Chapter 2 - Measurements and Calculations

2-1 The Scientific Method

"A logical approach to solving problems by observing and collecting data, formulating hypotheses, testing hypotheses, and formulating theories that are supported by data"

A. Observing and Collecting Data
    1. Observing
        a. The use of the senses to obtain information
            (1) quantitative data
            (2) qualitative data
    2. Experimenting
        a. Carrying out a procedure under <u>controlled</u> conditions
    3. System
        a. A specific portion of matter in a given region of space that has been selected for study during an experiment or observation

B. Formulating Hypotheses
    1. Generalizations about data are used to formulate a testable statement, or hypothesis

C. Testing Hypotheses
    1. Experimentation yields data that results in the discarding, modification, or adoption of a hypothesis or theory

D. Theorizing
    1. A theory is a broad generalization that explains a body of facts or phenomena
        a. It must allow for successful prediction of future behaviors within a system

E. Publish Results
    1. Experimental results must be repeatable by other scientists

2-2 Units of Measurement

I. <u>SI Measurement (*Le Systeme International d'Unites*)</u>

A. SI Base Units
    1. Mass - kilogram, kg
        a. <u>Mass</u> is a measure of the amount of matter contained in an object
            (1) Mass does not change with a change in position
        b. <u>Weight</u> is a measure of the force of attraction between an object and the earth
            (1) Weight may change with a change in position
    2. Length - meter, m
    3. Time - second, s
    4. Temperature - kelvin, K
    5. Amount of substance - mole, mol

B. Derived Units
    1. Combinations of SI base units form derived units

Common Derived Units

Quantity	Quantity Symbol	Unit	Unit Abbreviation	Derivation
Area	A	Square meter	m^2	length x width
Volume	V	Cubic meter	m^3	Length x width x height
Density	D	Kilogram per cubic meter	Kg/m^3	$\frac{\text{Mass}}{\text{volume}}$
Molar mass	M	Kilograms per mole	Kg/mol	$\frac{\text{Mass}}{\text{Amount of substance}}$
Concentration	c	Moles per liter	M	$\frac{\text{Amount of substance}}{\text{volume}}$
Energy	E	Joule	J	Force x length

    2. Volume
        a. Liter - non SI unit commonly used in chemistry
            (1) 1 liter = 1 cubic decimeter
            (2) 1 liter = 1000 ml = 1000 cm^3
    3. Density
        a. kg/m3 is inconveniently large for chemistry
        b. commonly used unit is g/cm^3 or g/ml
            (1) 1 g/cm^3 = 1 g/ml
        c. gas density is reported in g/liter

C. The Metric System
    1. Decimal system with each component a multiple or subdivision of 10
    2. Common prefixes used in chemistry
        a. milli = 1/1000
        b. centi = 1/100
        c. deci = 1/10
        d. kilo = 1000

II. Conversion Factors

A. Definition
    1. A ratio derived from the equality between two different units that can be used to convert from one unit to the other

        Quantity sought = Quantity given x Conversion factor

B. Deriving Conversion factors
    1. You can derive conversion factors from the known relationship between the unit you have and the unit you want

2-3 Using Scientific Measurement

I. Accuracy and Precision

A. Accuracy

1. The nearness of a measurement to its accepted value

B. Precision

1. The agreement between numerical values of two or more measurements that have been made in the same way
    a. You can be precise without being accurate
    b. Systematic errors can cause results to be precise but not accurate

C. Calculating Percent Error (Relative Error)

$$Percent\ \ Error = \left(\frac{Value_{accepted} - Value_{experimental}}{Value_{accepted}} \right) x100$$

1. Percent error can have negative or positive values

D. Error in Measurement

1. Some error or uncertainty exists in all measurement
    a. no measurement is known to an infinite number of decimal places
2. All measurements should include every digit known with certainty plus the first digit that is uncertain - these are the ***significant figures***

II. Significant Figures

A. Determining the Number of Significant Figures

1. All nonzero digits are significant
2. Rules for zeros

Rule	**Examples**
Zeros appearing between nonzero digits are significant	a) 40.7 L has three sig figs b) 87 009 km has five sig figs
Zeros appearing in front of nonzero digits are not significant	a) 0.095 987 m has five sig figs b) 0.0009 kg has one sig fig
Zeros at the end of a number and to the right of a decimal are significant	a) 85.00 g has four sig figs b) 9.000 000 000 mm has 10 sig figs
Zeros at the end of a number but to the left of a decimal may or may not be significant. If such a zero has been measured, or is the first estimated digit, it is significant. On the other hand, if the zero has not been measured or estimated but is just a placeholder, it is not significant. A decimal placed after the zeros indicates that they are significant.	**a)** 2000 m may contain from one to four sig figs, depending on how many zeros are placeholders. **For measurements given in this text, assume that 2000 has one sig fig.** b) 2000. m contains four sig figs, indicated by the presence of the decimal point

B. Rules for Rounding

Of the digit following the last digit to be retained is:	Then the last digit should	Example (rounded to three sig figs)
Greater than 5	Be increased by 1	42.68 g → 42.7 g
Less than 5	Stay the same	17.32 m → 17.3 m
5, followed by nonzero digit(s)	Be increased by 1	2.7851 cm → 2.79 cm
5, not followed by nonzero digit(s), and preceded by an odd digit	Be increased by 1	4.635 kg → 4.64 kg
5, not followed by nonzero digit(s), and the preceding significant digit is even	Stay the same	78.65 mL → 78.6 mL

C. Addition and Subtraction with Significant Figures
    1. The answer must have the same number of digits to the right of the decimal as there are in the measurement having the fewest digits to the right of the decimal point
D. Multiplication and Division with Significant Figures
    1. The answer can have no more sig figs than are in the measurement with the fewest total sig figs
E. Conversion Factors and Sig Figs
    1. Conversion factors that are known EXACTLY have no uncertainty factor and do not contribute to limitations in calculations
        a. 12 inches per foot
        b. 1000 grams per kilogram

III. <u>Scientific Notation</u>

A. <u>Scientific Notation</u>
    1. A method of representing very large or very small numbers
        a. $M \times 10^n$
            (1) M is a number between 1 and 10
            (2) n is an integer
            (3) all digits in M are significant
B. Reducing to Sci Notation
    1. Move decimal so that M is between 1 and 10
    2. Determine n by counting the number of places the decimal point was moved
        a. Moved to the left, n is positive
        b. Moved to the right, n is negative

C. Mathematical Operations Using Scientific Notation
    1. Addition and subtraction
        a. Operations can only be performed if the exponent on each number is the same
    2. Multiplication

a. M factors are multiplied
b. Exponents are added

3. Division
   a. M factors are divided
   b. Exponents are subtracted (numerator - denominator)

D. Operations with Units

1. Cancellation occurs with the units in the same way that it occurs with numbers common to both the numerator and denominator
   a. Units are handled algebraically, just like numbers
   b. Analysis of units can be a clue as to whether a problem was set up correctly
2. Calculations involving units must have the correct units shown throughout the working of the problem and attached to the answer

IV. Using Sample Problems

A. Analyze

1. Read the problem carefully at least twice and analyze the information in it

B. Plan

1. Develop a plan for solving the problem

C. Computer

1. Plug in the numbers

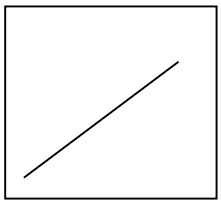
D. Evaluate

1. Examine your answer to determine what is reasonable

V. Proportions

A. Direct Proportion

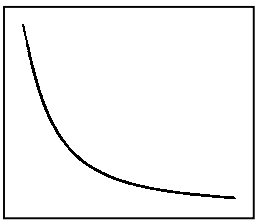
1. Quotient of two variables is a constant
   a. $y/x = k$ $y = kx$
   b. graph is a straight line



1. As the value of one variable increases, the value of the other must also increase

B. Indirect (inverse) Proportion

1. Product of the two variables is a constant
   a. $xy = k$ $y = k/x$
   c. graph is a hyperbola



2. As the value of one variable increases, the value of the other must decrease