CHAPTER 1

CHEMICAL FOUNDATIONS

Review Questions

1. a. Law versus theory: A law is a concise statement or equation that summarizes observed behavior. A theory is a set of hypotheses that gives an overall explanation of some phenomenon. A law summarizes what happens; a theory (or model) attempts to explain why it happens.

   b. Theory versus experiment: A theory is an explanation of why things behave the way they do, while an experiment is the process of observing that behavior. Theories attempt to explain the results of experiments and are, in turn, tested by further experiments.

   c. Qualitative versus quantitative: A qualitative observation only describes a quality while a quantitative observation attaches a number to the observation. Some qualitative observations would be: The water was hot to the touch. Mercury was found in the drinking water. Some quantitative observations would be: The temperature of the water was 62˚C. The concentration of mercury in the drinking water was 1.5 ppm.

   d. Hypothesis versus theory: Both are explanations of experimental observation. A theory is a set of hypotheses that has been tested over time and found to still be valid, with (perhaps) some modifications.

2. 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.

3. 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.

4. Volume readings are estimated to one decimal place past the markings on the glassware. The assumed uncertainty is ±1 in the estimated digit. For glassware a, the volume would be

estimated to the tenths place since the markings are to the ones place. A sample reading would be 4.2 with an uncertainty of ±0.1. This reading has two significant figures. For glassware b, 10.52 ±0.01 would be a sample reading and the uncertainty; this reading has four significant figures. For glassware c, 18 ±1 would be a sample reading and the uncertainty, with the reading having two significant figures.

5. 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

6. Significant figures are the digits we associate with a number. They contain all 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.).

7. In both sets of rules, the lease precise number determines the number of significant figures in the final result. For multiplication/division, the number of significant figures in the result is the same as the number of significant figures in the least precise number used in the calculation. For addition/subtraction, the result has the same number of decimal places as the least precise number used in the calculation (not necessarily the number with the fewest significant figures).

   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. Even though both numbers in the calculation had two significant figures, they both showed uncertainty to the tenths place. Any addition or subtraction of these numbers can at best be known to the tenths place. Next, the multiplication/division rule is applied to 0.50/0.5. A two significant figure number divided by a one significant figure number yields an answer with one significant figure (answer = 1).

8. The two scales have different zero points and different degree sizes. In converting from one to the other, one must account for both differences. The Fahrenheit scale has the smallest change in temperature per degree, while the Celsius and Kelvin scales have the largest change in temperature per degree.

9. Consider gold with a density of 19.32 g/cm^3. The two possible ways to express this density as a conversion factor are:

$$\frac{19.32\text{ g}}{1\text{ cm}^3} \quad \text{or} \quad \frac{1\text{ cm}^3}{19.32\text{ g}}$$

   Use the first conversion factor form when converting from the volume of gold in cm^3 to the mass of gold and use the second form when converting from mass of gold to volume of gold. When using conversion factors, concentrate on the units canceling each other.

10. Solid: a state of matter that has fixed volume and shape; a solid is rigid.

   Liquid: a state of matter that has definite volume but no specific shape; it assumes the shape of the container.

Gas: a state of matter that has no fixed volume or shape; it takes on the shape and volume of the container. Unlike the solid and liquid state where the molecules/atoms are very close together, a gas is mostly empty space. Gases are easily compressed.

Pure substance: a substance with constant composition

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

Compound: a substance with constant composition that can be broken down into elements by chemical processes.

Homogeneous mixture: a mixture having visibly indistinguishing parts.

Heterogeneous mixture: a mixture having visibly distinguishable parts.

Solution: another name for a homogeneous mixture

Chemical change: a change of substances into other substances through a reorganization of the atoms; a chemical reaction.

Physical change: a change in the form of a substance (solid, liquid, or gas), but not in its chemical composition: chemical bonds are not broken in a physical change.

Active Learning Questions

1. a. $1 \text{ month} \times \frac{1 \text{ yr}}{12 \text{ months}} \times \frac{365 \text{ days}}{\text{yr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{60 \text{ min}}{\text{hr}} = 4.38 \times 10^4 \text{ min}$

b. $1 \text{ month} \times \frac{4 \text{ wk}}{\text{month}} \times \frac{7 \text{ days}}{\text{wk}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{60 \text{ min}}{\text{hr}} = 4.03 \times 10^4 \text{ min}$

c. The 4.38×10^4 min answer is best. In each calculation, one of the conversion factors is not exact. In the first calculation, 365 days per year is fine for most months except for leap year where there are 366 days per year. In the second calculation, 4 weeks per month is an inexact conversion. There are 52 months per year, which comes out to 4.33 weeks per year. There is a larger percent error in the weeks to month conversion factor than in the days to year conversion factor. Hence, the first calculation gives the better estimate of minutes in a month.

2. The best explanation is c. The marble sinks because it is denser that water. Statement c says that given equal volumes of water and a marble, the same volume of the marble has a greater mass (it is denser). For statement a, surface tension is the resistance of a liquid to increase its surface area. Water can support a paper clip because the denser metal is spread out over a large volume. However, once the paper clip breaks through the surface, it sinks. For statement b, the mass per unit volume of marble is greater than the water, but the overall mass of water in a beaker is more than likely larger than the mass of the marble. For statement d, surface tension can support more dense items on the surface for a certain period of time, but the real reason substances sink in water is that they are denser than water. And for statement e, if the marble

has a greater mass and a greater volume, then the marble may be less dense than water and it would float. This is an ambiguous statement that does explain why the marble sinks.

3. a. The mass of the sugar and water combined will be 280.0 g (statement iii). No chemical reaction takes place, so no gases are lost when the sugar dissolves. Because everything is present before mixing as compared to after mixing, mass is conserved.

   b. The volume should be significantly less than 200.0 mL (statement v). Dry sugar in the beaker has a lot of empty space between the sugar molecules. When the sugar is dissolved in water, each sugar molecule is surrounded by water molecules. This eliminates the empty space that was present in the dry sugar. Therefore, the volume will be significantly less than 200.0 mL. However, since students probably don't realize the significant amount of empty space in a dry sugar, answer d is also a reasonable choice for students.

4. a. When a gas boils, water is converted from the liquid phase to the gaseous phase. So water molecules in the vapor phase are present in the bubbles.

   b. A physical change is the change of the form of a substance (solid or liquid or gas), but not in its chemical composition. Chemical bonds are not broken in a physical change. The boiling of water is a physical change; liquid water is converted to gaseous water. In a chemical change, a substance is converted into a different substance by breaking and making new chemical bonds.

5. a. Pudding takes the shape of the container, but the pudding molecules are close together so there is not a lot of empty space in the pudding. This defines a liquid. However, pouring pudding can be problematic. So, from this observation, a solid designation is also applicable.

   b. Sand takes the shape of the bucket and it can be poured, so a liquid designation can apply. However, sand is generally considered a solid made up of silicon and oxygen atoms bonded together in an extended structure. The structure of each sand particle is very ordered, hence the solid designation. A bucketful of sand can pour because there are significant amounts of air in between the sand particles in the bucket and this allows the sand to pour.

6. a. There is no single correct answer. Any drawing showing 2 different compounds, but having visibly distinguishable parts is correct. For example, a beaker of water (H_2O) with an insoluble compound like AgCl(s) at the bottom.

   b. Any drawing of an element and a compound have the same composition throughout is correct. The easiest drawings would be two different gases in a container. For example, a container with CO_2(g) and N_2(g) would be fine. The gases would be equally distributed throughout the container.

7. Yes, this is consistent with the scientific method. Paracelsus is instructing his students to learn by observation. Observation of facts along with experimentation of potential remedies to heal a patient are key parts of the scientific method.

8. Experimental results are the facts we deal with. Theories are our attempt to rationalize the facts. If the experiment is done correctly and the theory can't account for the facts, then the theory is wrong.

9. If the results of the measurements are all close to the true value, then the data is accurate. But if the data are all close to the true value, then they are reproduceable (they are precise).

10. You would need to know the average miles per gallon of the car used for the trip along with the miles that must be traveled to go from New York to Chicago. You would also need to know the average price of gasoline per gallon. Any calculation involving these three quantities is correct.

11. Volume readings are estimated to one decimal place past the markings on the glassware. The assumed uncertainty is ±1 in the estimated digit. The piece of glassware estimated to the thousandths place would have markings to hundredths place. The piece of glassware that is estimated to the ones place would have markings to tens place. Drawings illustrating these specific markings would be correct.

12. Each sample would displace 1.0-cm^3 of water. The masses of the two samples would not be equal. One would expect the 1.0 cm^3 sample of lead to have a much greater mass than the 1.0 cm^3 sample of glass since lead is denser than glass. Volume and mass are two distinctly different quantities.

13 The mathematician would say that the sum equal 43.4. The scientist rounds the sum to the ones place giving an answer of 43. Assuming these are measurements, 15.4 implies the measurement is somewhere between 15.3 and 15.5, while 28 implies that the measurement is somewhere between 27 and 29. The sum of these two measurements can at best be know to the ones place. The least precise measurement always determines the significant figures in a mathematical operation. With addition (or subtraction), the least precise measurement is determined by the measuring device with the fewest decimal places.

14. The mathematician says the result equals 430.466. The scientist says 430. is the result. Assuming these numbers are measurements, one of the measurements is known to 3 significant figures while the other is known to four significant figures. The 26.2 measurement implies a value known to ±0.1, somewhere between 26.1 and 26.3. If this value has uncertainty in the third significant figure, then any multiplication or division of this measurement can at best be known to 3 significant figures (assuming the other numbers used in the multiplication and/or division are known to at least 3 significant figures).

15. False; this is a correct statement for the multiplication and division operations, but it is false for subtraction and addition. Here, the number of decimal places designates the least precise measurement, which dictates the number of decimal places in the final result.

16. $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$; a 2:1 mixture of H_2 and O_2 would be a homogeneous mixture since it contains two different species randomly dispersed in the container. When reacted, a 2:1 ratio of H_2 and O_2 would react exactly together to form H_2O. Thus the final result would be a compound since no other species is present. A mixture must have two or more substances present.

17. a. $636.6\text{ g} \times \dfrac{1\text{ penny}}{3.03\text{ g}} = 210.\text{ pennies}$

b. $210.\text{ pennies} \times \frac{2\text{ dimes}}{3\text{ pennies}} = 140.\text{ dimes}$; $140.\text{ dimes} \times \frac{2.29\text{ g}}{\text{dime}} = 320.6\text{ g} = 321\text{ g}$

c. $140.\text{ dimes} \times \frac{4\text{ pieces candy}}{2\text{ dimes}} = 280.\text{ pieces of candy}$

We would get the same answer if we started with 210. pennies, then multiplied by 4 pieces of candy per 3 pennies.

$280.\text{ pieces of candy} \times \frac{10.23\text{ g}}{\text{piece of candy}} = 2864.4\text{ g} = 2860\text{ g}$

d. If only the number of dimes is doubled, you could still only purchase 280. pieces of candy. You need both dimes and pennies to purchase candy. Once 280. pieces of candy has been purchased, all 210. pennies have been spent. No matter how many more dimes you have, you can't purchase anymore candy unless the number of pennies also increases.

18. a. Wax undergoes both a physical change and a chemical change. The flame melts wax from the solid state to the liquid state which is a physical change. The liquid wax with oxygen then reacts in the flame by a chemical change.

b. The wick is undergoing a chemical change. Wicks are commonly made of braided cotton. In the presence of a flame, the cotton in the wick reacts with oxygen by chemical change.

c. The glass rod generally turns black. The black color is from the carbon produced in the wax chemical reaction. The glass itself is not undergoing any change; it just provides a surface for the black carbon to collect. So, the glass undergoes neither a chemical nor a physical change.

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. No, it is useful whenever a systematic approach of observation and hypothesis testing can be used.

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. No b. Yes c. Yes

Only statements b and c can be determined from experiment.

24. Accuracy: how close a measurement or series of measurements are to an accepted or true value. Precision: how close a series of measurements of the same item are to each other. The results, average = 14.91 ±0.03%, are precise (are close to each other) but are not accurate (are not close to the true value).

25. Many techniques of chemical analysis require relatively pure samples. Thus, a separation step often is necessary to remove materials that will interfere with the analytical measurement.

26. From Figure 1.9 of the text, a change in temperature of 180°F is equal to a change in temperature of 100°C and 100 K. A degree unit on the Fahrenheit scale is a smaller unit than a degree unit on the Celsius or Kelvin scales. Therefore, a 20° change in the Celsius or Kelvin temperature would correspond to a larger temperature change than a 20° change in the Fahrenheit scale. The 20° temperature change on the Celsius and Kelvin scales are equal to each other.

27. They are not equivalent. Doubling the temperature on the Kelvin scale is a larger increase than doubling the temperature on the Celsius scale. For example, doubling the Celsius temperature from 25ºC to 50ºC corresponds to taking the Kelvin temperature from 298 K to 333 K. However, doubling the Kelvin temperature from 298 K to 596 K corresponds with taking the Celsius temperature from 25ºC to 323ºC. Doubling the temperature are clearly different on the two scales.

28. When performing a multiple step calculation, always carry at least one extra significant figure in intermediate answers. If you round-off at each step, each intermediate answer gets further away from the actual value of the final answer. So to avoid round-off error, carry extra significant figures through intermediate answers, then round-off to the proper number of significant figures when the calculation is complete. In this solutions manual, we rounded off intermediate answers to the show the proper number significant figures at each step; our answers to multistep calculations will more than likely differ from yours because we are introducing round-off error into our calculations.

29. The gas phase density is much smaller than the density of a solid or a liquid. The molecules in a solid and a liquid are very close together. In the gas phase, the molecules are very far apart from one another. In fact, the molecules are so far apart that a gas is considered to be mostly empty space. Because gases are mostly empty space, their density is very small.

30. 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)

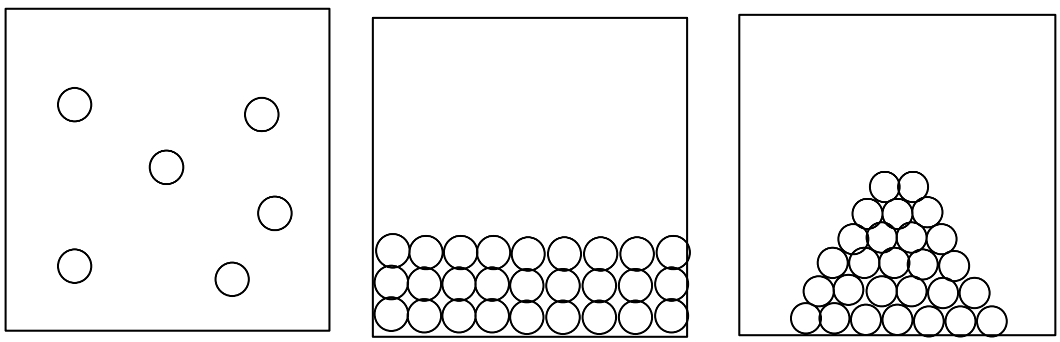
d. nitrogen (N_2); oxygen (O_2); copper (Cu); zinc (Zn)

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

f. Electrolysis 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.

31. The object that sinks has a greater density than water and the object that floats has a smaller density than water. Since both objects have the same mass, the sphere that sinks must have the smaller volume which makes it denser. Therefore, the object that floats has the larger volume along with the greater diameter.

32.



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

Exercises

Significant Figures and Unit Conversions

33. a. exact b. inexact

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

34. a. two significant figure (S.F.). The implied uncertainty is ±1000 pages.

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

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

35. 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.

36. 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.

37. 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

38. a. 2×10^{-4} b. 1.5×10^{-4} c. 1.51×10^{-4} d. 1.5051×10^{-4}

39. Volume measurements are estimated to one place past the markings on the glassware. The first graduated cylinder is labeled to 0.2 mL volume increments, so we estimate volumes to the hundredths place. Realistically, the uncertainty in this graduated cylinder is ±0.05 mL. The second cylinder, with 0.02 mL volume increments, will have an uncertainty of ±0.005 mL. The approximate volume in the first graduated cylinder is 2.85 mL, and the volume in the other graduated cylinder is approximately 0.280 mL. The total volume would be:

$$\begin{array}{r} 2.85 \text{ mL} \\ \underline{+0.280 \text{ mL}} \\ 3.13 \text{ mL} \end{array}$$

We should report the total volume to the hundredths place because the volume from the first graduated cylinder is only read to the hundredths (read to two decimal places). The first graduated cylinder is the least precise volume measurement because the uncertainty of this instrument is in the hundredths place, while the uncertainty of the second graduated cylinder is to the thousandths place. It is always the lease precise measurement that limits the precision of a calculation.

40. a. Volumes are always estimated to one position past the marked volume increments. The estimated volume of the first beaker is 32.7 mL, the estimated volume of the middle beaker is 33 mL, and the estimated volume in the last beaker is 32.73 mL.

b. Yes, all volumes could be identical to each other because the more precise volume readings can be rounded to the other volume readings. But because the volumes are in three different measuring devices, each with its own unique uncertainty, we cannot say with certainty that all three beakers contain the same amount of water.

c.
$$\begin{array}{l} 32.7 \text{ mL} \\ 33 \text{ mL} \\ \underline{32.73 \text{ mL}} \\ 98.43 \text{ mL} = 98 \text{ mL} \end{array}$$

The volume in the middle beaker can only be estimated to the ones place, which dictates that the sum of the volume should be reported to the ones place. As is always the case, the least precise measurement determines the precision of a calculation.

41. 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. $53.5 + 5.612 + 6 = 6\underline{5}.112 = 65$

b. $10.67 - 9.5 - 0.634 = 0.\underline{5}36 = 0.5$

c. $3.25 \times 10^3 + 6.174 \times 10^2 = 32.5 \times 10^2 + 6.174 \times 10^2 = 38.\underline{6}74 \times 10^2 = 3870$

d. $1.65 \times 10^{-2} - 9.73 \times 10^{-3} = 16.5 \times 10^{-3} - 9.73 \times 10^{-3} = 6.\underline{7}7 \times 10^{-3} = 0.0068$

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.

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

43. a. For this problem, 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. $\frac{9.5 + 4.1 + 2.8 + 3.175}{4} = \frac{19.575}{4} = 4.89 = 4.9$

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. $\frac{8.925 - 8.905}{8.925} \times 100 = \frac{0.020}{8.925} \times 100 = 0.22$

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

$= 1.130 \times 10^{3}$

45. 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. $903.3 \text{ nm} \times \frac{1 \text{ m}}{1 \times 10^{9} \text{ nm}} \times \frac{1 \times 10^{6}\ \mu\text{m}}{\text{m}} = 0.9033\ \mu\text{m}$

46. 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. $1 \ \mu\text{g} \times \dfrac{1 \text{ g}}{1 \times 10^6 \ \mu\text{g}} \times \dfrac{1 \times 10^{12} \text{ pg}}{\text{g}} = 1 \times 10^6 \text{ pg}$

47. a. $1.5 \text{ lb} \times \dfrac{453.6 \text{ g}}{1 \text{ lb}} = 680 \text{ g}$; 715 g is the larger mass.

b. $1.90 \text{ L} \ \dfrac{1 \text{ qt}}{0.9463 \text{ L}} = 2.01 \text{ qt}$; 1.90 L is the larger volume.

48. a. $70 \text{ in} \times \dfrac{1 \text{ yd}}{36 \text{ in}} \times \dfrac{1 \text{ m}}{1.094 \text{ yd}} = 1.78 \text{ m}$; The 1.80 m person is taller.

b. $\dfrac{100 \text{ km}}{\text{hr}} \times \dfrac{0.6214 \text{ mi}}{\text{km}} = 62 \text{ mi/hr}$; 65 mi/hr is the faster velocity.

49. 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.

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

50. $V = 1 \times w \times h = 11.0 \text{ in} \times 8.5 \text{ in} \times 1.75 \text{ in} = 164 \text{ in}^3$ (Carrying an extra significant figure.)

$164 \text{ in}^3 \times \left(\dfrac{2.54 \text{ cm}}{\text{in}}\right)^3 = 2700 \text{ cm}^3$; $2700 \text{ cm}^3 \times \dfrac{1 \text{ L}}{1000 \text{ cm}^3} = 2.7 \text{ L}$

51. 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. $125 \text{ mL} \times \dfrac{1 \text{ L}}{1000 \text{ mL}} \times \dfrac{1 \text{ qt}}{0.9463 \text{ L}} = 0.132 \text{ qt}$

52. a. $3.50 \text{ gal} \times \frac{4 \text{ qt}}{1 \text{ gal}} \times \frac{1 \text{ L}}{1.057 \text{ qt}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.32 \times 10^4 \text{ mL}$

b. $195 \text{ lb} \times \frac{453.6 \text{ g}}{1 \text{ lb}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 88.5 \text{ kg}$

c. $\frac{2.998 \times 10^8 \text{ m}}{\text{s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{0.62137 \text{ mi}}{\text{km}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{hr}} = 6.706 \times 10^8 \text{ mi/hr}$

53. 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 mi + 385 yd = 45,760. yd + 385 yd = 46,145 yards

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

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

54. 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.

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

55. 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. $1\ \text{troy lb} = 0.373\ \text{kg};\ 0.373\ \text{kg} \times \frac{1000\ \text{g}}{\text{kg}} \times \frac{1\ \text{cm}^3}{19.3\ \text{g}} = 19.3\ \text{cm}^3$

56. 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 49b.

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

57. $15.6\ \text{g} \times \frac{1\ \text{capsule}}{0.65\ \text{g}} = 24\ \text{capsules}$

58. $1.5\ \text{teaspoons} \times \frac{80.\ \text{mg acet}}{0.50\ \text{teaspoon}} = 240\ \text{mg acetaminophen}$

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

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

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

59. $$\text{warp } 1.71 = \left(5.00 \times \frac{3.00 \times 10^8 \text{ m}}{\text{s}}\right) \times \frac{1.094 \text{ yd}}{\text{m}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} \times \frac{1 \text{ knot}}{2030 \text{ yd/h}}$$

$$= 2.91 \times 10^9 \text{ knots}$$

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

60. $$\frac{100.\text{ m}}{9.58 \text{ s}} = 10.4 \text{ m/s}; \quad \frac{100.\text{ m}}{9.58 \text{ s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} = 37.6 \text{ km/h}$$

$$\frac{100.\text{ m}}{9.58 \text{ s}} \times \frac{1.0936 \text{ yd}}{\text{m}} \times \frac{3 \text{ ft}}{\text{yd}} = 34.2 \text{ ft/s}; \quad \frac{34.2 \text{ ft}}{\text{s}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} = 23.3 \text{ mi/h}$$

$$1.00 \times 10^2 \text{ yd} \times \frac{1 \text{ m}}{1.0936 \text{ yd}} \times \frac{9.58 \text{ s}}{100.\text{ m}} = 8.76 \text{ s}$$

61. $$1 \text{ s} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{65 \text{ mi}}{\text{h}} \times \frac{5280 \text{ ft}}{\text{mi}} = 95.3 \text{ ft} = 100 \text{ ft}$$

If you take your eyes off the road for one second traveling at 65 mph, your car travels approximately 100 feet.

62. $$112 \text{ km} \times \frac{0.6214 \text{ mi}}{\text{km}} \times \frac{1 \text{ h}}{65 \text{ mi}} = 1.1 \text{ h} = 1 \text{ h and } 6 \text{ min}$$

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

63. $$180 \text{ lb} \times \frac{1 \text{ kg}}{2.205 \text{ lb}} \times \frac{8.0 \text{ mg}}{\text{kg}} = 650 \text{ mg antibiotic/dose}$$

$$2 \text{ wk} \times \frac{7 \text{ days}}{\text{wk}} \times \frac{2 \text{ doses}}{\text{day}} \times \frac{650 \text{ mg}}{\text{dose}} = 18{,}000 \text{ mg} = 18 \text{ g antibiotic in total}$$

64. 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).

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

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

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

66. Volume of room = $18\ ft \times 12\ ft \times 8\ ft = 1700\ ft^3$ (carrying one extra significant figure)

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

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

Temperature

67. $T_C = T_K - 273 = 292 - 273 = 19°C$; $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(72°F - 32) = 22.2°C = 22°C$

292 K is the coldest temperature, then 72°F, then 24°C is the hottest temperature.

68. 340. – 273 = 67°C, 350. – 273 = 77°C; the 340. to 350. K temperature range is 67°C to 77°C.

$$T_F = \frac{9}{5} \times T_C + 32 = \frac{9}{5} \times 67°C + 32 = 153°F = 150\ °F,\ T_F = \frac{9}{5} \times 77°C + 32 = 171°F = 170\ °F$$

The 340. to 350. K temperature range is 150°F to 170°F.

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

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

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

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

70. 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. The uncertainty is:

$$\pm 0.2°F \times \frac{5°\ C}{9°\ F} = \pm 0.1°C.$$ Thus 96.1 ±0.2°F = 35.6 ±0.1°C.

71. 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

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

73. $T_F = \frac{9}{5} \times T_C + 32$; 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.

74. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(72 - 32) = 22°C$; $T_C = T_K - 273 = 313 - 273 = 40.°C$

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

75. a. A change in temperature of 140°C is equal to 50°X. Therefore, $\frac{140^o C}{50^o X}$ is the unit conversion between a degree on the X scale to a degree on the Celsius scale. To account for the different zero points, –10° must be subtracted from the temperature on the X scale to get to the Celsius scale. The conversion between °X to °C is:

$$T_C = T_X \times \frac{140^\circ C}{50^\circ X} - 10^\circ C,\ \ T_C = T_X \times \frac{14^\circ C}{5^\circ X} - 10^\circ C$$

The conversion between °C to °X would be:

$$T_X = (T_C + 10^\circ C)\ \frac{5^\circ X}{14^\circ C}$$

b. Assuming 10°C and $\frac{5^\circ X}{14^\circ C}$ are exact numbers:

$$T_X = (22.0^\circ C + 10^\circ C)\ \frac{5^\circ X}{14^\circ C} = 11.4^\circ X$$

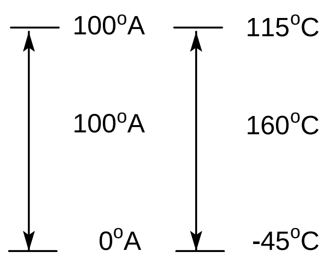
c. Assuming exact numbers in the temperature conversion formulas:

$$T_C = 58.0^\circ X \times \frac{14^\circ C}{5^\circ X} - 10^\circ C = 152^\circ C$$

$$T_K = 152^\circ C + 273 = 425\ K$$

$$T_F = \frac{9^\circ F}{5^\circ C} \times 152^\circ C + 32^\circ F = 306^\circ F$$

76. a.



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

So $\frac{160^\circ C}{100^\circ A}$ is our unit conversion for a degree change in temperature.

At the freezing point: 0°A = –45°C

Combining these two pieces of information:

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

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

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

c. $T_C = T_A \times \frac{8}{5} - 45$ and $T_C = T_A$; so $T_C = T_C \times \frac{8}{5} - 45$, $\frac{3T_C}{5} = 45$, $T_C = 75^\circ C = 75^\circ A$

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

e. $T_A = (45^\circ C + 45^\circ C) \times \frac{5^\circ A}{8^\circ C} = 56^\circ A$

Density

77. Density = $\frac{\text{mass}}{\text{volume}} = \frac{156\text{ g}}{11.5\text{ cm}^3} = 13.6\text{ g/cm}^3$; from the table, the toxic liquid is mercury.

78. The least dense substance (hydrogen) would occupy the largest volume. This volume would be:

$$15\text{ g} \times \frac{1\text{ cm}^3}{0.000084\text{ g}} = 1.8 \times 10^5\text{ cm}^3$$

The most-dense substance, gold, would occupy the smallest volume (15 g of gold occupies 0.78 cm^3).

79. 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.

80. Let d = density; $d_{cube} = \frac{140.4\text{ g}}{(3.00\text{ cm})^3} = 5.20\text{ g/cm}^3$

If this is correct to ±1.00% then the density is 5.20 ±0.05 g/cm^3

$$V_{sphere} = (4/3)\pi r^3 = (4/3)\pi(1.42\text{ cm})^3 = 12.0\text{ cm}^3$$

$$d_{sphere} = \frac{61.6\text{ g}}{12.0\text{ cm}^3} = 5.13\text{ g/cm}^3 = 5.13 \pm 0.05\text{ g/cm}^3$$

Since d_{cube} is between 5.15 and 5.25 g/cm^3 and d_{sphere} is between 5.08 and 5.18 g/cm^3, the error limits overlap and we can't decisively determine if they are built of the same material. The data are not precise enough to determine.

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

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

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

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

83. 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. $2.8 \text{ mL} \times \frac{1 \text{ cm}^3}{\text{mL}} \times \frac{3.51 \text{ g}}{\text{cm}^3} \times \frac{1 \text{ carat}}{0.200 \text{ g}} = 49 \text{ carats}$

84. $1 \text{ mL} = 1 \text{ cm}^3$; $125 \text{ cm}^3 \times \frac{3.12 \text{ g}}{\text{cm}^3} = 390. \text{ g } Br_2$; $85.0 \text{ g} \times \frac{1 \text{ mL}}{3.12 \text{ g}} = 27.2 \text{ mL } Br_2$

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

86. $5.25 \text{ g} \times \frac{1 \text{ cm}^3}{10.5 \text{ g}} = 0.500 \text{ cm}^3 = 0.500 \text{ mL}$

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

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

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

$1.0 \text{ mL} \times \frac{13.6 \text{ g}}{\text{mL}} = 14 \text{ g}$ 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

88. 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. $3.5 \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{\text{in}}\right)^3 \times \frac{13.6 \text{ g}}{\text{cm}^3} = 780 \text{ g mercury}$

89. 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.

90. 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.

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

$44.3\ cm^3 = l \times w \times h = 4.00\ cm \times 4.00\ cm \times h,\ \ h = 2.77\ cm$

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

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

Classification and Separation of Matter

93. 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).

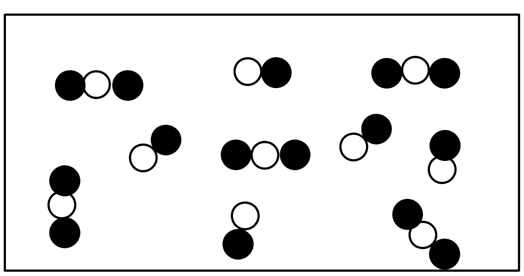
a. Picture iv represents a gaseous compound. Note that pictures ii and iii also contain a gaseous compound, but they also both have a gaseous element present.

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

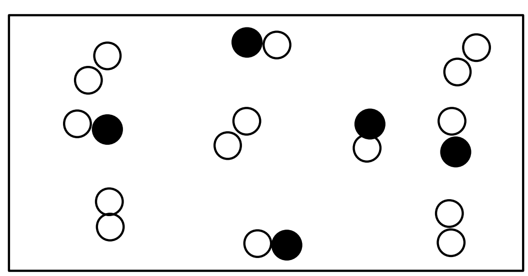
c. Picture v represents a solid element.

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

94.



2 compounds



compound and element (diatomic)

95. 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

96. a. heterogeneous   b. homogeneous

c. heterogeneous   d. homogeneous (assuming no imperfections in the glass)

e. heterogeneous (has visibly distinguishable parts)

97. 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).

98. 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.

99. 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).

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

101. 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 because all that is happening during the boiling process 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.

102. 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.

ChemWork Problems

103. The national debt is \$2.0875 × 10^{13} and the wealthiest 1.00% represents 3.32 × 10^6 people.

$$\frac{2.0875 \times 10^{13}\ \text{dollars}}{3.32 \times 10^{6}\ \text{people}} = 6.29 \times 10^6\ \text{dollars/person} = \$6.29\ \text{million dollars per richest 1\%.}$$

104. $$422\ \text{mg caffeine} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{6.02 \times 10^{23}\ \text{molecules}}{194\ \text{g caffeine}} = 1.31 \times 10^{21}\ \text{caffeine molecules}$$

105. $$4145\ \text{mi} \times \frac{5280\ \text{ft}}{\text{mi}} \times \frac{1\ \text{fathom}}{6\ \text{ft}} \times \frac{1\ \text{cable length}}{100\ \text{fathom}} = 3.648 \times 10^4\ \text{cable lengths}$$

$$4145\ \text{mi} \times \frac{1\ \text{km}}{0.62137\ \text{mi}} \times \frac{1000\ \text{m}}{\text{km}} = 6.671 \times 10^6\ \text{m}$$

$$3.648 \times 10^4\ \text{cable lengths} \times \frac{1\ \text{nautical mile}}{10\ \text{cable lengths}} = 3{,}648\ \text{nautical miles}$$

106. $$\frac{1.25\ \text{mi}}{119.2\ \text{s}} \times \frac{1\ \text{km}}{0.6214\ \text{mi}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 16.9\ \text{m/s}$$

107. Because each pill is 4.0% Lipitor by mass, for every 100.0 g of pills, there are 4.0 g of Lipitor present. Note that 100 pills is assumed to be an exact number.

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

108. $$126\ \text{gal} \times \frac{4\ \text{qt}}{\text{gal}} \times \frac{1\ \text{L}}{1.057\ \text{qt}} = 477\ \text{L}$$

109. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(134°F - 32) = 56.7°C$; phosphorus would be a liquid.

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

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

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

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

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

Volume of topsoil covered by 1 bag =

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

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

112. 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.

113. $$1\text{ light year} = 1\text{ yr} \times \frac{365\text{ day}}{\text{yr}} \times \frac{24\text{ h}}{\text{day}} \times \frac{60\text{ min}}{\text{h}} \times \frac{60\text{ s}}{\text{min}} \times \frac{186{,}000\text{ mi}}{\text{s}} = 5.87 \times 10^{12}\text{ miles}$$

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

114. $\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{0.384\text{ g}}{0.32\text{ cm}^3} = 1.2\text{ g/cm}^3$; from the table, the other ingredient is caffeine.

115. 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. $$0.25\text{ qt} \times \frac{0.9463\text{ L}}{\text{qt}} \times \frac{1.04\text{ kg}}{\text{L}} \times \frac{1000\text{ kg}}{\text{kg}} \times \frac{2.0\text{ g tryptophan}}{100.0\text{ g milk}} = 4.9\text{ g tryptophan}$$

116. 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.)

117. a. False; sugar is generally considered to be the pure compound sucrose, $C_{12}H_{22}O_{11}$.

b. False; elements and compounds are pure substances.

c. True; air is a mixture of mostly nitrogen and oxygen gases.

d. False; gasoline has many additives, so it is a mixture.

e. True; compounds are broken down to elements by chemical change.

118. The rusting of iron is the only change listed where chemical formulas change, so it is the only chemical change. The others are physical properties. Note that the red glow of a platinum wire assumes no reaction between platinum and oxygen; the red glow is just hot Pt.

119. $5.4 \text{ L blood} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{250 \text{ mg cholesterol}}{100.0 \text{ mL blood}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 13.5 \text{ g} = 14 \text{ g cholesterol}$

120. a. For $\frac{103 \pm 1}{101 \pm 1}$: maximum = $\frac{104}{100}$ = 1.04; minimum = $\frac{102}{102}$ = 1.00

So: $\frac{103 \pm 1}{101 \pm 1} = 1.02 \pm 0.02$

b. For $\frac{101 \pm 1}{99 \pm 1}$: maximum = $\frac{102}{98}$ = 1.04; minimum = $\frac{100}{100}$ = 1.00

So: $\frac{101 \pm 1}{99 \pm 1} = 1.02 \pm 0.02$

c. For $\frac{99 \pm 1}{101 \pm 1}$: maximum = $\frac{100}{100}$ = 1.00; minimum = $\frac{98}{102}$ = 0.96

So: $\frac{99 \pm 1}{101 \pm 1} = 0.98 \pm 0.02$

Considering the error limits, answers to parts a and b should be expressed to three significant figures while the part c answer should be expressed to two significant figures. Using the multiplication/division rule leads to a different result in part b; according to the rule, the part b answer should be to two significant figures. If this is the case, then the answer to part b is 1.0, which implies the answer to the calculation is somewhere between 0.95 and 1.05. The actual error limit to the answer is better than this, so we should use the more precise way of expressing the answer. The significant figure rules give general guidelines for estimating uncertainty; there are exceptions to the rules.

121. $18.5\text{ cm} \times \frac{10.0^\circ\text{F}}{5.25\text{ cm}} = 35.2^\circ\text{F increase}$; $T_{final} = 98.6 + 35.2 = 133.8^\circ\text{F}$

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

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

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

123. $$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times \left(69\text{ pm} \times \frac{1 \times 10^{-12}\text{ m}}{\text{pm}} \times \frac{100\text{ cm}}{\text{m}}\right)^3 = 1.4 \times 10^{-24}\text{ cm}^3$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{3.35 \times 10^{-23}\text{ g}}{1.4 \times 10^{-24}\text{ cm}^3} = 24\text{ g/cm}^3$$

124. $$\frac{22{,}610\text{ kg}}{\text{m}^3} \times \frac{1000\text{ g}}{\text{kg}} \times \frac{1\text{ m}^3}{1 \times 10^6\text{ cm}^3} = 22.61\text{ g/cm}^3$$

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

125. 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 denser. 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.

126. 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.

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

$d_{max} = \frac{mass_{max}}{V_{min}}$; 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.

128. 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:

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

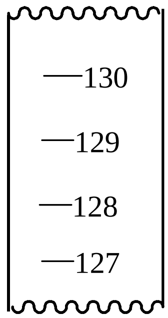
The density of the liquid is between 0.7840 and 0.7860 g/cm^3. These measurements are sufficiently precise to distinguish between ethanol (d = 0.789 g/cm^3) and isopropyl alcohol (d = 0.785 g/cm^3).

Challenge Problems

129. 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.

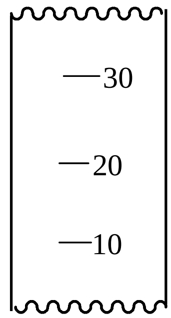
130. In general, glassware is estimated to one place past the markings.

a. 128.7 mL glassware



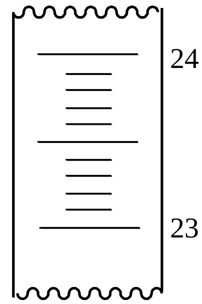
read to tenth's place

b. 18 mL glassware



read to one's place

c. 23.45 mL glassware



read to two decimal places

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

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

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

132. 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.

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

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

Because we are assuming that volume is additive, let's calculate the volume of 100.0 g of each type of penny, then calculate the density of the alloy. For 100.0 g of the old pennies, 95 g will be Cu (copper) and 5 g will be Zn (zinc).

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

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

For 100.0 g of new pennies, 97.6 g will be Zn and 2.4 g will be Cu.

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

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

d = $\frac{\text{mass}}{\text{volume}}$; 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: $\frac{\text{mass}_{new}}{\text{mass}_{old}} = \frac{2.51\ \text{g}}{3.08\ \text{g}}$ = 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.

134. a. At 8 a.m., approximately 57 cars pass through the intersection per hour.

b. At 12 a.m. (midnight), only 1 or 2 cars pass through the intersection per hour.

c. Traffic at the intersection is limited to less than 10 cars per hour from 8 p.m. to 5 a.m. Starting at 6 a.m., there is a steady increase in traffic through the intersection, peaking at 8 a.m. when approximately 57 cars pass per hour. Past 8 a.m. traffic moderates to about 40 cars through the intersection per hour until noon, and then decreases to 21 cars per hour by 3 p.m. Past 3 p.m. traffic steadily increases to a peak of 52 cars per hour at 5 p.m., and then steadily decreases to the overnight level of less than 10 cars through the intersection per hour.

d. The traffic pattern through the intersection is directly related to the work schedules of the general population as well as to the store hours of the businesses in downtown.

e. Run the same experiment on a Sunday, when most of the general population doesn't work and when a significant number of downtown stores are closed in the morning.

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

105.0 g = $x + y$ and 10.12 mL = $\frac{x}{8.96} + \frac{y}{10.5}$; solving and carrying 1 extra sig. fig.:

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

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

136. 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:

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

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:

$$T_C = T_K - 273$$
$$y = mx + b$$

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

137. 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.

138. 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