Chapter 1: Chemistry: Measurements and Methods

- 1.1 The Discovery Process
    - **Chemistry** - The study of matter…
    - **Matter** - Anything that has mass and occupies space, the stuff that things are made of.
        - This desk
        - A piece of Aluminum foil
        - What about air?
        - Yes it is matter.
            - All matter consists of chemicals. Chemicals can be used wisely or unwisely, but are not "good" or "bad" in themselves.
        - **Chemistry** - The study of matter and the changes it undergoes.
    - Chemical and physical changes
        - Energy changes
        - **Energy** - The capacity to do work to accomplish some change.
            - (We will discuss energy in chapter 8)
    - Major Areas of Chemistry
        - Biochemistry - the study of life at the molecular level
        - Organic Chemistry - the study of matter containing carbon and hydrogen.
        - Inorganic Chemistry - the study of matter containing all other elements.
        - Analytic Chemistry - analyze matter to determine identity and composition.
        - Physical Chemistry - attempts to explain the way matter behaves.
    - **THE SCIENTIFIC METHOD**
        - **The scientific method -** a systematic approach to the discovery of new information, a logical approach to the solution of scientific problems.
    - <u>**Characteristics of the scientific process**</u>
        - 1. Observation.
        - 2. Formulation of a question
        - 3. Pattern recognition (often looking for cause-and-effect relationships)
        - 4. Developing theories. This begins with a **hypothesis** - an attempt to explain an observation in a common sense way. If the hypothesis is supported by many experiments it then becomes a **theory**.
        - 5. Experimentation. Used to demonstrate the correctness of hypotheses and theories.
        - 6. Summarizing information. A scientific **law** - the summary of a large quantity of information.
    - This cycle is typical of the Scientific Method. The hypothesis may be revised and tested many times.
    - A Theory: a hypothesis or set of hypotheses that are supported by the results of many experiments.
    - A Law: expresses a principle that is true for every experimental observation so far, but does not attempt to explain the principle.
    - Theories are useful because:

        - A well-developed theory allows scientists to predict the results of experiments.
        - The total of scientific theories gives the scientists' best explanation for how the physical universe functions.
- 1.2 Matter and Properties
    - Properties - characteristics of matter
        - chemical vs. physical
    - Three physical states of matter
        - 1. Gas - particles widely separated, no definite shape or volume solid (vapor)
        - 2. Liquid - particles closer together, definite volume but no definite shape
        - 3. Solid - particles are very close together, define shape and definite volume
    - Physical change - produces a difference in the appearance of a substance without causing any change in its composition or identity.
        - conversion from one state to another.
        - melting an ice cube
    - Physical property - a property or quality that is observed without changing the composition or identity of a substance.
    - Chemical property - result in a change in composition and can be observed only through a chemical reaction.
    - Chemical reaction (chemical change) a process of rearranging, replacing, or adding atoms to produce new substances.
    - Intensive properties - a property of matter that is independent of the quantity of the substance
        - Density, conductivity, malleability, melting point, boiling point, odor are examples
    - Extensive properties - depends on the quantity
        - Mass, volume, solubility are examples
    - **Pure substance** - a substance that has only one component
    - **Element** - a pure substance that cannot be changed into a simpler form of matter by any chemical reaction.
    - **Compound** – combination of 2 or more elements in a definite, reproducible way.
    - **Mixture** - a combination of two or more pure substances in which each substance retains its own identity
        - **Homogeneous mixture** - uniform composition
        - **Heterogeneous mixture** - non-uniform composition.
- 1.3 Measurement in Chemistry
    - **Data, Results and Units**
        - **Data** - individual result of a single measurement or observation.
            - obtain the mass of a sample
            - record the temperature of
        - **Results** - the outcome of the experiment
        - **Units** - the basic quantity of mass, volume or whatever being measured.
        - **A measurement is useless without its units.**
    - May Be of Two Kinds

- **Qualitative** - are evaluations (subjective) that describe or compare without values.
- **Quantitative** - evaluations that give results as numbers or values.
  - Also Depend on Accuracy and Precision
- **Accuracy** - how close a measurement is to the true value.
- **Precision** - refers to the reproducibility of the measurement, how often the same value is reached.
- **ENGLISH AND METRIC UNITS**
- **English system** - a collection of measures accumulated throughout English history.
  - no systematic correlation between measurements.
  - 1 gal = 4 quarts = 8 pints
- **Metric (SI) System** - composed of a set of units that are related to each other decimally.
  - That is, by powers of tens
- **UNIT CONVERSION**
  - You need to be able to convert between units within the metric system and between the English and metric system
  - The method used for conversion is called the Factor-Label Method or Dimensional Analysis
  - Let your units do the work for you by simply memorizing connections between units.
    - For example: How many donuts are in one dozen?
    - We say: "Twelve donuts are in a dozen."
    - Or: 12 donuts = 1 dozen donuts
    - What does any number divided by itself equal? ONE!
  - This fraction is called a **unit factor** or a **conversion factor**
    - What does any number times one equal? That number.
  - We use these two mathematical facts to do the factor label method
    - a number divided by itself = 1
    - any number times one gives that number back
  - **Example:** How many donuts are in 3.5 dozen?
  - You can probably do this in your head but let's see how to do it using the Factor-Label Method.

- 1.4 Significant Figures and Scientific Notation
  - The measuring devise determines the number of significant figures a measurement has.
  - In this section you will learn
    - to determine the correct number of significant figures (sig figs) to record in a measurement
    - to count the number of sig figs in a recorded value
    - to determine the number of sig figs that should be retained in a calculation.
  - **Significant figures** - all digits in a number representing data or results that are known with certainty plus one uncertain digit.
  - **RECOGNITION OF SIGNIFICANT FIGURES**
    - All nonzero digits are significant.

- The number of significant digits is independent of the position of the decimal point
- Zeros located between nonzero digits are significant
  - 4055 has 4 sig figs
- Zeros at the end of a number (trailing zeros) are significant if the number contains a decimal point.
  - 5.700
- Trailing zeros are insignificant if the number does not contain a decimal point
  - 2000. versus 2000
- Zeros to the left of the first nonzero integer are not significant.
  - 0.00045

SCIENTIFIC NOTATION

- Represents a number as a power of ten.
- Often used to represent very large or very small numbers or to clarify the number of significant figures in a number.
  - Example: $4{,}300 = 4.3 \times 1{,}000 = 4.3 \times 10^3$
- RULE: To convert a number greater than 1 to scientific notation, the original decimal point is moved *x* places to the left, and the resulting number is multiplied by 10^x.
  - Example: $53{,}000{,}000 = 5.3 \times 10^7$
- What if you want to show the above number has four sig figs?
  - $= 5.300 \times 10^7$
- RULE: To convert a number less than 1 to scientific notation, the original decimal point is moved *x* places to the right, and the resulting number is multiplied by 10^{-x}.
  - Example: $0.000430 = 4.30 \times 10^{-4}$

SIGNIFICANT FIGURES IN CALCULATION OF RESULTS

- I. Rules for Addition and Subtraction
  - The answer in a calculation cannot have greater significance than any of the quantities that produced the answer.
  - example: 54.4 cm +2.02 cm

$$\begin{array}{r} 54.4\ \text{cm} \\ \underline{2.02\ \text{cm}} \\ 56.42\ \text{cm} \end{array}$$

  - correct answer 56.4 cm
- II. Rules for Multiplication and Division
  - The answer can be no more precise than the least precise number from which the answer is derived.
  - The least precise number is the one with the fewest sig figs.

Rules for Rounding Off Numbers

- When the number to be dropped is less than 5 the preceding number is not changed.
- When the number to be dropped is 5 or larger, the preceding number is increased by one unit.
- Round the following number to 3 sig figs: $3.34966 \times 10^4 = 3.35 \times 10^4$

- 1.5 Experimental Quantities
  - **Mass** - the quantity of matter in an object
    - Not synonymous with weight.
  - **Weight** = mass x acceleration due to the force of gravity
    - Mass must be measured on a balance (not a scale.)
    - Use the appropriate mass scale for the size object.
      - A dump truck is measured in tons
      - A person is measured in kg or pounds
      - A paperclip is measured in g or ounces
      - An atom?
    - For atoms, we use the atomic mass unit (amu)
      - 1 amu = 1.661×10^{-24} g
  - **Length** - the distance between two points
    - long distances are measured in km
    - distances between atoms are measured in nm. 1 nm = 10^{-9} m
  - **Volume** - the space occupied by an object.
    - he liter is the volume occupied by 1000 grams of water at 4 degrees Celsius (^oC)
    - 1 mL = 1/1000 L = 1 cm^3
    - The milliliter and the cubic centimeter are equivalent
  - **Time**
    - Metric unit is the second
  - **Temperature** - the degree of "hotness" of an object
  - **Conversions between Fahrenheit and Celsius**
    - The Kelvin scale is another temperature scale. Absolute zero!
    - It is of particular importance because it is directly related to molecular motion.
    - As molecular speed increases, the Kelvin temperature proportionately increases.
      - °C = (°F-32)/1.8
      - °F = (1.8 x °C) + 32
      - K = °C + 273, °C = K - 273
  - **Energy** - the ability to do work
    - **kinetic energy** - the energy of motion
    - **potential energy** - the energy of position (stored energy)
    - Energy can also be categorized by form:
      - light
      - heat
      - electrical
      - mechanical
      - chemical
    - Characteristics of Energy
      - Energy may be converted from one form to another.
      - Energy cannot be created or destroyed.
      - All chemical reactions involve either a "gain" or "loss" of energy.

        - Energy conversion always occurs with less than 100% efficiency.
    - Units of Energy:
        - calorie or joule
        - 1 calorie (cal) = 4.184 joules (J)
    - A kilocalorie (kcal) also known as the large Calorie. This is the same Calorie as Food Calories.
        - 1 kcal = 1 Calorie = 1000 calories
    - 1 calorie = the amount of heat energy required to increase the temperature of 1 gram of water $1^{o}C$.
- **Concentration** - the number of particles of a substance, or the mass of those particles, that are contained in a specified volume.
    - We will look at this in more detail in sections 7.6 and 9.2
- **Density** - the ratio of mass to volume.
    - d = mass/volume or m/V
- **Specific gravity** - the ratio of the density of the object in question to the density of pure water at $4^{o}C$.
    - Specific gravity is a unitless term.
    - Specific Gravity = density of object (g/mL)/density of water (g/mL)
    - Often the health industry uses specific gravity to test urine and blood samples