
1.89 Physical properties are (a) mass, (b) density, and (e) melting point. In each case, you can measure the property without actually changing the substance. The mass of a penny can be measured without changing its composition. Similarly, when ice melts to form water, the chemical formula is still the same (H_2O). Chemical properties are (c) flammability, (d) resistance to corrosion, and (f) reactivity with water. Chemical properties are observed when new substances are formed. When substances burn, corrode, or react, new substances are formed.

1.90 Physical properties are (a) boiling point and (d) volume. Physical properties can be observed without changing the substance. In each case, you can measure the property without actually changing the substance. The act of measuring volume does not change the substance. When water boils, you don't form any new substances (i.e. it's still H_2O although its phase has changed). Chemical properties are (b) reactivity to oxygen and (c) resistance to forming compounds with other elements. Chemical properties are observed when new substances are formed. When you burn a substance or measure how resistive a substance is to reacting, you chemically change that substance.

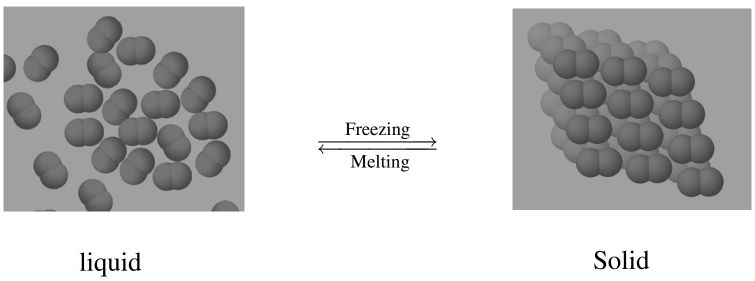
1.91 Physical changes are (a) boiling acetone, (b) dissolving oxygen gas in water, and (e) screening rocks from sand. In each case the substance is not changed. Chemical changes are (c) combining hydrogen and oxygen to make *water*, (d) *burning* gasoline, and (f) conversion of ozone to *oxygen*. In each case, new substances are formed.

1.92 Physical changes are (a) condensation of ethanol, (c) dissolving sugar in water, and (f) filtering algae from water. In each case the substance is not changed. Chemical changes are (b) combining of zinc and oxygen to make the compound *zinc oxide*, (d) *burning* a piece of paper, and (e) combining sodium metal with water producing *sodium hydroxide* and *hydrogen gas*. In each case, a new substance is formed.

1.93 Symbolically the condensation of chlorine gas can be represented by: $Cl_2(g) \rightarrow Cl_2(l)$. This representation means that chlorine in the gas state is converted to chlorine in the liquid state. This is a phase change since the substance has not changed. At the molecular level, we know that molecules in the gas state are relatively far apart and that they are moving very rapidly. In the liquid state, the molecules are much closer together and are no longer able to move freely from each other. Note that vaporization is the opposite of condensation.



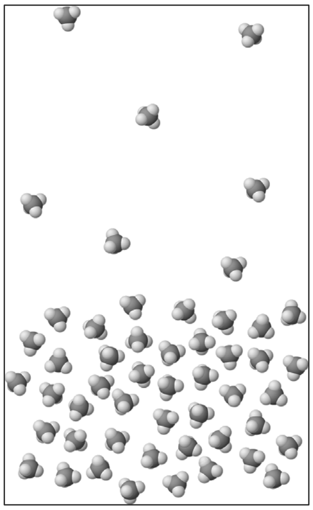
1.94 Symbolically the freezing of liquid oxygen can be represented by: $O_2(l) \rightarrow O_2(s)$. This representation means that oxygen in the liquid state is converted to oxygen in the solid state. At the molecular level, we know that molecules in the liquid state are close together, but are still able to move relative to each other. In the solid state, the molecules are no longer able to move relative to each other. One such representation is illustrated below. Note that freezing is the opposite of melting.



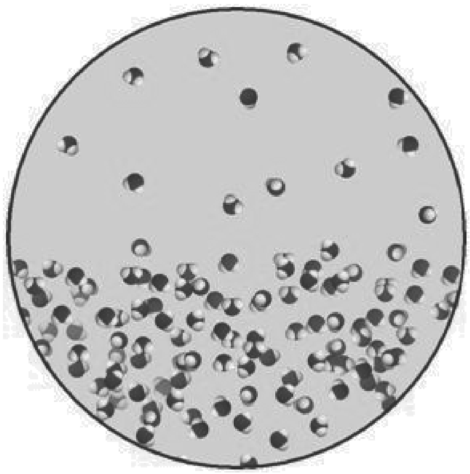
1.95 Chemical change. During a physical change, all the molecules would remain the same. In this case, molecules are transformed from pure A and B_2 to AB_4. This is a chemical change since a new substance is formed.

1.96 Since the atoms have not recombined with other atoms to form new substances, this must represent a physical change.

1.97 When methane condenses, it goes from the gas state to the liquid state. One possible representation of this process would be the figure shown to the right. Condensation occurs when methane leaves the gas phase (top of the container) and goes to the bottom (liquid phase). Vaporization could be described by the same image if we reverse the process and imagine molecules leaving the liquid and going into the gas.



1.98 When water boils, it undergoes a physical change from molecules in the liquid state to molecules in the gas state. The only difference between this and what we normally call evaporation is the rate at which the molecules vaporize and the pressure that these molecules exert (which is much higher than what we attribute to evaporation).



1.99 In each of the sections which expand the molecular structure, the iodine atoms are paired. In other words, since new substances are not formed, this must be a physical change.

1.100 The formation of new substances (water and carbon dioxide) from methane indicates a chemical change.

1.101 The ability to understand if something possesses kinetic or potential energy really depends on how well we understand what is going on. On a large scale (macroscopic), kinetic energy is the easiest to observe. If it moves, it has kinetic energy. We assume that sparks, the welder's hands, and the smoke are all moving. These possess kinetic energy. On a macroscopic level, potential energy is also relatively easy to find. By definition, if an object is attracted to (e.g. pulled on by gravity of the earth) or repelled by an object (i.e. a spring) and is separated by some distance (e.g. it can fall) it possesses potential energy. On a molecular and atomic level (microscopic), kinetic and potential energy are much harder to classify. Can the energy be used to do work or to create? That would be potential energy. For example, the welder's fuel is probably acetylene and oxygen. It contains stored or potential energy. Electricity is also a form of potential energy (when it is not being used). However, if it is making something happen, then we are seeing kinetic energy.

1.102 When the player strikes the ball, it begins to move. In fact, anything that moves has kinetic energy: the running players, jumping players, the flying sand. The light from the sun provides heat energy which causes the molecules to move faster (which you can't really see but can imagine). Potential energy is any form of stored energy.

1.103 The molecules in image A appear to be moving faster. Since kinetic energy increases with the velocity of the molecules, the molecules in A have greater kinetic energy.

1.104 The molecules in image A. As the temperature increases, the velocity of the molecules increases. Since kinetic energy increases with velocity, the higher the temperature, the higher the kinetic energy. The molecules in image A are at a higher temperature.

1.105 The ability to understand if something possesses kinetic or potential energy really depends on how well we understand what is going on. Objects that possess potential energy will move if they are allowed. For example, a picture will fall if the nail that holds it up comes out of the wall. Because the picture starts moving when it is released, it had potential energy. When the picture reaches the ground, all the potential energy has been used. Your bed mattress expands when you get up. This means that the bed, when you were lying on it, had potential energy (the ability to move and do work).

1.106 If an object or substance is moving, it has kinetic energy (energy of motion). The movement of a clock hand, your breathing, the pencil (if you writing with it), the air moving in your room, a goldfish swimming in the tank, etc.

1.107 If an object or substance is moving, it has kinetic energy. The people walking, the wheel chair rolling, and the suitcase being pushed all have kinetic energy. If an object or substance can fall, it has potential energy. Anything raised above the ground has potential energy. The people, the wall art, and objects on the tables all have potential energy. Many objects in this picture have both potential and kinetic energy.

1.108 If an object or substance is moving, it has kinetic energy. The basketball players all appear to have kinetic energy. If an object or substance can fall, it has potential energy. The players, the fans, and the ball all have potential energy. Many objects in this picture have both potential and kinetic energy

1.109 Here is an example. Your car is on a hill and you have applied the brake. When you release the brake, what happens? The car rolls down the hill and begins to move faster and faster. As it moves down the hill, potential energy is lost, but kinetic energy is gained. When the car reaches the bottom of the hill, it begins to slow down. This happens because of friction, which produces heat energy. This heat energy is directly related to the motion of molecules (kinetic energy). When the car has reached the bottom of the hill, the potential energy has been used up.

1.110 The energy released is directly related to the energy in the bonds of the substances that make up gasoline. During chemical reactions, substances are transformed into new substances. The energy that is released (or absorbed) is related to the relative amounts of energy stored in the bonds of the starting substances and the bonds of the new substances that are formed.

1.111 When the batter swings the bat potential energy is converted into kinetic energy (moving bat). The bat strikes the ball and the kinetic energy of the bat is transferred to kinetic energy of the ball. As the ball leaves the bat, it rises against the gravity of the earth and some of the kinetic energy is converted to potential energy. When the ball starts dropping again, potential energy is converted to kinetic energy.

1.112 When the ball is dribbled, potential energy (from the energy stored in the player) is transformed into kinetic energy (the ball moving). Potential energy is also stored and released each time the ball hits the ground and compresses. The player also uses potential energy as the ball is shot. As the ball rises against the gravity of the earth, some kinetic energy is converted to potential energy. When the ball starts dropping again, potential energy is converted back to kinetic energy.

1.113 To calculate the BMI, you must first calculate the person's mass in kg. The height is converted from feet and inches into meters. These results are used to calculate the BMI according to the equation given.

Map: mass in lb $\xrightarrow{1\text{ lb} = 453.6\text{ g}}$ mass in g $\xrightarrow{1\text{ kg} = 10^3\text{g}}$ mass in kg

$$\text{mass in kg} = 169\,\cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\text{ kg}}{10^3\ \cancel{\text{g}}} = 76.7\text{ kg}$$

To calculate the height, we first calculate the height in inches. 6 feet is 72 inches, so the person's height is 74 inches.

Map: height in in $\xrightarrow{1\text{ in} = 2.54\text{ cm}}$ height in cm $\xrightarrow{1\text{ cm} = 10^{-2}\text{ m}}$ height in m

$$\text{height in m} = 74\,\cancel{\text{in}} \times \frac{2.54\ \cancel{\text{cm}}}{1\ \cancel{\text{in}}} \times \frac{10^{-2}\text{ m}}{1\ \cancel{\text{cm}}} = 1.88\text{ m}$$

$$\text{BMI} = \frac{\text{weight(kg)}}{(\text{height (m)})^2} = \frac{76.7\text{ kg}}{(1.88\text{ m})^2} = 21.7\frac{\text{kg}}{\text{m}^2}$$

Based on the BMI, the person would be considered healthy.

1.114 Propane possesses potential energy. The fuel is burned in a piston. As the fuel burns, the released energy causes the kinetic energy (temperature) of the gas molecules to increase. The gases in the engine expand. This makes the piston move, and the moving piston causes gears and eventually the wheels to turn (kinetic energy).

1.115 As the water leaves the top of the fountain, it possesses kinetic energy (going up). However, its upward movement slows as it reaches the top of its arc. This happens because the kinetic energy it possessed is transformed into potential energy as it moves away from the earth. At some point, the kinetic energy is "used up" and the water starts moving in the downward direction. As it does so, its kinetic energy increases. When the water reaches the pool at the base of the fountain, it has used up its potential energy. As the water enters the pool, it causes the water in the pool to move (kinetic energy is distributed into the pool).

1.116 A hypothesis is often defined as a tentative explanation. It is often subject to change. A theory is a more complete explanation which has few exceptions. You can think of a hypothesis as the painter's canvas when she first starts painting. With only a few lines and curves placed on the canvas, you could imagine any number of potential images. However, as the painting nears its completion, it is (usually) much easier to tell what the painting represents. Why is that? It is because you now have more data to evaluate. The nearly completed painting is similar to the theory because it is difficult to make large changes.

1.117 A hypothesis has three important features. It summarizes what you know, it allows predictions under certain conditions (i.e. experiments), and it is flexible or can be modified. In research, often an investigator has ideas about how something works. The ideas are based on the investigator's previous experiences and, to a large part, intuition. The hypothesis is formed from these ideas and guides the research that is done. Information gathered from the research allows the investigator to evaluate and modify the hypothesis. Thus a new hypothesis is formed. Rarely are complete answers found in research (otherwise we might simply call it "search" rather than "re-search").

1.118 The difference between a hypothesis and a theory is a little fuzzy. A hypothesis has many exceptions and a theory should have very few. A law has no known exceptions. Finally, an observation does not make any attempt to explain observations or predict outcomes of an experiment. (a) is a natural law, almost by definition. Combustion uses oxygen and produces heat. It could probably be argued that (b) is a law since the behavior is so well established. It can be shown that it is always true (i.e. there are no exceptions). (c) is an observation about matter. However, there was a point in history where it had not been determined that all matter was composed of atoms. (d) is probably closer to a hypothesis than a theory because it makes a prediction or summarizes observations that are based on anecdotal evidence.

1.119 To start with, none of these observations are laws since laws have no known exceptions. Also, the difference between a hypothesis and a theory is a little fuzzy. A hypothesis has many exceptions and a theory should have very few. Finally, an observation does not make any attempt to explain observations or predict outcomes of an experiment. This means (b) and (d) are observations. (a) is closer to a hypothesis since many people walk under ladders all day without bad luck (painters for example). (c) is similar to (b), but it attributes the floating of the oil to the density of the oil. This can be shown to be true in many different types of experiments. As a result, (c) is more similar to a theory than a hypothesis.

1.120 You could research where fountains are made and visit those places to see how fountains are made. In addition, you could call contractors and ask to visit sites where fountains are being installed to see if the coins are already present.

1.121 Quick, run to the library! A college librarian will be able to find data on many different types of woods (you could also do an internet search for wood densities). Included in this data will be data on types of woods and their densities (or specific gravities). Since water has a density of approximately 1.0 g/cm^3, you would look for woods that have densities both higher and lower than water. After obtaining samples of these woods, you could carefully measure and weigh samples of wood and see if they float on water. (Ironwood has a density of 63 lb/ft^3. Will that sink or float?)

1.122 To properly compare values for magnitude, you need to convert everything to the same units. This means we should convert 3.0×10^{-6} km and 4.0×10^2 mm to meters.

$$\text{Length in km} \xrightarrow{1\text{ km} = 1000\text{ m}} \text{m}$$

$$3.0 \times 10^{-6}\ \cancel{\text{km}} \times \frac{1000\text{ m}}{\cancel{\text{km}}} = 3.0 \times 10^{-3}\text{ m}$$

$$\text{Length in mm} \xrightarrow{1\text{mm} = 10^{-3}\text{ m}} \text{m}$$

$$4.0 \times 10^{2}\ \cancel{\text{mm}} \times \frac{10^{-3}\text{ m}}{\cancel{\text{mm}}} = 4.0 \times 10^{-1}\text{ m}$$

Now we can order the numbers from smallest to largest.

$$0.0\text{ m} < 2.0 \times 10^{-5}\text{ m} < 1.0 \times 10^{-4}\text{ m} < 3.0 \times 10^{-3}\text{ m} < 4.0 \times 10^{-1}\text{ m} < 1.0\text{ m}$$

1.123 At high altitude, the air pressure is lower. As a result, when a balloon rises, it expands. Since the mass of air in the balloon has not changed but the volume has increased, the density of the balloon is lower.

1.124 The unit size on the Kelvin and Celsius scales are the same. That means a 10.0°C change will be a change of 10.0 K on the Kelvin scale.

1.125 Volume depends on the density and mass. If we solve the density equation for volume we have:

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

This means that if the density is smaller, the volume will be larger. Table 1.6 lists the densities of several common substances. The density of zinc and copper are listed as 7.14 g/mL and 8.92 g/mL respectively. Since the masses of the samples are the same and the density of zinc is lower, the block of zinc is larger.

1.126 Potassium is K and phosphorus is P. While that might seem strange, the symbol for potassium was derived from its Latin name *kalium*. The designation kalium is used for potassium in many other countries (Germany for example).

1.127 (a) He; (b) Ne; (c) Ar; (d) Kr; (e) Xe; (f) Rn

1.128 Start by converting the volume of blood to microliters and then use the RBC count to convert to number of RBCs (#RBC).

$$\text{Volume-gal} \xrightarrow{1\ \text{gal} = 3.785\ \text{L}} \text{Volume-L} \xrightarrow{1\ \mu\text{L} = 10^{-6}\ \text{L}} \text{Volume-}\mu\text{L} \xrightarrow{1\ \mu\text{L} = 5\times10^{6}\ \text{RBC}} \#\ \text{RBC}$$

Problem solution:

$$\#\text{RBC} = 1\cancel{\text{gal}} \times \frac{3.785\ \cancel{\text{L}}}{1\ \cancel{\text{gal}}} \times \frac{1\ \mu\text{L}}{10^{-6}\ \cancel{\text{L}}} \times \frac{5\times10^{6}\ \text{RBC}}{1\cancel{\mu\text{L}}} = 2\times10^{13}\ \text{RBC}$$

1.129 Since the objects that are separated are not changed (i.e. they float or they don't float), this must be a process based on physical properties. If it was based on a chemical property, new substances would have to be formed.

1.130 Density is the mass of an object divided its volume. Since the samples have the same mass, the smaller sample (A) must be more densely packed (i.e. its mass is divided by a smaller volume).

1.131 Convert the person's body mass into kilograms and then use epinephrine's dosage information (1 kg = 0.1 mg) to calculate the milligrams of epinephrine (mg-epi).

$$\text{Mass-lb} \xrightarrow{1\ \text{lb} =\ 453.6\ \text{g}} \text{Mass-g} \xrightarrow{1\ \text{kg} = 10^{3}\ \text{g}} \text{Mass-kg} \xrightarrow{1\ \text{kg} = 0.1\ \text{mg-epi}} \text{Mass-mg-epi}$$

$$\text{mg-epi} = 180\cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\ \cancel{\text{kg}}}{10^{3}\ \cancel{\text{g}}} \times \frac{0.1\ \text{mg-epi}}{1\cancel{\text{kg}}} = 8\ \text{mg-epi}$$

1.132 Convert the paper mass into kilograms using the conversion path shown and then divide that by the number of people.

$$\text{Mass-ton} \xrightarrow{1\ \text{ton} = 2000\ \text{lb}} \text{Mass-lb} \xrightarrow{1\ \text{lb} =\ 453.6\ \text{g}} \text{Mass-g} \xrightarrow{1\ \text{kg} = 10^{3}\ \text{g}} \text{Mass-kg}$$

$$\text{Mass-kg} = 70\times10^{6}\ \cancel{\text{ton}} \times \frac{2000\ \cancel{\text{lb}}}{1\ \cancel{\text{ton}}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\ \text{kg}}{10^{3}\ \cancel{\text{g}}} = 6\times10^{10}\ \text{kg paper}$$

$$\frac{\text{Mass}}{\text{person}} = \frac{6\times10^{10}\ \text{kg paper}}{301.6\times10^{6}\,\text{person}} = \frac{200\ \text{kg paper}}{\text{person}}$$

1.133 The conversion of 240 mg/dL involves the conversion of mg to lbs and also dL to fluid ounces. Remember that these conversions can be applied in either order and that units must cancel properly.

$$\frac{\text{mg}}{\text{dL}} \xrightarrow{1\ \text{mg} = 10^{-3}\ \text{g}} \frac{\text{g}}{\text{dL}} \xrightarrow{1\ \text{lb} = 453.6\ \text{g}} \frac{\text{lb}}{\text{dL}} \xrightarrow{1\ \text{dL} = 10^{-1}\ \text{L}} \frac{\text{lb}}{\text{L}} \xrightarrow{1\ \text{mL} = 10^{-3}\ \text{L}} \frac{\text{lb}}{\text{mL}} \xrightarrow{1\ \text{fl oz} = 29.57\ \text{mL}} \frac{\text{lb}}{\text{fl oz}}$$

$$\frac{\text{lb}}{\text{fl oz}} = 260\frac{\cancel{\text{mg}}}{1\ \cancel{\text{dL}}} \times \frac{10^{-3}\ \cancel{\text{g}}}{1\ \cancel{\text{mg}}} \times \frac{1\ \text{lb}}{453.6\,\cancel{\text{g}}} \times \frac{1\ \cancel{\text{dL}}}{10^{-1}\ \cancel{\text{L}}} \times \frac{10^{-3}\ \cancel{\text{L}}}{1\ \cancel{\text{mL}}} \times \frac{29.57\,\cancel{\text{mL}}}{1\ \text{fl oz}} = 1.7\times10^{-4}\ \frac{\text{lb}}{\text{fl oz}}$$

To determine the mass range of cholesterol, the masses must be calculated for both 4 and 6 liters of blood.

$$\text{Volume-L} \xrightarrow{1\ \text{dL} = 10^{-1}\ \text{L}} \text{Volume-dL} \xrightarrow{1\ \text{dL} = 260\ \text{mg}} \text{Mass-mg} \xrightarrow{1\ \text{mg} = 10^{-3}\ \text{g}} \text{Mass-g} \xrightarrow{1\ \text{lb} = 453.6\ \text{g}} \text{Mass-lb}$$

$$\text{Mass-kg} = 4\cancel{\text{L}} \times \frac{1\ \cancel{\text{dL}}}{10^{-1}\ \cancel{\text{L}}} \times \frac{260\ \cancel{\text{mg}}}{1\ \cancel{\text{dL}}} \times \frac{10^{-3}\ \text{g}}{1\cancel{\text{mg}}} \times \frac{1\ \text{lb}}{453.6\cancel{\text{g}}} = 0.02\ \text{lb}$$

$$\text{Mass-kg} = 6\cancel{\text{L}} \times \frac{1\ \cancel{\text{dL}}}{10^{-1}\ \cancel{\text{L}}} \times \frac{260\ \cancel{\text{mg}}}{1\ \cancel{\text{dL}}} \times \frac{10^{-3}\ \text{g}}{1\cancel{\text{mg}}} \times \frac{1\ \text{lb}}{453.6\cancel{\text{g}}} = 0.03\ \text{lb}$$

The mass range is 0.02 to 0.03 lb

1.134 The more dense solutions (in units of g/mL) will be toward the bottom. From top to bottom

Corn oil 0.93
Water 1.0
Shampoo 1.01
Dish detergent 1.03
Antifreeze 1.13
Maple syrup 1.32

1.135 The Kelvin scale most directly describes the lowest possible temperature because it is absolute with no negative values and zero being the lowest possible temperature.

(a) 0.00 K (The number of significant figures here is arbitrary since this is an exact number.)

(b) –273.15°C (Calculated from 0.00 K using the formula $T_{°C} = T_K - 273.15$)

(c) –459.67°F (Calculated from –273.15 °C using the formula $T_{°F} = 1.8(T_{°C}) + 32$)

1.136 The spheres in the molecular-level diagram are all the same color and shape.

(a) The atoms of an element are the same so this is a representation of an element.

(b) Single spheres are shown. They are not connected (attached to other spheres) so the image represents atoms.

1.137 (a) $NaNO_3(s)$ represents a compound because the formula contains more than one element symbol (so it is not an element). The physical state symbol shows that it is a solid so it is a pure substance, not a mixture.

(b) $N_2(g)$ represents an element because the formula contains only the element symbol for one type of element (nitrogen). The physical state symbol shows that it is a gas so it is a pure substance, not a mixture.

(c) NaCl(*aq*) represents a mixture because the physical state symbol (*aq*) shows that this compound is dissolved in water.

1.138

Physical Property	**Chemical Property**
Strong metal	Resistant to corrosion
Low density	Resists tarnishing
Shiny	Reacts with air to form an oxide layer
White-metallic color	Nontoxic
	Inert biomaterial

1.139 Blood is a mixture because it contains more than one substance. It is further classified as a heterogeneous mixture because the solids are suspended, not dissolved. If blood was homogeneous, it would be clear and transparent.

1.140 A fuel is something that reacts with oxygen to produce more stable products (and generates energy). As a fuel burns by reacting with oxygen, it converts potential energy to kinetic energy as it releases heat to the surrounding environment. A fuel also has kinetic energy because its molecules have motion. (All atoms and molecules have some sort of motion, and therefore kinetic energy, if they are not at absolute temperature.)

1.141 From the conversion factor 1 m = 100 cm we have to determine the relationship between m^3 and cm^3 so that units cancel properly. To cube the units, we have to cube the entire conversion factor ratio, including the numbers.

$$10.0\ \text{m}^3 \times \left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^3 = 10.0\ \text{m}^3 \times \frac{(100)^3\ \text{cm}^3}{1^3\ \text{m}^3} = 10.0\ \cancel{\text{m}^3} \times \frac{10^6\ \text{cm}^3}{1\ \cancel{\text{m}^3}} = 1.00 \times 10^7\ \text{cm}^3$$

1.142 (a) $4.8\ \cancel{\text{L}} \times \dfrac{1000\ \text{mL}}{1\ \cancel{\text{L}}} = 4.8 \times 10^3\ \text{mL}$

(b) $4.8 \times 10^3\ \cancel{\text{mL}} \times \dfrac{1\ \text{cm}^3}{1\ \cancel{\text{mL}}} = 4.8 \times 10^3\ \text{cm}^3$

(c) $4.8 \times 10^3\ \text{cm}^3 \times \left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right)^3 = 4.8 \times 10^3\ \cancel{\text{cm}^3} \times \dfrac{1^3\ \text{m}^3}{(100)^3\ \cancel{\text{cm}^3}} = 4.8 \times 10^{-3}\ \text{m}^3$

1.143 Mass in kilograms (using density as conversion factor): $0.00500\ \cancel{\text{m}^3} \times \dfrac{1060\ \text{kg}}{\cancel{\text{m}^3}} = 5.30\ \text{kg}$

Mass in pounds (converting kg to g to lb): $5.30\ \cancel{\text{kg}} \times \dfrac{1000\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \dfrac{1\ \text{lb}}{453.6\ \cancel{\text{g}}} = 11.7\ \text{lb}$

1.144 (a) Solid to liquid is melting.
(b) Liquid to gas is vaporization.
(c) Gas to liquid is condensation.
(d) Liquid to solid is freezing.

1.145 To calculate the distance traveled, we have to consider the two different parts of the trip. We can calculate the distance traveled in the first leg by considering the speed, 29.1 m/s, and the time, 2.5 hr. Since the speed is in units of meters per second, we'll have to convert the time traveled in the first leg to seconds before multiplying by the speed. The distance traveled in the second part of the trip is in units of kilometers. To add the two distances, we'll have to use common units. Since it's a rather long distance, it would be more convenient to convert the distance of the first leg to kilometers.

$$\text{distance, first leg} = 2.5\,\cancel{\text{hr}} \times \frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{hr}}} \times \frac{60\,\cancel{\text{s}}}{1\,\cancel{\text{min}}} \times \frac{29.1\,\cancel{\text{m}}}{1\,\cancel{\text{s}}} \times \frac{1\text{ km}}{1000\,\cancel{\text{m}}} = 2\underline{6}1.9\text{ km}$$

$$\text{total distance in km} = 2\underline{6}1.9\text{ km} + 75\text{ km} = 3\underline{3}6.9\text{ km}$$

$$\text{total distance in mi} = 3\underline{3}6.9\,\cancel{\text{km}} \times \frac{1\text{ mi}}{1.609\,\cancel{\text{km}}} = 2.\underline{0}94 \times 10^2\text{ mi} = 2.1 \times 10^2\text{ mi}$$

1.146 With the information provided, we could determine if the metal might be gold by comparing the density of the metal with that of gold. From Table 1.6 we find that gold's density is 19.3 g/mL. The density of the unknown metal is calculated by taking the ratio of its mass and volume. We have the initial volume of water and the final volume of the metal plus water. To determine the volume occupied by the metal, we'll have to calculate the difference between these two quantities. The initial and final volumes need to be expressed in common units to calculate the volume of the metal. We can identify the proper conversions from Math Toolbox 1.3.

$$\text{metal volume in mL} = \left(38.4\,\cancel{\text{fl oz}} \times \frac{29.57\text{ mL}}{1\,\cancel{\text{fl oz}}}\right) - \left(1.0\,\cancel{\text{qt}} \times \frac{0.9464\,\cancel{\text{L}}}{1\,\cancel{\text{qt}}} \times \frac{1000\text{ mL}}{1\,\cancel{\text{L}}}\right)$$
$$= \left(11\underline{3}5.488\text{ mL}\right) - \left(9\underline{4}6.4\text{ mL}\right) = 1\underline{8}9.088\text{ mL}$$

We can now calculate the density of the metal in units of lb/mL, then convert the ratio to g/mL.

$$\text{density, g/mL} = \frac{2.00\,\cancel{\text{lb}}}{\underline{1}89.088\text{ mL}} \times \frac{453.6\text{ g}}{1\,\cancel{\text{lb}}} = 4.8\text{ g/mL}$$

This density isn't even close to the density of gold, 19.3 g/mL. It's more likely that the unknown solid is fool's gold, a compound of iron and sulfur.

CONCEPT REVIEW

1.147 Answer: B; Lake water contains a variety of dissolved and undissolved materials.

A. element
C. compound
D. element
E. compound

1.148 Answer: B and D; Both contain pure substances that are composed of molecules.

A. mixture of two different elements
B. compound
C. mixture of an element (composed of molecules) and a compound
D. element (composed of molecules)
E. element

1.149 Answer D; Liquid particles are free to move around each other.

A. They consist of particles that are relatively close together compared to gases.
B. They can only be compressed slightly.
C. The symbol for a liquid is (*l*)
E. They have the shape of the container and may or may not fill it.

1.150 Answer: C; The ratio of mass to volume corresponds to aluminum.

$$\text{density, g/cm}^3 = \frac{456\text{ g}}{(10.2\text{ cm} \times 5.08\text{ cm} \times 3.26\text{ cm})} = \frac{456\text{ g}}{169\text{ cm}^3} = 2.70\text{ g/cm}^3$$

A. $\text{mass of zinc} = 169\,\cancel{\text{cm}^3} \times \frac{7.14\text{ g}}{1\,\cancel{\text{cm}^3}} = 1.21 \times 10^3\text{ g}$

B. $\text{mass of lead} = 169\,\cancel{\text{cm}^3} \times \frac{11.3\text{ g}}{1\,\cancel{\text{cm}^3}} = 1.91 \times 10^3\text{ g}$

D. $\text{mass of nickel} = 169\,\cancel{\text{cm}^3} \times \frac{8.91\text{ g}}{1\,\cancel{\text{cm}^3}} = 1.51 \times 10^3\text{ g}$

E. $\text{mass of titanium} = 169\,\cancel{\text{cm}^3} \times \frac{4.51\text{ g}}{1\,\cancel{\text{cm}^3}} = 762\text{ g}$

1.151 Answer: A; A chemical change is a process in which one or more substances are converted into one or more new substances. In this reaction, natural gas and oxygen are converted to water and carbon dioxide.

B. In a physical change, atoms do not rearrange to form new substances.
C. When a substance undergoes a chemical change, its chemical composition changes.
D. Formation of rust on an old car is an example of a chemical change.
E. The boiling point of nitrogen is −196°C. At −210°C nitrogen is expected to be a liquid.

1.152 Answer: C; Chemical energy is potential energy arising from the positions of the atoms and molecules in a compound.

A. Heat coming off a car engine is an example of energy.
B. Kinetic energy is the energy of motion.
D. Exhaust released from the tailpipe of an old truck is an example of matter.
E. A skateboarder rolling down a hill is converting potential energy to kinetic energy.

1.153 Answer: B; This statement is a tentative explanation for the behavior of zinc and copper and it can be tested.

A. This is a statement of the law of conservation of mass.
C. This is an observation.
D. This is an observation.
E. This is a statement of atomic theory.

1.154 Answer: C; To express the value 0.00063780 in decimal form, we move the decimal point to the right four places. The exponent is −4. The zero at the end of the number is counted as significant.

A. 0.000638
B. 0.0006378
D. 63,780
E. 0.000063780

1.155 Answer: D; The value 0.050 has only two significant figures so the answer to the calculation should be expressed to two significant figures.

A. 7.93×10^{-3}
B. 6×10^{3}
C. 3.73×10^{3}
D. 8.1×10^{-4}
E. 3×10^{-10}

1.156 Answer: A; To compare the magnitudes of the masses, they should be converted to a common unit. The value 4.1×10^{-2} kg is equal to 41 g. The mass of B, 1.8×10^{4} g, converted to grams is 18 g. The mass of E, 6.5×10^{6} μg, converted to grams is 6.5 g. The order of increasing mass is E < D < B < C < A.

1.157 Answer: C; The mathematical operations in this calculation have appropriate conversion factors and units cancel appropriately to give final units of miles per hour.

A. The conversion factor for meters to kilometers is incorrect. It should be 1000 m = 1 km.
B. The conversion factor in the third step is inverted.
D. The conversion factors in the last two steps are inverted.
E. The conversion factors in the second and last two steps are inverted.