CHAPTER 1

CHEMICAL FOUNDATIONS

Questions

19. A law summarizes what happens, e.g., law of conservation of mass in a chemical reaction or the ideal gas law, PV = nRT. A theory (model) is an attempt to explain why something happens. Dalton's atomic theory explains why mass is conserved in a chemical reaction. The kinetic molecular theory explains why pressure and volume are inversely related at constant temperature and moles of gas present, as well as explaining the other mathematical relationships summarized in PV = nRT.

20. A dynamic process is one that is active as opposed to static. In terms of the scientific method, scientists are always performing experiments to prove or disprove a hypothesis or a law or a theory. Scientists do not stop asking questions just because a given theory seems to account satisfactorily for some aspect of natural behavior. The key to the scientific method is to continually ask questions and perform experiments. Science is an active process, not a static one.

21. The fundamental steps are
    (1) making observations;
    (2) formulating hypotheses;
    (3) performing experiments to test the hypotheses.

    The key to the scientific method is performing experiments to test hypotheses. If after the test of time the hypotheses seem to account satisfactorily for some aspect of natural behavior, then the set of tested hypotheses turns into a theory (model). However, scientists continue to perform experiments to refine or replace existing theories.

22. A random error has equal probability of being too high or too low. This type of error occurs when estimating the value of the last digit of a measurement. A systematic error is one that always occurs in the same direction, either too high or too low. For example, this type of error would occur if the balance you were using weighed all objects 0.20 g too high, that is, if the balance wasn't calibrated correctly. A random error is an indeterminate error, whereas a systematic error is a determinate error.

23. A qualitative observation expresses what makes something what it is; it does not involve a number; e.g., the air we breathe is a mixture of gases, ice is less dense than water, rotten milk stinks.

    The SI units are mass in kilograms, length in meters, and volume in the derived units of m^3. The assumed uncertainty in a number is ± 1 in the last significant figure of the number. The precision of an instrument is related to the number of significant figures associated with an experimental reading on that instrument. Different instruments for measuring mass, length, or volume have varying degrees of precision. Some instruments only give a few significant figures for a measurement, whereas others will give more significant figures.

24. Precision: reproducibility; accuracy: the agreement of a measurement with the true value.

a. Imprecise and inaccurate data: 12.32 cm, 9.63 cm, 11.98 cm, 13.34 cm

b. Precise but inaccurate data: 8.76 cm, 8.79 cm, 8.72 cm, 8.75 cm

c. Precise and accurate data: 10.60 cm, 10.65 cm, 10.63 cm, 10.64 cm

Data can be imprecise if the measuring device is imprecise as well as if the user of the measuring device has poor skills. Data can be inaccurate due to a systematic error in the measuring device or with the user. For example, a balance may read all masses as weighing 0.2500 g too high or the user of a graduated cylinder may read all measurements 0.05 mL too low.

A set of measurements that are imprecise implies that all the numbers are not close to each other. If the numbers aren't reproducible, then all the numbers can't be very close to the true value. Some say that if the average of imprecise data gives the true value, then the data are accurate; a better description is that the data takers are extremely lucky.

25. Significant figures are the digits we associate with a number. They contain all of the certain digits and the first uncertain digit (the first estimated digit). What follows is one thousand indicated to varying numbers of significant figures: 1000 or 1×10^3 (1 S.F.); 1.0×10^3 (2 S.F.); 1.00×10^3 (3 S.F.); 1000. or 1.000×10^3 (4 S.F.).

To perform the calculation, the addition/subtraction significant figure rule is applied to 1.5 − 1.0. The result of this is the one-significant-figure answer of 0.5. Next, the multiplication/division rule is applied to 0.5/0.50. A one-significant-figure number divided by a two-significant-figure number yields an answer with one significant figure (answer = 1).

26. The volume per mass is the reciprocal of the density (1/density). The volume per mass conversion factor has units of cm^3/g and is useful when converting from the mass of an object to its volume in cm^3.

27. Straight line equation: $y = mx + b$, where m is the slope of the line and b is the y-intercept. For the T_F vs. T_C plot:

$$T_F = (9/5)T_C + 32$$
$$y = \quad m \quad x + b$$

The slope of the plot is 1.8 (= 9/5) and the y-intercept is 32°F.

For the T_C vs. T_K plot:

$$T_C = \quad T_K - 273$$
$$y = m\,x \quad + b$$

The slope of the plot is 1, and the y-intercept is −273°C.

28. a. coffee; saltwater; the air we breathe (N_2 + O_2 + others); brass (Cu + Zn)

b. book; human being; tree; desk

c. sodium chloride (NaCl); water (H_2O); glucose ($C_6H_{12}O_6$); carbon dioxide (CO_2)

d. nitrogen (N_2); oxygen (O_2); copper (Cu); zinc (Zn)

e. boiling water; freezing water; melting a popsicle; dry ice subliming

f. Elecrolysis of molten sodium chloride to produce sodium and chlorine gas; the explosive reaction between oxygen and hydrogen to produce water; photosynthesis, which converts H_2O and CO_2 into $C_6H_{12}O_6$ and O_2; the combustion of gasoline in our car to produce CO_2 and H_2O

Exercises

Significant Figures and Unit Conversions

29. a. exact b. inexact

c. exact d. inexact (π has an infinite number of decimal places.)

30. a. one significant figure (S.F.). The implied uncertainty is ±1000 pages. More significant figures should be added if a more precise number is known.

b. two S.F. c. four S.F.

d. two S.F. e. infinite number of S.F. (exact number) f. one S.F.

31. a. $\underline{6.07} \times 10^{-15}$; 3 S.F. b. $0.00\underline{3840}$; 4 S.F. c. $\underline{17.00}$; 4 S.F.

d. $\underline{8} \times 10^{8}$; 1 S.F. e. $\underline{463.8052}$; 7 S.F. f. $\underline{3}00$; 1 S.F.

g. $\underline{301}$; 3 S.F. h. $\underline{300.}$; 3 S.F.

32. a. $\underline{1}00$; 1 S.F. b. $\underline{1.0} \times 10^{2}$; 2 S.F. c. $\underline{1.00} \times 10^{3}$; 3 S.F.

d. $\underline{100.}$; 3 S.F. e. $0.00\underline{48}$; 2 S.F. f. $0.00\underline{480}$; 3 S.F.

g. $\underline{4.80} \times 10^{-3}$; 3 S.F. h. $\underline{4.800} \times 10^{-3}$; 4 S.F.

33. When rounding, the last significant figure stays the same if the number after this significant figure is less than 5 and increases by one if the number is greater than or equal to 5.

a. 3.42×10^{-4} b. 1.034×10^{4} c. 1.7992×10^{1} d. 3.37×10^{5}

34. a. 4×10^{5} b. 3.9×10^{5} c. 3.86×10^{5} d. 3.8550×10^{5}

35. For addition and/or subtraction, the result has the same number of decimal places as the number in the calculation with the fewest decimal places. When the result is rounded to the correct number of significant figures, the last significant figure stays the same if the number after this significant figure is less than 5 and increases by one if the number is greater than or equal to 5. The underline shows the last significant figure in the intermediate answers.

a. $212.2 + 26.7 + 402.09 = 640.\underline{9}9 = 641.0$

b. $1.0028 + 0.221 + 0.10337 = 1.32\underline{7}17 = 1.327$

c. $52.331 + 26.01 - 0.9981 = 77.3\underline{4}29 = 77.34$

d. $2.01 \times 10^2 + 3.014 \times 10^3 = 2.01 \times 10^2 + 30.14 \times 10^2 = 32.1\underline{5} \times 10^2 = 3215$

When the exponents are different, it is easiest to apply the addition/subtraction rule when all numbers are based on the same power of 10.

e. 7.255 − 6.8350 = 0.42 = 0.420 (first uncertain digit is in the third decimal place).

36. For multiplication and/or division, the result has the same number of significant figures as the number in the calculation with the fewest significant figures.

a. $\dfrac{0.102 \times 0.0821 \times 273}{1.01} = \underline{2.26}35 = 2.26$

b. $0.14 \times 6.022 \times 10^{23} = \underline{8.4}31 \times 10^{22} = 8.4 \times 10^{22}$; since 0.14 only has two significant figures, the result should only have two significant figures.

c. $4.0 \times 10^4 \times 5.021 \times 10^{-3} \times 7.34993 \times 10^2 = \underline{1.4}76 \times 10^5 = 1.5 \times 10^5$

d. $\dfrac{2.00 \times 10^6}{3.00 \times 10^{-7}} = \underline{6.66}67 \times 10^{12} = 6.67 \times 10^{12}$

37. a. Here, apply the multiplication/division rule first; then apply the addition/subtraction rule to arrive at the one-decimal-place answer. We will generally round off at intermediate steps in order to show the correct number of significant figures. However, you should round off at the end of all the mathematical operations in order to avoid round-off error. The best way to do calculations is to keep track of the correct number of significant figures during intermediate steps, but round off at the end. For this problem, we underlined the last significant figure in the intermediate steps.

$$\frac{2.526}{3.1} + \frac{0.470}{0.623} + \frac{80.705}{0.4326} = 0.8\underline{1}48 + 0.75\underline{4}4 + 186.\underline{5}58 = 188.1$$

b. Here, the mathematical operation requires that we apply the addition/subtraction rule first, then apply the multiplication/division rule.

$$\frac{6.404 \times 2.91}{18.7 - 17.1} = \frac{6.404 \times 2.91}{1.\underline{6}} = 12$$

c. $6.071 \times 10^{-5} - 8.2 \times 10^{-6} - 0.521 \times 10^{-4} = 60.71 \times 10^{-6} - 8.2 \times 10^{-6} - 52.1 \times 10^{-6}$

$= 0.\underline{4}1 \times 10^{-6} = 4 \times 10^{-7}$

d. $\dfrac{3.8 \times 10^{-12} + 4.0 \times 10^{-13}}{4 \times 10^{12} + 6.3 \times 10^{13}} = \dfrac{38 \times 10^{-13} + 4.0 \times 10^{-13}}{4 \times 10^{12} + 63 \times 10^{12}} = \dfrac{4\underline{2} \times 10^{-13}}{6\underline{7} \times 10^{12}} = 6.3 \times 10^{-26}$

e. $\dfrac{9.5 + 4.1 + 2.8 + 3.175}{4} = \dfrac{19.\underline{5}75}{4} = 4.89 = 4.9$

Uncertainty appears in the first decimal place. The average of several numbers can only be as precise as the least precise number. Averages can be exceptions to the significant figure rules.

f. $\frac{8.925 - 8.905}{8.925} \times 100 = \frac{0.02\underline{0}}{8.925} \times 100 = 0.22$

38. a. $6.022 \times 10^{23} \times 1.05 \times 10^{2} = 6.32 \times 10^{25}$

b. $\frac{6.6262 \times 10^{-34} \times 2.998 \times 10^{8}}{2.54 \times 10^{-9}} = 7.82 \times 10^{-17}$

c. $1.285 \times 10^{-2} + 1.24 \times 10^{-3} + 1.879 \times 10^{-1}$
$= 0.1285 \times 10^{-1} + 0.0124 \times 10^{-1} + 1.879 \times 10^{-1} = 2.020 \times 10^{-1}$

When the exponents are different, it is easiest to apply the addition/subtraction rule when all numbers are based on the same power of 10.

d. $\frac{(1.00866 - 1.00728)}{6.02205 \times 10^{23}} = \frac{0.00138}{6.02205 \times 10^{23}} = 2.29 \times 10^{-27}$

e. $\frac{9.875 \times 10^{2} - 9.795 \times 10^{2}}{9.875 \times 10^{2}} \times 100 = \frac{0.080 \times 10^{2}}{9.875 \times 10^{2}} \times 100 = 8.1 \times 10^{-1}$

f. $\frac{9.42 \times 10^{2} + 8.234 \times 10^{2} + 1.625 \times 10^{3}}{3} = \frac{0.942 \times 10^{3} + 0.824 \times 10^{3} + 1.625 \times 10^{3}}{3}$
$= 1.130 \times 10^{3}$

39. a. $8.43 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times \frac{1000 \text{ mm}}{\text{m}} = 84.3 \text{ mm}$

b. $2.41 \times 10^{2} \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 2.41 \text{ m}$

c. $294.5 \text{ nm} \times \frac{1 \text{ m}}{1 \times 10^{9} \text{ nm}} \times \frac{100 \text{ cm}}{\text{m}} = 2.945 \times 10^{-5} \text{ cm}$

d. $1.445 \times 10^{4} \text{ m} \times \frac{1 \text{ km}}{1000 \text{ m}} = 14.45 \text{ km}$

e. $235.3 \text{ m} \times \frac{1000 \text{ mm}}{\text{m}} = 2.353 \times 10^{5} \text{ mm}$

f. $903.3 \text{ nm} \times \frac{1 \text{ m}}{1 \times 10^{9} \text{ nm}} \times \frac{1 \times 10^{6} \text{ µm}}{\text{m}} = 0.9033 \text{ µm}$

40. a. $1 \text{ Tg} \times \frac{1 \times 10^{12} \text{ g}}{\text{Tg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1 \times 10^{9} \text{ kg}$

b. $6.50 \times 10^{2} \text{ Tm} \times \frac{1 \times 10^{12} \text{ m}}{\text{Tm}} \times \frac{1 \times 10^{9} \text{ nm}}{\text{m}} = 6.50 \times 10^{23} \text{ nm}$

c. $25\text{ fg} \times \dfrac{1\text{ g}}{1 \times 10^{15}\text{ fg}} \times \dfrac{1\text{ kg}}{1000\text{ g}} = 25 \times 10^{-18}\text{ kg} = 2.5 \times 10^{-17}\text{ kg}$

d. $8.0\text{ dm}^3 \times \dfrac{1\text{ L}}{\text{dm}^3} = 8.0\text{ L}$ $(1\text{ L} = 1\text{ dm}^3 = 1000\text{ cm}^3 = 1000\text{ mL})$

e. $1\text{ mL} \times \dfrac{1\text{ L}}{1000\text{ mL}} \times \dfrac{1 \times 10^6\ \mu\text{L}}{\text{L}} = 1 \times 10^3\ \mu\text{L}$

f. $1\ \mu\text{g} \times \dfrac{1\text{ g}}{1 \times 10^6\ \mu\text{g}} \times \dfrac{1 \times 10^{12}\text{ pg}}{\text{g}} = 1 \times 10^6\text{ pg}$

41. a. Appropriate conversion factors are found in Appendix 6. In general, the number of significant figures we use in the conversion factors will be one more than the number of significant figures from the numbers given in the problem. This is usually sufficient to avoid round-off error.

$3.91\text{ kg} \times \dfrac{1\text{ lb}}{0.4536\text{ kg}} = 8.62\text{ lb};\ \ 0.62\text{ lb} \times \dfrac{16\text{ oz}}{\text{lb}} = 9.9\text{ oz}$

Baby's weight = 8 lb and 9.9 oz or, to the nearest ounce, 8 lb and 10. oz.

$51.4\text{ cm} \times \dfrac{1\text{ in}}{2.54\text{ cm}} = 20.2\text{ in} \approx 20\ 1/4\text{ in} = \text{baby's height}$

b. $25{,}000\text{ mi} \times \dfrac{1.61\text{ km}}{\text{mi}} = 4.0 \times 10^4\text{ km};\ \ 4.0 \times 10^4\text{ km} \times \dfrac{1000\text{ m}}{\text{km}} = 4.0 \times 10^7\text{ m}$

c. $V = 1 \times w \times h = 1.0\text{ m} \times \left(5.6\text{ cm} \times \dfrac{1\text{ m}}{100\text{ cm}}\right) \times \left(2.1\text{ dm} \times \dfrac{1\text{ m}}{10\text{ dm}}\right) = 1.2 \times 10^{-2}\text{ m}^3$

$1.2 \times 10^{-2}\text{ m}^3 \times \left(\dfrac{10\text{ dm}}{\text{m}}\right)^3 \times \dfrac{1\text{ L}}{\text{dm}^3} = 12\text{ L}$

$12\text{ L} \times \dfrac{1000\text{ cm}^3}{\text{L}} \times \left(\dfrac{1\text{ in}}{2.54\text{ cm}}\right)^3 = 730\text{ in}^3;\ \ 730\text{ in}^3 \times \left(\dfrac{1\text{ ft}}{12\text{ in}}\right)^3 = 0.42\text{ ft}^3$

42. a. $908\text{ oz} \times \dfrac{1\text{ lb}}{16\text{ oz}} \times \dfrac{0.4536\text{ kg}}{\text{lb}} = 25.7\text{ kg}$

b. $12.8\text{ L} \times \dfrac{1\text{ qt}}{0.9463\text{ L}} \times \dfrac{1\text{ gal}}{4\text{ qt}} = 3.38\text{ gal}$

c. $125\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{1\text{ qt}}{0.9463\text{ L}} = 0.132\text{ qt}$

d. $2.89\text{ gal} \times \frac{4\text{ qt}}{1\text{ gal}} \times \frac{1\text{ L}}{1.057\text{ qt}} \times \frac{1000\text{ mL}}{1\text{ L}} = 1.09 \times 10^4\text{ mL}$

e. $4.48\text{ lb} \times \frac{453.6\text{ g}}{1\text{ lb}} = 2.03 \times 10^3\text{ g}$

f. $550\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{1.06\text{ qt}}{\text{L}} = 0.58\text{ qt}$

43. a. $1.25\text{ mi} \times \frac{8\text{ furlongs}}{\text{mi}} = 10.0\text{ furlongs};\ 10.0\text{ furlongs} \times \frac{40\text{ rods}}{\text{furlong}} = 4.00 \times 10^2\text{ rods}$

$4.00 \times 10^2\text{ rods} \times \frac{5.5\text{ yd}}{\text{rod}} \times \frac{36\text{ in}}{\text{yd}} \times \frac{2.54\text{ cm}}{\text{in}} \times \frac{1\text{ m}}{100\text{ cm}} = 2.01 \times 10^3\text{ m}$

$2.01 \times 10^3\text{ m} \times \frac{1\text{ km}}{1000\text{ m}} = 2.01\text{ km}$

b. Let's assume we know this distance to ±1 yard. First, convert 26 miles to yards.

$26\text{ mi} \times \frac{5280\text{ ft}}{\text{mi}} \times \frac{1\text{ yd}}{3\text{ ft}} = 45{,}760.\text{ yd}$

$26\text{ mi} + 385\text{ yd} = 45{,}760.\text{ yd} + 385\text{ yd} = 46{,}145\text{ yards}$

$46{,}145\text{ yard} \times \frac{1\text{ rod}}{5.5\text{ yd}} = 8390.0\text{ rods};\ 8390.0\text{ rods} \times \frac{1\text{ furlong}}{40\text{ rods}} = 209.75\text{ furlongs}$

$46{,}145\text{ yard} \times \frac{36\text{ in}}{\text{yd}} \times \frac{2.54\text{ cm}}{\text{in}} \times \frac{1\text{ m}}{100\text{ cm}} = 42{,}195\text{ m};\ 42{,}195\text{ m} \times \frac{1\text{ km}}{1000\text{ m}} = 42.195\text{ km}$

44. a. $1\text{ ha} \times \frac{10{,}000\text{ m}^2}{\text{ha}} \times \left(\frac{1\text{ km}}{1000\text{ m}}\right)^2 = 1 \times 10^{-2}\text{ km}^2$

b. $5.5\text{ acre} \times \frac{160\text{ rod}^2}{\text{acre}} \times \left(\frac{5.5\text{ yd}}{\text{rod}} \times \frac{36\text{ in}}{\text{yd}} \times \frac{2.54\text{ cm}}{\text{in}} \times \frac{1\text{ m}}{100\text{ cm}}\right)^2 = 2.2 \times 10^4\text{ m}^2$

$2.2 \times 10^4\text{ m}^2 \times \frac{1\text{ ha}}{1 \times 10^4\text{ m}^2} = 2.2\text{ ha};\ 2.2 \times 10^4\text{ m}^2 \times \left(\frac{1\text{ km}}{1000\text{ m}}\right)^2 = 0.022\text{ km}^2$

c. Area of lot = 120 ft × 75 ft = $9.0 \times 10^3\text{ ft}^2$

$9.0 \times 10^3\text{ ft}^2 \times \left(\frac{1\text{ yd}}{3\text{ ft}} \times \frac{1\text{ rod}}{5.5\text{ yd}}\right)^2 \times \frac{1\text{ acre}}{160\text{ rod}^2} = 0.21\text{ acre};\ \frac{\$6{,}500}{0.21\text{ acre}} = \frac{\$31{,}000}{\text{acre}}$

We can use our result from (b) to get the conversion factor between acres and hectares (5.5 acre = 2.2 ha.). Thus 1 ha = 2.5 acre.

$$0.21 \text{ acre} \times \frac{1 \text{ ha}}{2.5 \text{ acre}} = 0.084 \text{ ha}; \text{ the price is: } \frac{\$6,500}{0.084 \text{ ha}} = \frac{\$77,000}{\text{ha}}$$

45. a. $1 \text{ troy lb} \times \frac{12 \text{ troy oz}}{\text{troy lb}} \times \frac{20 \text{ pw}}{\text{troy oz}} \times \frac{24 \text{ grains}}{\text{pw}} \times \frac{0.0648 \text{ g}}{\text{grain}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.373 \text{ kg}$

$1 \text{ troy lb} = 0.373 \text{ kg} \times \frac{2.205 \text{ lb}}{\text{kg}} = 0.822 \text{ lb}$

b. $1 \text{ troy oz} \times \frac{20 \text{ pw}}{\text{troy oz}} \times \frac{24 \text{ grains}}{\text{pw}} \times \frac{0.0648 \text{ g}}{\text{grain}} = 31.1 \text{ g}$

$1 \text{ troy oz} = 31.1 \text{ g} \times \frac{1 \text{ carat}}{0.200 \text{ g}} = 156 \text{ carats}$

c. $1 \text{ troy lb} = 0.373 \text{ kg}; \; 0.373 \text{ kg} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ cm}^3}{19.3 \text{ g}} = 19.3 \text{ cm}^3$

46. a. $1 \text{ grain ap} \times \frac{1 \text{ scruple}}{20 \text{ grain ap}} \times \frac{1 \text{ dram ap}}{3 \text{ scruples}} \times \frac{3.888 \text{ g}}{\text{dram ap}} = 0.06480 \text{ g}$

From the previous question, we are given that 1 grain troy = 0.0648 g = 1 grain ap. So the two are the same.

b. $1 \text{ oz ap} \times \frac{8 \text{ dram ap}}{\text{oz ap}} \times \frac{3.888 \text{ g}}{\text{dram ap}} \times \frac{1 \text{ oz troy}^*}{31.1 \text{ g}} = 1.00 \text{ oz troy}$; *see Exercise 45b.

c. $5.00 \times 10^2 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ dram ap}}{3.888 \text{ g}} \times \frac{3 \text{ scruples}}{\text{dram ap}} = 0.386 \text{ scruple}$

$0.386 \text{ scruple} \times \frac{20 \text{ grains ap}}{\text{scruple}} = 7.72 \text{ grains ap}$

d. $1 \text{ scruple} \times \frac{1 \text{ dram ap}}{3 \text{ scruples}} \times \frac{3.888 \text{ g}}{\text{dram ap}} = 1.296 \text{ g}$

47. $\text{warp } 1.71 = \left(5.00 \times \frac{3.00 \times 10^8 \text{ m}}{\text{s}}\right) \times \frac{1.094 \text{ yd}}{\text{m}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} \times \frac{1 \text{ knot}}{2000 \text{ yd/h}}$

$= 2.95 \times 10^9 \text{ knots}$

$$\left(5.00 \times \frac{3.00 \times 10^8 \text{ m}}{\text{s}}\right) \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{1 \text{ mi}}{1.609 \text{ km}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} = 3.36 \times 10^9 \text{ mi/h}$$

48. $\frac{100.\text{ m}}{9.74\text{ s}} = 10.3\text{ m/s}; \quad \frac{100.\text{ m}}{9.74\text{ s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{\text{min}} \times \frac{60\text{ min}}{\text{h}} = 37.0\text{ km/h}$

$$\frac{100.\text{ m}}{9.74\text{ s}} \times \frac{1.0936\text{ yd}}{\text{m}} \times \frac{3\text{ ft}}{\text{yd}} = 33.7\text{ ft/s}; \quad \frac{33.7\text{ ft}}{\text{s}} \times \frac{1\text{ mi}}{5280\text{ ft}} \times \frac{60\text{ s}}{\text{min}} \times \frac{60\text{ min}}{\text{h}} = 23.0\text{ mi/h}$$

$$1.00 \times 10^2\text{ yd} \times \frac{1\text{ m}}{1.0936\text{ yd}} \times \frac{9.74\text{ s}}{100.\text{ m}} = 8.91\text{ s}$$

49. $\frac{65\text{ km}}{\text{h}} \times \frac{0.6214\text{ mi}}{\text{km}} = 40.4 = 40.\text{ mi/h}$

To the correct number of significant figures, 65 km/h does not violate a 40. mi/h speed limit.

50. $112\text{ km} \times \frac{0.6214\text{ mi}}{\text{km}} \times \frac{1\text{ h}}{65\text{ mi}} = 1.1\text{ h} = 1\text{ h and 6 min}$

$$112\text{ km} \times \frac{0.6214\text{ mi}}{\text{km}} \times \frac{1\text{ gal}}{28\text{ mi}} \times \frac{3.785\text{ L}}{\text{gal}} = 9.4\text{ L of gasoline}$$

51. $\frac{2.45\text{ euros}}{\text{kg}} \times \frac{1\text{ kg}}{2.2046\text{ lb}} \times \frac{\$1.46}{\text{euro}} = \$1.62/\text{lb}$

One pound of peaches costs $1.62.

52. Volume of room = 18 ft × 12 ft × 8 ft = 1700 ft^3 (carrying one extra significant figure)

$$1700\text{ ft}^3 \times \left(\frac{12\text{ in}}{\text{ft}}\right)^3 \times \left(\frac{2.54\text{ cm}}{\text{in}}\right)^3 \times \left(\frac{1\text{ m}}{100\text{ cm}}\right)^3 = 48\text{ m}^3$$

$$48\text{ m}^3 \times \frac{400{,}000\ \mu\text{g CO}}{\text{m}^3} \times \frac{1\text{ g CO}}{1 \times 10^6\ \mu\text{g CO}} = 19\text{ g} = 20\text{ g CO (to 1 sig. fig.)}$$

Temperature

53. a. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(-459°\text{F} - 32) = -273°\text{C}; \ T_K = T_C + 273 = -273°\text{C} + 273 = 0\text{ K}$

b. $T_C = \frac{5}{9}(-40.°\text{F} - 32) = -40.°\text{C}; \ T_K = -40.°\text{C} + 273 = 233\text{ K}$

c. $T_C = \frac{5}{9}(68°\text{F} - 32) = 20.°\text{C}; \ T_K = 20.°\text{C} + 273 = 293\text{ K}$

d. $T_C = \frac{5}{9}(7 \times 10^7°\text{F} - 32) = 4 \times 10^7°\text{C}; \ T_K = 4 \times 10^7°\text{C} + 273 = 4 \times 10^7\text{ K}$

54. 96.1°F ±0.2°F; first, convert 96.1°F to °C. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(96.1 - 32) = 35.6°C$

A change in temperature of 9°F is equal to a change in temperature of 5°C. So the uncertainty is:

$\pm0.2°F \times \frac{5°\,C}{9°\,F} = \pm0.1°C$. Thus 96.1 ±0.2°F = 35.6 ±0.1°C.

55. a. $T_F = \frac{9}{5} \times T_C + 32 = \frac{9}{5} \times 39.2°C + 32 = 102.6°F$ (*Note*: 32 is exact.)

$T_K = T_C + 273.2 = 39.2 + 273.2 = 312.4$ K

b. $T_F = \frac{9}{5} \times (-25) + 32 = -13°F$; $T_K = -25 + 273 = 248$ K

c. $T_F = \frac{9}{5} \times (-273) + 32 = -459°F$; $T_K = -273 + 273 = 0$ K

d. $T_F = \frac{9}{5} \times 801 + 32 = 1470°F$; $T_K = 801 + 273 = 1074$ K

56. a. $T_C = T_K - 273 = 233 - 273 = -40.°C$

$T_F = \frac{9}{5} \times T_C + 32 = \frac{9}{5} \times (-40.) + 32 = -40.°F$

b. $T_C = 4 - 273 = -269°C$; $T_F = \frac{9}{5} \times (-269) + 32 = -452°F$

c. $T_C = 298 - 273 = 25°C$; $T_F = \frac{9}{5} \times 25 + 32 = 77°F$

d. $T_C = 3680 - 273 = 3410°C$; $T_F = \frac{9}{5} \times 3410 + 32 = 6170°F$

57. $T_F = \frac{9}{5} \times T_C + 32$; from the problem, we want the temperature where $T_F = 2T_C$.

Substituting:

$2T_C = \frac{9}{5} \times T_C + 32$, $(0.2)T_C = 32$, $T_C = \frac{32}{0.2} = 160°C$

$T_F = 2T_C$ when the temperature in Fahrenheit is 2(160) = 320°F. Because all numbers when solving the equation are exact numbers, the calculated temperatures are also exact numbers.

58. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(72 - 32) = 22°C$

$T_C = T_K - 273 = 313 - 273 = 40.°C$

The difference in temperature between Jupiter at 313 K and Earth at 72°F is 40.°C – 22 °C = 18°C.

Density

59. Mass $= 350 \text{ lb} \times \frac{453.6 \text{ g}}{\text{lb}} = 1.6 \times 10^5 \text{ g}$; $V = 1.2 \times 10^4 \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{\text{in}}\right)^3 = 2.0 \times 10^5 \text{ cm}^3$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1 \times 10^5 \text{ g}}{2.0 \times 10^5 \text{ cm}^3} = 0.80 \text{ g/cm}^3$$

Because the material has a density less than water, it will float in water.

60. $V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times (0.50 \text{ cm})^3 = 0.52 \text{ cm}^3$; $d = \frac{2.0 \text{ g}}{0.52 \text{ cm}^3} = 3.8 \text{ g/cm}^3$

The ball will sink.

61. $V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times \left(7.0 \times 10^5 \text{ km} \times \frac{1000 \text{ m}}{\text{km}} \times \frac{100 \text{ cm}}{\text{m}}\right)^3 = 1.4 \times 10^{33} \text{ cm}^3$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{2 \times 10^{36} \text{ kg} \times \frac{1000 \text{ g}}{\text{kg}}}{1.4 \times 10^{33} \text{ cm}^3} = 1.4 \times 10^6 \text{ g/cm}^3 = 1 \times 10^6 \text{ g/cm}^3$$

62. $V = l \times w \times h = 2.9 \text{ cm} \times 3.5 \text{ cm} \times 10.0 \text{ cm} = 1.0 \times 10^2 \text{ cm}^3$

$$d = \text{density} = \frac{615.0 \text{ g}}{1.0 \times 10^2 \text{ cm}^3} = \frac{6.2 \text{ g}}{\text{cm}^3}$$

63. a. $5.0 \text{ carat} \times \frac{0.200 \text{ g}}{\text{carat}} \times \frac{1 \text{ cm}^3}{3.51 \text{ g}} = 0.28 \text{ cm}^3$

b. $2.8 \text{ mL} \times \frac{1 \text{ cm}^3}{\text{mL}} \times \frac{3.51 \text{ g}}{\text{cm}^3} \times \frac{1 \text{ carat}}{0.200 \text{ g}} = 49 \text{ carats}$

64. For ethanol: $100. \text{ mL} \times \frac{0.789 \text{ g}}{\text{mL}} = 78.9 \text{ g}$

For benzene: $1.00 \text{ L} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{0.880 \text{ g}}{\text{mL}} = 880. \text{ g}$

Total mass = 78.9 g + 880. g = 959 g

65. V = 21.6 mL – 12.7 mL = 8.9 mL; density $= \frac{33.42 \text{ g}}{8.9 \text{ mL}} = 3.8 \text{ g/mL} = 3.8 \text{ g/cm}^3$

66. $5.25 \text{ g} \times \frac{1 \text{ cm}^3}{10.5 \text{ g}} = 0.500 \text{ cm}^3 = 0.500 \text{ mL}$

The volume in the cylinder will rise to 11.7 mL (11.2 mL + 0.500 mL = 11.7 mL).

67. a. Both have the same mass of 1.0 kg.

b. 1.0 mL of mercury; mercury is more dense than water. *Note*: 1 mL = 1 cm^3.

$$1.0\text{ mL} \times \frac{13.6\text{ g}}{\text{mL}} = 14\text{ g of mercury; } 1.0\text{ mL} \times \frac{0.998\text{ g}}{\text{mL}} = 1.0\text{ g of water}$$

c. Same; both represent 19.3 g of substance.

$$19.3\text{ mL} \times \frac{0.9982\text{ g}}{\text{mL}} = 19.3\text{ g of water; } 1.00\text{ mL} \times \frac{19.32\text{ g}}{\text{mL}} = 19.3\text{ g of gold}$$

d. 1.0 L of benzene (880 g versus 670 g)

$$75\text{ mL} \times \frac{8.96\text{ g}}{\text{mL}} = 670\text{ g of copper; } 1.0\text{ L} \times \frac{1000\text{ mL}}{\text{L}} \times \frac{0.880\text{ g}}{\text{mL}} = 880\text{ g of benzene}$$

68. a. $1.50\text{ qt} \times \frac{1\text{ L}}{1.0567\text{ qt}} \times \frac{1000\text{ mL}}{\text{L}} \times \frac{0.789\text{ g}}{\text{mL}} = 1120\text{ g ethanol}$

b. $3.5\text{ in}^3 \times \left(\frac{2.54\text{ cm}}{\text{in}}\right)^3 \times \frac{13.6\text{ g}}{\text{cm}^3} = 780\text{ g mercury}$

69. a. 1.0 kg feather; feathers are less dense than lead.

b. 100 g water; water is less dense than gold. c. Same; both volumes are 1.0 L.

70. a. $H_2(g)$: $V = 25.0\text{ g} \times \frac{1\text{ cm}^3}{0.000084\text{ g}} = 3.0 \times 10^5\text{ cm}^3$ [$H_2(g)$ = hydrogen gas.]

b. $H_2O(l)$: $V = 25.0\text{ g} \times \frac{1\text{ cm}^3}{0.9982\text{ g}} = 25.0\text{ cm}^3$ [$H_2O(l)$ = water.]

c. $Fe(s)$: $V = 25.0\text{ g} \times \frac{1\text{ cm}^3}{7.87\text{ g}} = 3.18\text{ cm}^3$ [$Fe(s)$ = iron.]

Notice the huge volume of the gaseous H_2 sample as compared to the liquid and solid samples. The same mass of gas occupies a volume that is over 10,000 times larger than the liquid sample. Gases are indeed mostly empty space.

71. $V = 1.00 \times 10^3\text{ g} \times \frac{1\text{ cm}^3}{22.57\text{ g}} = 44.3\text{ cm}^3$

$44.3\text{ cm}^3 = 1 \times w \times h = 4.00\text{ cm} \times 4.00\text{ cm} \times h$, $h = 2.77\text{ cm}$

72. $V = 22 \text{ g} \times \dfrac{1 \text{ cm}^3}{8.96 \text{ g}} = 2.5 \text{ cm}^3$; $V = \pi r^2 \times l$, where l = length of the wire

$$2.5 \text{ cm}^3 = \pi \times \left(\frac{0.25 \text{ mm}}{2}\right)^2 \times \left(\frac{1 \text{ cm}}{10 \text{ mm}}\right)^2 \times l, \ \ l = 5.1 \times 10^3 \text{ cm} = 170 \text{ ft}$$

Classification and Separation of Matter

73. A gas has molecules that are very far apart from each other, whereas a solid or liquid has molecules that are very close together. An element has the same type of atom, whereas a compound contains two or more different elements. Picture i represents an element that exists as two atoms bonded together (like H_2 or O_2 or N_2). Picture iv represents a compound (like CO, NO, or HF). Pictures iii and iv contain representations of elements that exist as individual atoms (like Ar, Ne, or He).

a. Picture iv represents a gaseous compound. Note that pictures ii and iii also contain a gaseous compound, but they also both have a gaseous element present.

b. Picture vi represents a mixture of two gaseous elements.

c. Picture v represents a solid element.

d. Pictures ii and iii both represent a mixture of a gaseous element and a gaseous compound.

74. Solid: rigid; has a fixed volume and shape; slightly compressible

Liquid: definite volume but no specific shape; assumes shape of the container; slightly compressible

Gas: no fixed volume or shape; easily compressible

Pure substance: has constant composition; can be composed of either compounds or elements

Element: substances that cannot be decomposed into simpler substances by chemical or physical means.

Compound: a substance that can be broken down into simpler substances (elements) by chemical processes.

Homogeneous mixture: a mixture of pure substances that has visibly indistinguishable parts.

Heterogeneous mixture: a mixture of pure substances that has visibly distinguishable parts.
Solution: a homogeneous mixture; can be a solid, liquid or gas
Chemical change: a given substance becomes a new substance or substances with different properties and different composition.

Physical change: changes the form (g, l, or s) of a substance but does no change the chemical composition of the substance.

75. Homogeneous: Having visibly indistinguishable parts (the same throughout).
Heterogeneous: Having visibly distinguishable parts (not uniform throughout).

a. heterogeneous (due to hinges, handles, locks, etc.)

b. homogeneous (hopefully; if you live in a heavily polluted area, air may be heterogeneous.)

c. homogeneous

d. homogeneous (hopefully, if not polluted)

e. heterogeneous

f. heterogeneous

76. a. heterogeneous

b. homogeneous

c. heterogeneous

d. homogeneous (assuming no imperfections in the glass)

e. heterogeneous (has visibly distinguishable parts)

77. a. pure b. mixture c. mixture d. pure e. mixture (copper and zinc)

f. pure g. mixture h. mixture i. mixture

Iron and uranium are elements. Water (H_2O) is a compound because it is made up of two or more different elements. Table salt is usually a homogeneous mixture composed mostly of sodium chloride (NaCl) but will usually contain other substances that help absorb water vapor (an anticaking agent).

78. Initially, a mixture is present. The magnesium and sulfur have only been placed together in the same container at this point, but no reaction has occurred. When heated, a reaction occurs. Assuming the magnesium and sulfur had been measured out in exactly the correct ratio for complete reaction, the remains after heating would be a pure compound composed of magnesium and sulfur. However, if there were an excess of either magnesium or sulfur, the remains after reaction would be a mixture of the compound produced and the excess reactant.

79. Chalk is a compound because it loses mass when heated and appears to change into another substance with different physical properties (the hard chalk turns into a crumbly substance).

80. Because vaporized water is still the *same substance* as solid water (H_2O), no chemical reaction has occurred. Sublimation is a physical change.

81. A physical change is a change in the state of a substance (solid, liquid, and gas are the three states of matter); a physical change does not change the chemical composition of the substance. A chemical change is a change in which a given substance is converted into another substance having a different formula (composition).

a. Vaporization refers to a liquid converting to a gas, so this is a physical change. The formula (composition) of the moth ball does not change.

b. This is a chemical change since hydrofluoric acid (HF) is reacting with glass (SiO_2) to form new compounds that wash away.

c. This is a physical change since all that is happening is the conversion of liquid alcohol to gaseous alcohol. The alcohol formula (C_2H_5OH) does not change.

d. This is a chemical change since the acid is reacting with cotton to form new compounds.

82. a. Distillation separates components of a mixture, so the orange liquid is a mixture (has an average color of the yellow liquid and the red solid). Distillation utilizes boiling point differences to separate out the components of a mixture. Distillation is a physical change because the components of the mixture do not become different compounds or elements.

b. Decomposition is a type of chemical reaction. The crystalline solid is a compound, and decomposition is a chemical change where new substances are formed.

c. Tea is a mixture of tea compounds dissolved in water. The process of mixing sugar into tea is a physical change. Sugar doesn't react with the tea compounds, it just makes the solution sweeter.

Connecting to Biochemistry

83. $15.6 \text{ g} \times \frac{1 \text{ capsule}}{0.65 \text{ g}} = 24 \text{ capsules}$

84. Because each pill is 4.0% Lipitor by mass, for every 100.0 g of pills, there are 4.0 g of Lipitor present.

$$100. \text{ pills} \times \frac{2.5 \text{ g}}{\text{pill}} \times \frac{4.0 \text{ g Lipitor}}{100.0 \text{ g pills}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.010 \text{ kg Lipitor}$$

85. $1.5 \text{ teaspoons} \times \frac{80. \text{ mg acet}}{0.50 \text{ teaspoon}} = 240 \text{ mg acetaminophen}$

$$\frac{240 \text{ mg acet}}{24 \text{ lb}} \times \frac{1 \text{ lb}}{0.454 \text{ kg}} = 22 \text{ mg acetaminophen/kg}$$

$$\frac{240 \text{ mg acet}}{35 \text{ lb}} \times \frac{1 \text{ lb}}{0.454 \text{ kg}} = 15 \text{ mg acetaminophen/kg}$$

The range is from 15 to 22 mg acetaminophen per kg of body weight.

86. a. $0.25 \text{ lb} \times \frac{453.6 \text{ g}}{\text{lb}} \times \frac{1.0 \text{ g trytophan}}{100.0 \text{ g turkey}} = 1.1 \text{ g tryptophan}$

b. $0.25 \text{ qt} \times \frac{0.9463 \text{ L}}{\text{qt}} \times \frac{1.04 \text{ kg}}{\text{L}} \times \frac{1000 \text{ kg}}{\text{kg}} \times \frac{2.0 \text{ g tryptophan}}{100.0 \text{ g milk}} = 4.9 \text{ g tryptophan}$

87. For the gasoline car:

$$500. \text{ mi} \times \frac{1 \text{ gal}}{28.0 \text{ mi}} \times \frac{\$3.50}{\text{gal}} = \$62.5$$

For the E85 car:

$$500.\text{ mi} \times \frac{1\text{ gal}}{22.5\text{ mi}} \times \frac{\$2.85}{\text{gal}} = \$63.3$$

The E85 vehicle would cost slightly more to drive 500. miles as compared to the gasoline vehicle ($63.3 versus $62.5).

88. $\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{0.384\text{ g}}{0.32\text{ cm}^3} = 1.2\text{ g/cm}^3$

From the table, the other ingredient is caffeine.

89. $\text{Volume of lake} = 100\text{ mi}^2 \times \left(\frac{5280\text{ ft}}{\text{mi}}\right)^2 \times 20\text{ ft} = 6 \times 10^{10}\text{ ft}^3$

$$6 \times 10^{10}\text{ ft}^3 \times \left(\frac{12\text{ in}}{\text{ft}} \times \frac{2.54\text{ cm}}{\text{in}}\right)^3 \times \frac{1\text{ mL}}{\text{cm}^3} \times \frac{0.4\ \mu\text{g}}{\text{mL}} = 7 \times 10^{14}\ \mu\text{g mercury}$$

$$7 \times 10^{14}\ \mu\text{g} \times \frac{1\text{ g}}{1 \times 10^6\ \mu\text{g}} \times \frac{1\text{ kg}}{1 \times 10^3\text{ g}} = 7 \times 10^5\text{ kg of mercury}$$

90. a. mixture b. mixture c. pure substance (C_6H_6)

d. mixture e. pure substance (NH_3) f. mixture

g. pure substance (C_2H_5OH) h. mixture

91. A chemical change involves the change of one or more substances into other substances through a reorganization of the atoms. A physical change involves the change in the form of a substance, but not its chemical composition.

a. physical change (Just smaller pieces of the same substance.)
b. chemical change (Chemical reactions occur.)
c. chemical change (Bonds are broken.)
d. chemical change (Bonds are broken.)
e. physical change (Water is changed from a liquid to a gas.)
f. physical change (Chemical composition does not change.)

Additional Exercises

92. $126\text{ gal} \times \frac{4\text{ qt}}{\text{gal}} \times \frac{1\text{ L}}{1.057\text{ qt}} = 477\text{ L}$

93. $\text{Total volume} = \left(200.\text{ m} \times \frac{100\text{ cm}}{\text{m}}\right) \times \left(300.\text{ m} \times \frac{100\text{ cm}}{\text{m}}\right) \times 4.0\text{ cm} = 2.4 \times 10^9\text{ cm}^3$

Volume of topsoil covered by 1 bag =

$$\left[10.\ \text{ft}^2 \times \left(\frac{12\ \text{in}}{\text{ft}}\right)^2 \times \left(\frac{2.54\ \text{cm}}{\text{in}}\right)^2\right] \times \left(1.0\ \text{in} \times \frac{2.54\ \text{cm}}{\text{in}}\right) = 2.4 \times 10^4\ \text{cm}^3$$

$$2.4 \times 10^9\ \text{cm}^3 \times \frac{1\ \text{bag}}{2.4 \times 10^4\ \text{cm}^3} = 1.0 \times 10^5\ \text{bags topsoil}$$

94. a. No; if the volumes were the same, then the gold idol would have a much greater mass because gold is much more dense than sand.

b. $\text{Mass} = 1.0\ \text{L} \times \frac{1000\ \text{cm}^3}{\text{L}} \times \frac{19.32\ \text{g}}{\text{cm}^3} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 19.32\ \text{kg}\ (= 42.59\ \text{lb})$

It wouldn't be easy to play catch with the idol because it would have a mass of over 40 pounds.

95. $$1\ \text{light year} = 1\ \text{yr} \times \frac{365\ \text{day}}{\text{yr}} \times \frac{24\ \text{h}}{\text{day}} \times \frac{60\ \text{min}}{\text{h}} \times \frac{60\ \text{s}}{\text{min}} \times \frac{186{,}000\ \text{mi}}{\text{s}} = 5.87 \times 10^{12}\ \text{miles}$$

$$9.6\ \text{parsecs} \times \frac{3.26\ \text{light yr}}{\text{parsec}} \times \frac{5.87 \times 10^{12}\ \text{mi}}{\text{light yr}} \times \frac{1.609\ \text{km}}{\text{mi}} \times \frac{1000\ \text{m}}{\text{km}} = 3.0 \times 10^{17}\ \text{m}$$

96. 60 million = 60,000,000 = 6.0×10^7

$$6.0 \times 10^7\ \text{km} \times \frac{1\ \text{mi}}{1.609\ \text{km}} \times \frac{1\ \text{s}}{186{,}000\ \text{mi}} = 2.0 \times 10^2\ \text{s} = 3.3\ \text{minutes}$$

97. $18.5\ \text{cm} \times \frac{10.0^\circ\text{F}}{5.25\ \text{cm}} = 35.2^\circ\text{F increase};\ T_{final} = 98.6 + 35.2 = 133.8^\circ\text{F}$

$T_c = 5/9\ (133.8 - 32) = 56.56^\circ\text{C}$

98. $\text{Mass}_{benzene} = 58.80\ \text{g} - 25.00\ \text{g} = 33.80\ \text{g};\ V_{benzene} = 33.80\ \text{g} \times \frac{1\ \text{cm}^3}{0.880\ \text{g}} = 38.4\ \text{cm}^3$

$V_{solid} = 50.0\ \text{cm}^3 - 38.4\ \text{cm}^3 = 11.6\ \text{cm}^3;\ \ \text{density} = \frac{25.00\ \text{g}}{11.6\ \text{cm}^3} = 2.16\ \text{g/cm}^3$

99. a. Volume × density = mass; the orange block is more dense. Because mass (orange) > mass (blue) and because volume (orange) < volume (blue), the density of the orange block must be greater to account for the larger mass of the orange block.

b. Which block is more dense cannot be determined. Because mass (orange) > mass (blue) and because volume (orange) > volume (blue), the density of the orange block may or may not be larger than the blue block. If the blue block is more dense, its density cannot be so large that its mass is larger than the orange block's mass.

c. The blue block is more dense. Because mass (blue) = mass (orange) and because volume (blue) < volume (orange), the density of the blue block must be larger in order to equate the masses.

d. The blue block is more dense. Because mass (blue) > mass (orange) and because the volumes are equal, the density of the blue block must be larger in order to give the blue block the larger mass.

100. Circumference = c = 2πr; $V = \frac{4\pi r^3}{3} = \frac{4\pi}{3}\left(\frac{c}{2\pi}\right)^3 = \frac{c^3}{6\pi^2}$

$$\text{Largest density} = \frac{5.25\ \text{oz}}{\frac{(9.00\ \text{in})^3}{6\pi^2}} = \frac{5.25\ \text{oz}}{12.3\ \text{in}^3} = \frac{0.427\ \text{oz}}{\text{in}^3}$$

$$\text{Smallest density} = \frac{5.00\ \text{oz}}{\frac{(9.25\ \text{in})^3}{6\pi^2}} = \frac{5.00\ \text{oz}}{13.4\ \text{in}^3} = \frac{0.73\ \text{oz}}{\text{in}^3}$$

Maximum range is: $\frac{(0.373 - 0.427)\ \text{oz}}{\text{in}^3}$ or 0.40 ± 0.03 oz/in^3 (Uncertainty is in 2nd decimal place.)

101. $V = V_{final} - V_{initial}$; $d = \frac{28.90\ \text{g}}{9.8\ \text{cm}^3 - 6.4\ \text{cm}^3} = \frac{28.90\ \text{g}}{3.4\ \text{cm}^3} = 8.5\ \text{g/cm}^3$

$d_{max} = \frac{mass_{max}}{V_{min}}$; we get V_{min} from 9.7 cm^3 − 6.5 cm^3 = 3.2 cm^3.

$d_{max} = \frac{28.93\ \text{g}}{3.2\ \text{cm}^3} = \frac{9.0\ \text{g}}{\text{cm}^3}$; $d_{min} = \frac{mass_{min}}{V_{max}} = \frac{28.87\ \text{g}}{9.9\ \text{cm}^3 - 6.3\ \text{cm}^3} = \frac{8.0\ \text{g}}{\text{cm}^3}$

The density is 8.5 ±0.5 g/cm^3.

102. We need to calculate the maximum and minimum values of the density, given the uncertainty in each measurement. The maximum value is:

$$d_{max} = \frac{19.625\ \text{g} + 0.002\ \text{g}}{25.00\ \text{cm}^3 - 0.03\ \text{cm}^3} = \frac{19.627\ \text{g}}{24.97\ \text{cm}^3} = 0.7860\ \text{g/cm}^3$$

The minimum value of the density is:

$$d_{min} = \frac{19.625\ \text{g} - 0.002\ \text{g}}{25.00\ \text{cm}^3 + 0.03\ \text{cm}^3} = \frac{19.623\ \text{g}}{25.03\ \text{cm}^3} = 0.7840\ \text{g/cm}^3$$

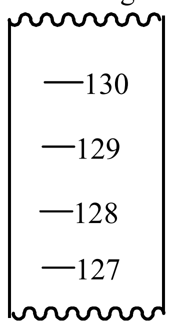
The density of the liquid is between 0.7840 and 0.7860 g/cm^3. These measurements are sufficiently precise to distinguish between ethanol (d = 0.789 g/cm^3) and isopropyl alcohol (d = 0.785 g/cm^3).

Challenge Problems

103. In a subtraction, the result gets smaller, but the uncertainties add. If the two numbers are very close together, the uncertainty may be larger than the result. For example, let's assume we want to take the difference of the following two measured quantities, 999,999 ± 2 and 999,996 ± 2. The difference is 3 ± 4. Because of the uncertainty, subtracting two similar numbers is poor practice.

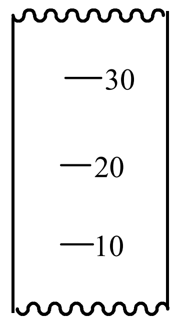
104. In general, glassware is estimated to one place past the markings.

a. 128.7 mL glassware



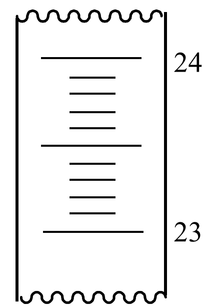
read to tenth's place

b. 18 mL glassware



read to one's place

c. 23.45 mL glassware



read to two decimal places

128.7 + 18 + 23.45 = 170.15 = 170. (Due to 18, the sum would be known only to the ones place.)

105. a. $\dfrac{2.70 - 2.64}{2.70} \times 100 = 2\%$ b. $\dfrac{|16.12 - 16.48|}{16.12} \times 100 = 2.2\%$

c. $\dfrac{1.000 - 0.9981}{1.000} \times 100 = \dfrac{0.002}{1.000} \times 100 = 0.2\%$

106. a. At some point in 1982, the composition of the metal used in minting pennies was changed because the mass changed during this year (assuming the volume of the pennies were constant).

b. It should be expressed as 3.08 ± 0.05 g. The uncertainty in the second decimal place will swamp any effect of the next decimal places.

107. Heavy pennies (old): mean mass = 3.08 ± 0.05 g

Light pennies (new): mean mass = $\dfrac{(2.467 + 2.545 + 2.518)}{3}$ = 2.51 ± 0.04 g

Because we are assuming that volume is additive, let's calculate the volume of 100. g of each type of penny, then calculate the density of the alloy. For 100. g of the old pennies, 95 g will be Cu (copper) and 5 g will be Zn (zinc).

$V = 95 \text{ g Cu} \times \dfrac{1\text{ cm}^3}{8.96\text{ g}} + 5 \text{ g Zn} \times \dfrac{1\text{ cm}^3}{7.14\text{ g}} = 11.3\text{ cm}^3$ (carrying one extra sig. fig.)

Density of old pennies $= \dfrac{100.\text{ g}}{11.3\text{ cm}^3} = 8.8\text{ g/cm}^3$

For 100. g of new pennies, 97.6 g will be Zn and 2.4 g will be Cu.

$$V = 2.4\text{ g Cu} \times \frac{1\text{ cm}^3}{8.96\text{ g}} + 97.6\text{ g Zn} \times \frac{1\text{ cm}^3}{7.14\text{ g}} = 13.94\text{ cm}^3 \text{ (carrying one extra sig. fig.)}$$

Density of new pennies $= \dfrac{100.\text{ g}}{13.94\text{ cm}^3} = 7.17\text{ g/cm}^3$

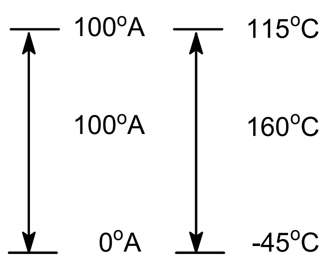
$d = \dfrac{\text{mass}}{\text{volume}}$; because the volume of both types of pennies are assumed equal, then:

$$\frac{d_{new}}{d_{old}} = \frac{\text{mass}_{new}}{\text{mass}_{old}} = \frac{7.17\text{ g/cm}^3}{8.8\text{ g/cm}^3} = 0.81$$

The calculated average mass ratio is: $\dfrac{\text{mass}_{new}}{\text{mass}_{old}} = \dfrac{2.51\text{ g}}{3.08\text{ g}} = 0.815$

To the first two decimal places, the ratios are the same. If the assumptions are correct, then we can reasonably conclude that the difference in mass is accounted for by the difference in alloy used.

108. a.



A change in temperature of 160°C equals a change in temperature of 100°A.

So $\dfrac{160°\text{C}}{100°\text{A}}$ is our unit conversion for a degree change in temperature.

At the freezing point: 0°A = -45°C

Combining these two pieces of information:

$$T_A = (T_C + 45°\text{C}) \times \frac{100°\text{A}}{160°\text{C}} = (T_C + 45°\text{C}) \times \frac{5°\text{A}}{8°\text{C}} \text{ or } T_C = T_A \times \frac{8°\text{C}}{5°\text{A}} - 45°\text{C}$$

b. $T_C = (T_F - 32) \times \dfrac{5}{9}$; $T_C = T_A \times \dfrac{8}{5} - 45 = (T_F - 32) \times \dfrac{5}{9}$

$$T_F - 32 = \frac{9}{5} \times \left(T_A \times \frac{8}{5} - 45\right) = T_A \times \frac{72}{25} - 81,\ T_F = T_A \times \frac{72°\text{F}}{25°\text{A}} - 49°\text{F}$$

c. $T_C = T_A \times \dfrac{8}{5} - 45$ and $T_C = T_A$; so $T_C = T_C \times \dfrac{8}{5} - 45$, $\dfrac{3T_C}{5} = 45$, $T_C = 75°\text{C} = 75°\text{A}$

d. $T_C = 86°A \times \dfrac{8°C}{5°A} - 45°C = 93°C$; $T_F = 86°A \times \dfrac{72°F}{25°A} - 49°F = 199°F = 2.0 \times 10^2°F$

e. $T_A = (45°C + 45°C) \times \dfrac{5°A}{8°C} = 56°A$

109. Let x = mass of copper and y = mass of silver.

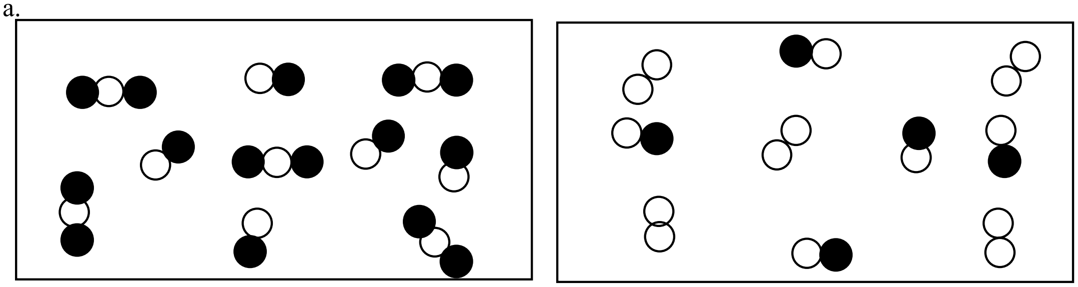
$105.0\text{ g} = x + y$ and $10.12\text{ mL} = \dfrac{x}{8.96} + \dfrac{y}{10.5}$; solving:

$$\left(10.12 = \frac{x}{8.96} + \frac{105.0 - x}{10.5}\right) \times 8.96 \times 10.5,\ \ 952.1 = (10.5)x + 940.8 - (8.96)x$$

(carrying 1 extra sig. fig.)

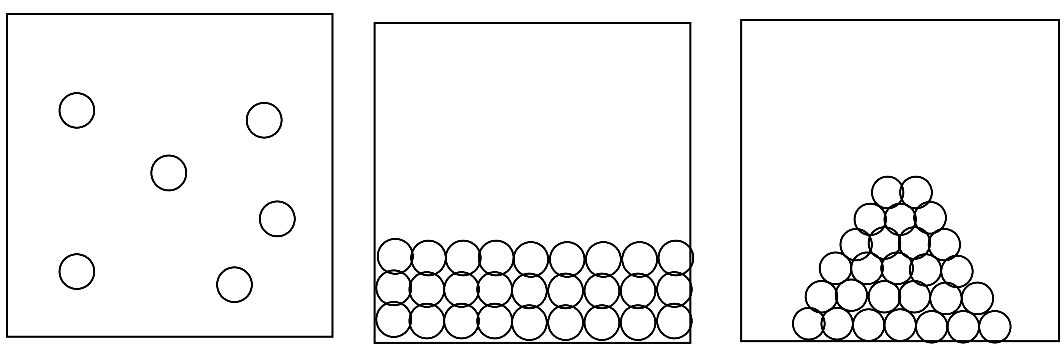
$11.3 = (1.54)x$, $x = 7.3$ g; mass % Cu $= \dfrac{7.3\text{ g}}{105.0\text{ g}} \times 100 = 7.0\%$ Cu

110. a.



2 compounds — compound and element (diatomic)

b.



gas element (monoatomic)

atoms/molecules far apart; random order; takes volume of container

liquid element

atoms/molecules close together; somewhat ordered arrangement; takes volume of container

solid element

atoms/molecules close together; ordered arrangement; has its own volume

111. a. One possibility is that rope B is not attached to anything and rope A and rope C are connected via a pair of pulleys and/or gears.

b. Try to pull rope B out of the box. Measure the distance moved by C for a given movement of A. Hold either A or C firmly while pulling on the other rope.

112. The bubbles of gas is air in the sand that is escaping; methanol and sand are not reacting. We will assume that the mass of trapped air is insignificant.

Mass of dry sand = 37.3488 g – 22.8317 g = 14.5171 g

Mass of methanol = 45.2613 g – 37.3488 g = 7.9125 g

Volume of sand particles (air absent) = volume of sand and methanol – volume of methanol

Volume of sand particles (air absent) = 17.6 mL – 10.00 mL = 7.6 mL

Density of dry sand (air present) = $\frac{14.5171\text{ g}}{10.0\text{ mL}}$ = 1.45 g/mL

Density of methanol = $\frac{7.9125\text{ g}}{10.00\text{ mL}}$ = 0.7913 g/mL

Density of sand particles (air absent) = $\frac{14.5171\text{ g}}{7.6\text{ mL}}$ = 1.9 g/mL

Integrative Problems

113. 2.97×10^8 persons × 0.0100 = 2.97×10^6 persons contributing

$$\frac{\$4.75 \times 10^8}{2.97 \times 10^6 \text{ persons}} = \$160./\text{person}; \quad \frac{\$160.}{\text{person}} \times \frac{20 \text{ nickels}}{\$1} = 3.20 \times 10^3 \text{ nickels/person}$$

$$\frac{\$160.}{\text{person}} \times \frac{1 \text{ pound sterling}}{\$1.869} = 85.6 \text{ pounds sterling/person}$$

114. $\frac{22610\text{ kg}}{\text{m}^3} \times \frac{1000\text{ g}}{\text{kg}} \times \frac{1\text{ m}^3}{1 \times 10^6\text{ cm}^3} = 22.61\text{ g/cm}^3$

Volume of block = 10.0 cm × 8.0 cm × 9.0 cm = 720 cm^3; $\frac{22.61\text{ g}}{\text{cm}^3} \times 720\text{ cm}^3 = 1.6 \times 10^4$ g

115. At 200.0°F: $T_C = \frac{5}{9}(200.0°\text{F} - 32°\text{F}) = 93.33°\text{C}$; $T_K = 93.33 + 273.15 = 366.48$ K

At −100.0°F: $T_C = \frac{5}{9}(-100.0°\text{F} - 32°\text{F}) = -73.33°\text{C}$; $T_K = -73.33°\text{C} + 273.15 = 199.82$ K

$\Delta T(°\text{C}) = [93.33°\text{C} - (-73.33°\text{C})] = 166.66°\text{C}$; $\Delta T(\text{K}) = (366.48\text{ K} - 199.82\text{ K}) = 166.66$ K

The "300 Club" name only works for the Fahrenheit scale; it does not hold true for the Celsius and Kelvin scales.

Marathon Problem

116. a. $V_{gold} = \pi r^2 h = 3.14 \times (0.25/2 \text{ in})^2 \times 1.5 \text{ in} \times \left(\frac{2.54 \text{ cm}}{\text{in}}\right)^3 = 1.2 \text{ cm}^3$

$$d_{gold} \text{ (at 86°F)} = \frac{23.1984 \text{ g}}{1.2 \text{ cm}^3} = 19 \text{ g/cm}^3$$

b. Calculate the density of the liquid at 86°F, then determine the density at 40.°F.

$\text{Mass}_{liquid} = 79.16 \text{ g} - 73.47 \text{ g} = 5.69 \text{ g}$

$\text{Volume}_{final} = 8.5 \text{ cm}^3 = V_{gold} + V_{liquid}$, $V_{liquid} = 8.5 \text{ cm}^3 - 1.2 \text{ cm}^3 = 7.3 \text{ cm}^3$

$$d_{liquid} \text{ (at 86°F)} = \frac{5.69 \text{ g}}{7.3 \text{ cm}^3} = 0.78 \text{ g/cm}^3$$

The density will increase by 1.0% for every 10.°C drop in temperature. The temperature drop is 86 − 40. = 46°F. Because 1°F is equivalent to 5/9°C, the temperature drop in °C equals 46(5/9) = 26°C. Because there is a 1% increase in density for every 10.°C drop in temperature, there will be a 2.6% increase in density for the 26°C temperature drop.

$\text{Density}_{liquid} \text{ (at 40.°C)} = 1.026 \times 0.78 \text{ g/cm}^3 = 0.80 \text{ g/cm}^3$