Chapter 3

Section 3.1

1. Measurements are fundamental to the experimental sciences. It is important to be able to make measurements and to decide whether a measurement is correct.
2. Significant Figures (Significant Digits). Measurements must always be reported to the correct number of significant figures because calculated answers often depend on the number of significant figures in the values used in the calculation.
   a. Every nonzero digit in a reported measurement is assumed to be significant
      i. Examples: 24.7 meters [3] 0.743 meter [3]
         54.96 mg [4] 98°C [2]
   b. Zeros appearing between nonzero digits are significant.
      i. Examples: 160.8 kg [4] 9.0008 mm [5]
         7003 m [4] 40.79 ml [4]
   c. All zeros to the left of the first nonzero digit (leading zeros) are NOT significant. They act as placeholders.
      i. Examples: 0.000099 km [2] 0.00253 g [3]
         0.0071 m [2] 0.4213 km [4]
   d. Zeros to the right of the last nonzero digit (trailing zeros) are always significant if the # has a decimal point
      i. Examples: 43.00 m [4] 1.010 km [4]
         60.0 kg [3] 4.000 L [4]
   e. For measured data without a decimal point, all trailing zeros are not significant. They act as placeholders.
      i. Examples: 300 m [1] 7000 m [1]
         350 kg [2] 27210 [4]
   f. Scientific notation shows only the significant digits in the decimal portion of the expression
      i. Examples: 1.50×10^5 g [3] 3.000×10^8 cm [4]
         3.09×10^2 m [3] 1.5×10^{-7} L [2]

g. A decimal point ___following___ the last zero indicates that the zero in the one's place is ___significant___.

i. Examples: 100. g [_3_] 1650. m [_4_]

27210. ft [_5_] 30. m [_2_]

h. A ___line___ over a zero indicates that the zero is significant

i. Examples: 15$\bar{0}$00 km [_3_] 23$\bar{0}$,000,000 [_3_]

10,4$\bar{0}$0,000 [_4_] 1$\bar{0}$,000 [_2_]

i. Significant figures only apply to ___measured___ data.

i. ___Counted___ or ___pure___ numbers are not evaluated for significant figures

1) Examples: _23_ people; _2_ dozen eggs; _π_

ii. Ratios that are exactly ___one___ by definition are not evaluated for significant figures

1)Examples: 12 inches = 1 foot 60 min = 1 hour

100 cm = 1 m 1 kg = 1000 g

j. Another way to think about it:

- Numbers *without* a decimal, draw an arrow from the **right** until you hit a nonzero number; then start counting the digits that follow.
- Numbers **with** a decimal, draw an arrow from the **left** until you hit a nonzero number; then start counting the digits that follow.

Without decimal - draw arrow from right With decimal - draw arrow from left

EXAMPLES:

→12.000 5 a) 12.000

→105 3 b) 0.105

→5320 4 c) 0.0005320

36← 2 d) 3 600

405← 3 e) 405 000

1 000 07← 6 f) 1 000 070

→1.370 x10^{-4} 4 g) 1.370 x 10^{-4}

→2.000 x 10^{3} 4 h) 2.000 x 10^{3}

→1.78000 6 i) 1.78000

3. Significant Figures and Rounding.
   a. If the digit immediately to the right of the last significant digit you want to keep is:
      i. Greater than 5, increase the last digit by 1
         1) Round these examples to 3 significant figures:
            a. 56.87 g 56.9 g
            b. 3.295 g 3.30 g
            c. 0.06079 L 0.0608L
      ii. Less than 5, do not change the last digit
         1) Round these examples to 3 significant figures:
            a. 12.02 L 12.0 L
            b. 382.1 g 382 g
            c. 14.94 kg 14.9 Kg
4. Significant Figures and Calculations
   a. For addition and subtraction, do all of the required math, then round your answer.
      i. The answer cannot have more digits to the right of the decimal than the original number with the least amount of numbers to the right of the decimal.
         1) Examples:

2 digits after decimal a. 2.578 g + 1.90 g = 4.478 Final Answer= 4.48

1 digit after decimal b. 8.635 mL – 6.5 mL = 2.135 Final Answer= 2.1

1 digit after decimal c. 9.672 m – 5.7 m = 3.972 Final Answer = 4.0

   b. For multiplication and division, do all of the required math, then round your answer.
      i. The answer cannot have more total digits than the original number with the least amount of significant figures.
         1) Examples:

3 digits a. 2.57cm x 8.345 cm = 21.44665 Final Answer = 21.4 cm^2

1 digit b. 3.975 km x 0.01 km = 0.03975 Final Answer = 0.04 km^2

3 digits c. 3.75 m x 2.00 m = 7.5 Final Answer = 7.50 m^2

3 digits d. 1.57 g ÷ 2.38 L = 0.6596638655 Final Answer = 0.660 g/L

5. Scientific Notation, a given number is written as the product of a coefficient and a base raised to a power.
   a. Example: 5.67×10^5
      i. 5.67 is referred to as the Coefficient. The correct format for the coefficient is to have one number and then a decimal followed by any remaining significant figures.
      ii. 10 is the base and 5 is the exponent
         1) A positive exponent means that the number is very large
         2) A negative exponent means that the number is very small, usually a decimal
   b. Changing a number into Scientific Notation.
      i. Move the decimal point to the right of the first nonzero digit. Count the number of places you moved the decimal point.
      ii. Place an "x 10" after the number. The number of places you moved becomes the exponent.
         1) It is a + exponent if you moved the decimal to the left (very large number)
         2) It is a − exponent if you moved the decimal to the right (very small number)
      iii. For these examples, change each number into scientific notation with 3 significant figures:
         1) 45 198 345 4.5198345 4.52×10^7
         2) 0.081 27 8.127 8.13×10^{-2}
         3) 3 199 3.199 3.20×10^3
         4) 54.768 5.4768 5.48×10^1
         5) 0.000 000 000 062 339 6.2339 6.23×10^{-11}

c. Changing a number from Scientific Notation to regular (Standard) Notation

i. If the exponent on the base is positive ("+"), move the decimal to the right the same number of places as the exponent (very large number). Add zeros as necessary.

ii. If the exponent on the base is negative ("−"), move the decimal to the left the same number of places as the exponent (very small number). Add zeros as necessary.

iii. For these examples, change each number to regular (standard) notation with 3 significant figures:

.0000876
1) 8.76×10^{-5} 0.0000876

307000000
2) 3.07×10^{8} 307 000 000

41000
3) 4.1×10^{4} 41 000 needs 3 digits

0000006.2
4) 6.2×10^{-7} 0.000 000 620 needs 3 digits

5198590
5) 5.1985×10^{6} 5 200 000 needs 3 digits

6. Scientific Notation and Calculators:

a. Punch the number (the coefficient) into your calculator.

b. Push the EE or EXP button. Do **NOT** use the x (times) button!!

c. Enter the exponent number. Use the +/- button to change its sign.

d. To check yourself, multiply (6.0×10^{5}) times (4.0×10^{3}) on your calculator. Your answer should be 2.4×10^{9}.

e. Examples.

Write each answer in Scientific Notation, remembering Significant Figure Rules

i. Multiplication: (3.45×10^{4}) x (6.12×10^{8}) 2.1114×10^{13}

3 digits 2.11×10^{13}

ii. Division: (9.45×10^{6}) ÷ (5.46×10^{-8}) $1.730769231 \times 10^{14}$

3 digits 1.73×10^{14}

iii. Addition: (1.34×10^{3}) + (5.98×10^{7}) 59801340

2 after decimal 5.98×10^{7}

iv. Subtraction: $(9.12 \times 10^{-1}) - (4.7 \times 10^{-2})$ .865

1 after decimal 8.7×10^{-1}

7. Accuracy and Precision
   a. Accuracy – measure of how close a measurement comes to the actual or true value of whatever is measured (See Figure 3.2)
   b. Precision – measure of how close a series of measurements are to one another. (See Figure 3.2)
   c. Determining error:
      i. Error = experimental value – accepted value
      ii. Percent error = $\frac{|\text{experimental value} - \text{accepted value}|}{\text{accepted value}} \times 100\%$
      iii. Example: What is the percent error of a measured value of 114 pounds (experimental value) if the person's actual weight is 107 pounds (accepted value)?

         1) Percent error = $\frac{|114 - 107|}{107} \times 100\%$ 6.542056075 $\boxed{6.54\%}$ 3 digits

Section 3.2

8. Measuring with SI Units
   a. International System of Units (abbreviated SI after the French name, Le Système International d'Unités). Revised version of the metric system. International convention adopted in 1960.
9. Five SI Base Units commonly used by Chemists:
   a. Meter (m) – measurement of length.
   b. Kilogram (kg) – measurement of mass.
   c. Kelvin (K) – measurement of temperature.
   d. Second (s) – measurement of time.
   e. Mole (mol) – measurement of amount of substance.
10. Prefixes are used for convenience
    a. tera (T) 10^{12}
    b. giga (G) 10^{9}
    c. mega (M) 10^{6}
    d. Kilo (k) 10^{3}
    e. hecto (h) 10^{2}

f. deci (d) 10^{-1}
g. centi (c) 10^{-2}
h. milli (m) 10^{-3}
i. micro (μ) 10^{-6}
j. nano (n) 10^{-9}
k. pico (p) 10^{-12}

11. Units of Length
    a. The SI unit of length is the meter (m).
    b. Common metric units of length include the centimeter (cm), meter (m), and kilometer (km)
    c. See Table 3.3 on page 74

12. Units of Volume
    a. Volume – space occupied by any sample of matter.
    b. The SI unit of volume is cubic meters (m^3).
    c. Can be calculated: Volume = length x width x height
    d. Often use cubic centimeters (cm^3), milliliters (mL), or Liters (L)
    e. See Table 3.4 on page 75

13. Units of Mass
    a. The SI unit of mass is the kilogram (kg)
        i. Don't confuse mass with weight. Weight is a measure of the gravitational pull on matter. Weight can change based on gravity or position.
    b. Common metric units of mass include the kilogram (kg), gram (g), milligram (mg), and microgram (μg)
    c. See Table 3.4 on page 76

14. Units of Temperature
    a. Temperature is a measure of how hot or cold an object is.
    b. The SI unit of temperature is the Kelvin. (The degree sign is not used)
        i. K = °C + 273

(constant) Don't base significant figures on it. Look @ original given number

    c. Convert 45.6°C to K $\boxed{318.6\ K}$ 1 after decimal
    d. Convert 397.6 K to °C

1 after decimal

$C = K - 273$

$C = 397.6 - 273 = \boxed{124.6°C}$

15. Units of Energy

    a. Energy is the capacity to do work or to produce heat.

    b. The SI unit of energy is the Joule (J).

    c. The calorie (cal) is also a common unit of energy.

       i. 1 J = 0.2390 cal

       ii. 1 cal = 4.184 J

16. SI Derived Units

    a. Area

       i. Square meters (m^2)

       ii. Area = length x width

    b. Speed

       i. Meters per second (m/s) or kilometers per hour (km/h)

       ii. Speed = distance / time

Section 3.3

17. Conversion Factor – ratio of equivalent measurements. Conversion factors are useful in solving problems. When a measurement is multiplied by a conversion factor, the numerical value is generally changed, but the actual size of the quantity measured remains the same.

18. Dimensional Analysis – way to analyze and solve problems using the units or dimensions of the measurements.

    original # * Conversion info sig. digits?

    a. Example: How long will it take to haul 240 bricks? You can carry 30 bricks per trip. Each round trip takes 10 minutes.

    $$240\ \text{bricks} \cdot \frac{1\ \text{trip}}{30\ \text{bricks}} \cdot \frac{10\ \text{minutes}}{1\ \text{trip}} = 80 \qquad \boxed{80.\ \text{minutes}}$$

    2

19. Problems in which a measurement with one unit is converted to an equivalent measurement with another unit are easily solved using dimensional analysis.

    a. 324 µm to m

    3 digits $$324\ \mu m \cdot \frac{1\ m}{1\ 000\ 000\ \mu m} = .000\ 324\ m$$

    $(3.24 \times 10^{-4} m)$

    b. 7 536 L to mL

    4 digits $$7536\ L \cdot \frac{1000\ mL}{1\ L} = 7\ 536\ 000\ mL$$ $(7.536 \times 10^{6} mL)$

    c. 10.8 g to kg

    3 digits $$10.8\ g \cdot \frac{1\ kg}{1000\ g} = .0108\ kg$$

    $(1.08 \times 10^{-2} kg)$

d. 395 028 mm to nm $395028\,mm \cdot \frac{1\,000\,000\,nm}{1\,mm} = 3.95028 \times 10^{11}\,nm$ 6 digits

e. 4 296 kg to metric tons $4296\,Kg \cdot \frac{1\text{ metric ton}}{1000\,kg} = 4.296\text{ metric tons}$ 4 digits

f. 175 pounds to kg $175\,lb \cdot \frac{1\,kg}{2.2\,lb} = 79.54545455$ $\boxed{79.5\,kg}$ 3 digits

g. 5 930 mL to μL $5930\,mL \cdot \frac{1000\,\mu L}{1\,mL} = 5930000\,\mu L$ $5.93 \times 10^6\,\mu L$ 3 digits

h. 58.03 miles to km $58.03\text{ miles} \cdot \frac{1.609\,km}{1\text{ mile}} = 93.37027$ $\boxed{93.37\,km}$ 4 digits

i. 7.8 m^3 to cm^3
$7.8\,m3 \cdot \left(\frac{100\,cm}{1\text{ meter}}\right)^3 \rightarrow 7.8\,m^3\left(\frac{100cm}{1m}\right)\left(\frac{100cm}{1m}\right)\left(\frac{100cm}{1m}\right) = 7800\,000\,cm^3$ $7.8 \times 10^6\,cm^3$ 2 digits

20. Multistep Problems

a. 5.6 gallons to mL
$5.6\text{ gallons} \cdot \frac{4\,qts}{1\text{ gallon}} \cdot \frac{946\,mL}{1\,qt} = 21190.4$ $\boxed{21\,000\,mL}$ 2 digits

b. 87.9 kg to ounces
$87.9\,kg \cdot \frac{2.2\,lb}{1\,Kg} \cdot \frac{16\,oz}{1\,lb} = 3094.08\text{ ounces}$ $\boxed{3090\text{ ounces}}$ 3 digits

c. 41.56 cm to yards
$41.56\,cm \cdot \frac{1\,in}{2.54\,cm} \cdot \frac{1\,yd}{36\,in} = 0.4545056868$ $\boxed{0.4545\,yd}$ 4 digits

d. 67.9 miles/hour to meters/second
$\frac{67.9\,mi}{hr} \cdot \frac{1609\,m}{1\,mi} \cdot \frac{1\,hr}{3600\,s} = 30.34752778$ $\boxed{30.3\,m/s}$ 3 digits

e. 4.301 yards to meters
$4.301\,yd \cdot \frac{3\,ft}{1\,yd} \cdot \frac{.3048\,m}{1\,ft} = 3.9328344$ $\boxed{3.933\,m}$ 4 digits

f. 505 kg to μg
$505\ kg \cdot \frac{1000\ g}{1\ kg} \cdot \frac{1000\ 000\ \mu g}{1\ g} = 5.05 \times 10^{11}\ \mu g$ 3 digits

Section 3.4

21. Density

a. Ratio of the mass of an object to its volume

b. It is an intensive property that depends on the composition of a substance, not on the size of the sample.

c. The density of a substance generally decreases as its temperature increases

d. Formula Density = $\frac{mass}{volume}$

e. Units: g/L, g/mL, g/cm^3, kg/cm^3, etc. 1 mL = 1 cm^3

f. Example: A sample of aluminum metal has a mass of 8.4 grams. The volume of the sample is 3.1 cm^3. Calculate the density of the aluminum

i. Density = $\frac{mass}{volume} = \frac{8.4 g}{3.1 cm^3} = 2.709677419$ $\boxed{2.7 g/cm^3}$
2 digits

g. Using the formula for density, you can also solve for mass or volume

i. Mass = (Density)(Volume)

ii. Volume = $\frac{mass}{density}$

h. See Table 3.6 on page 90 for the Densities of Common Materials