Chapter 1: Some basic concepts

1.1 Introduction to matter

-**Matter** is the physical material of the universe; it is anything that has mass and takes up space.
-Three states of matter: gas, solid, liquid
-**Gas**: no fixed volume or shape
-**Solid**: fixed volume and shape
-**Liquid**: fixed volume, no fixed shape

Substances

-**Pure substance**: matter that has a fixed composition and distinct properties

Physical and Chemical Properties

-**Physical properties**: properties we can measure without changing the basic identity of the substance
-**Chemical properties**: describe the way a substance may change or "react" to form other substances

Physical and Chemical Changes

-**Physical change**: substance changes its physical appearance but not its basic identity
-**Chemical change**: aka **chemical reactions**; substance is transformed into a chemically different substance.

Mixtures

-**Mixture**: combination of two or more substances in which each substance retains its own chemical identity, and hence its own properties
    Heterogeneous: mixtures that do NOT have the same appearance throughout, composition, or properties
    Homogeneous: mixtures that are uniform throughout
-**Filtration**: passing a solution through a porous substance, such as a filter, to separate any solid residue from liquid
-**Distillation**: process of changing water vapor back to liquid state

1.2 Elements and Compounds

-**Elements**: substances that cannot be decomposed into simpler substances by chemical means
-**Compounds:** can be decomposed by chemical means into two or more elements
-**Law of Constant Composition**: aka **Law of Definite Proportions**; elemental composition is always the same

1.3 Units of Measurements

Physical Quantity	Name of unit	Abbreviation
Mass	Kilogram	Kg
Length	Meter	M
Time	Second	s[a]
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	cd
Amount of substance	Mole	mol

-**Intensive properties**: properties whose values do NOT depend on the amount of material chosen
-**Extensive properties**: properties whose values depend on the amount of material

1.4 Uncertainty in Measurement

Precision and Accuracy

-**Precision**: measure of how closely individual measurements agree with one another
-**Accuracy**: how closely individual measurements agree with the accepted value

Significant Figures

1. All nonzero digits are significant- 457 cm (3), 2.5 (2)
2. Zeros between nonzero digits are significant- 1005 kg (4), 1.03 (3)
3. Zeros to the left of the first nonzero digit are not significant; they merely indicate the position of the decimal point- 0.02 (1), 0.0026 (2)
4. Zeros that fall both at the end of a number and to the right of a decimal point are significant- 0.0200g (3), 3.0 (2)
5. When a number ends in zeros but contains no decimal point, the zeros may or may not be significant- 130 cm (2,3), 10,300 (3,4,5)

Chapter 2: Atoms, Molecules, and Ions

2.1 The Atomic Theory of Matter

1. Each element is composed of extremely small particles called atoms
2. All atoms of a given element are identical; the atoms of different elements are different and have different properties (including different masses)
3. Atoms of an element are not changed into different types of atoms by chemical reactions; atoms are neither created nor destroyed in a chemical reaction
4. Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms

-**Law of Conservation of Mass**: aka **Law of Conservation of Matter**; total mass of materials present after a chemical reaction is the same as the total mass before the reaction

-**Law of Multiple Proportions**: if two elements A and B combine to form more than one compound, then the masses of B that can combine with the masses of A are in the ratio of small whole numbers

2.2 The Discovery of Atomic Structure

Cathode Rays and Electrons

-**Cathode rays**: radiation produced as a result from high voltage; originates from the negative electrode, or the cathode

Radioactivity

-**Radioactivity**: spontaneous emission of high-energy radiation
Three types of radiation; alpha (α), beta (β), and gamma (γ)

Alpha (α): positive, more massive than beta particles, charge of 2+
Beta (β): high-speed electrons, negative, charge of 1-
Gamma (γ): doesn't consist of particles, not affected by electrical fields

2.3 The Modern View of Atomic Structure

Isotopes, Atomic Numbers, and Mass Numbers

-**Isotopes**: atoms of a given element that differ in the number of neutrons, and consequently the mass

$^{12}_{6}C$ means carbon-12, carbon atom with 6 protons and 6 neutrons.
*Number on bottom (6): **atomic number**: number of protons/electrons (since an atom always has the same number of protons and electrons in order to retain a neutral charge)*
*Number on top (12): **mass number**: total number of protons and neutrons in the atom*

Symbol	Number of protons	Number of electrons	Number of neutrons
^{11}C	6	6	5
^{12}C	6	6	6
^{13}C	6	6	7
^{14}C	6	6	8

-**Nuclide**: atom of a specific isotope (atom of ^{14}C is referred to as ^{14}C nuclide)

2.1 The Periodic Table

-**Family**: aka **Groups**, columns of the periodic table.

Group	Name	Elements
1A	Alkali metals	Li, Na, K, Rb, Cs, Fr
2A	Alkaline earth metals	Be, Mg, Ca, Sr, Ba, Ra
6A	Chalcogens ("chalk formers")	O, S, Se, Te, Po
7A	Halogens ("salt formers")	F, Cl, Br, I, At
8A	Noble gases (or inert gases or rare gases)	He, Ne, Ar, Kr, Xe, Rn

-**Metallic elements**: all the elements on the left side and in the middle of the periodic table, except for Hydrogen. Properties include: luster, high electrical conductivity, and heat conductivity.
-**Nonmetallic elements**: separated from the metallic elements by "staircase" that runs from Boron (B) to Astatine (At). At room temperature, nonmetals can exist in any of the three states of matter.
-**Metalloids**: elements that lie along the line that separates metals from nonmetals; have properties that fall between those of metals and nonmetals.

2.5 Molecules and Ions

Molecules and Chemical Formulas

-**Chemical formula**: represents molecular form of an element. Subscript in the formula indicates number of atoms of given elements.
-**Diatomic molecule**: any molecule that is made up of two atoms
Most molecular substances contain only nonmetals

Molecular, Empirical, and Structural Formulas

-**Molecular formulas**: chemical formulas that indicate the *actual* numbers and types of atoms in a molecule
-**Empirical formulas**: chemical formulas that give only the *relative* number of atoms of each type in a molecule. They are always expressed in the smallest whole-number ratio.
-**Structural formulas**: formula of a molecule written to show how its atoms are joined together

Ionic Compounds

-**Ionic compound**: compound that contains positively charged ions and negatively charged ions
Ionic compounds are generally combinations of metals and nonmetals, as in NaCl. In contrast, *molecular compounds are generally composed of nonmetals only,* as in H_2O

2.6 Naming Inorganic Compounds

Organic compounds contain carbon, usually in combination with hydrogen, oxygen, nitrogen, or sulfur. All other compounds are called *inorganic compounds*.

ClO^- hypochlorite ion (one less oxygen than chlorite)
ClO_2^- chlorite ion (one less oxygen than chlorate)
ClO_3^- chlorate ion
ClO_4^- perchlorate ion (one more oxygen than chlorate)

Chapter 3: Stoichiometry: Calculations with Chemical Formulas and Equations

3.1 Chemical Equations

-**Chemical equations**: represent chemical *reactions* in a concise way

3.2 Patterns of Chemical Reactivity

Combustion in Air

-**Combustion reactions**: rapid reactions that produce a flame; most involve O_2 from air as a reactant. Two types:

1. *Complete (if enough oxygen is present for reaction)*
   $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
2. *Incomplete (insufficient oxygen)*
   $C_xH_y + O_2 \rightarrow CO + H_2O$ *(if you have lots of oxygen)*
   $C_xH_y + O_2 \rightarrow C + CO + H_2O$ *(if huge lack of oxygen)*

Combination and Decomposition Reactions

-**Combination reactions:** aka **Synthesis reactions**; two or more substances react to form one product. Ex. $A + B \rightarrow C$
-**Decomposition reactions**: one substance undergoes a reaction to produce two or more substances; many undergo decomposition when heated. Ex. $AB \rightarrow A + B$

3.3 Atomic and Molecular Weights

Average Atomic Masses

Can be determined using masses of an element's various isotopes as well as their relative abundances.
-**Atomic weight**: aka **average atomic mass**; expressed in amu

Formula and Molecular Weights

-**Formula weight**: sum of the atomic weights of each atom in its chemical formula
-**Molecular weight**: aka **formula weight** if the chemical formula of a substance is its molecular formula

3.4 The Mole

-**Mole**: amount of matter that contains as many object (atoms, molecules, etc…) as the number of atoms in exactly 12g of ^{12}C
-**Avogadro's number**: number of atoms in a mole, 6.022×10^{23}.

Molar Mass

-**Molar mass**: mass in grams of 1 mol of a substance; always numerically equal to its formula weight (in amu)

3.5 Empirical Formulas from Analyses

Molecular Formula from Empirical Formula

The subscripts in the molecular formula of a substance are always whole-number multiple of the corresponding subscripts in its empirical formula

3.6 Quantitative Information from Balanced Equations

The coefficients in a balanced chemical equations can be interpreted both as the relative number of molecules (or formula units) involved in the reaction and as relative number of moles.

3.7 Limiting Reactants

-**Limiting reactant**: aka **Limiting reagent**; reactant that is completely consumed in a reaction; determines, or limits, the amount of product formed

Theoretical Yields

-**Theoretical yield**: quantity of product that is calculated to form when all of the limiting reactant reacts. *Amount of product obtained in a reaction is called the* actual yield.
-**Percent yield**: actual yield/theoretical yield x 100

Chapter 4: Aqueous Reactions and Solution Stoichiometry

-**Aqueous solutions**: solutions in which water is the dissolving medium

4.1 Solution Composition

Molarity

-**Molarity**: moles solute/ liters of solution

Dilution

-**Dilution**: reducing the concentration (or molarity) of a solution, by adding water to it

Moles solute before dilution = moles solute after dilution

$M_{initial}V_{initial} = M_{final}V_{final,}$ where M is molarity and V is volume

4.2 Electrolytes

-**Electrolytes**: solutions that exist as ions in solution
-**Nonelectrolytes**: nonionizing substances, usually molecular substances

Strong and Weak Electrolytes

-**Strong electrolytes**: substances that exist in solution almost completely as ions; nearly all ionic compounds are strong electrolytes.
-**Weak electrolytes**: compound that only partly ionize in a solution *(when a weak electrolyte ionizes, a double arrow is used as a yield sign. This is because ions are dissolving and recombining at the same time. ONLY happens with WEAK electrolytes)*
-**Chemical equilibrium**: balance between opposing processes (dissolving and recombining of weak electrolytes) that determines the relative concentrations of neutral molecules and ions

4.3 Acids, Bases, and Salts

-**Acids**: substances that are able to ionize to form a hydrogen ion and thereby increase the concentration of H^+ ions in aqueous solutions. *Monoprotic acids= acids that yield only one H^+ per molecule of acid. Diprotic yields two H^+ per molecule of acid.*

Bases

-**Bases**: substances that can react with or accept H^+ ions, such as OH^- ions
-**Strong Acids/Bases**: acids and bases that are strong electrolytes
-**Weak Acids/Bases**: acids and bases that are weak electrolytes
-*Some of the most common acids are STRONG*
-*Three of the strong acids result from combining a hydrogen atom and a halogen*
-*The list of strong acids is very short. Most acids are WEAK*

Strong acids	**Strong bases**
Chloric, $HClO_3$	Group 1A metal hydroxides (LiOH, NaOH, KOH, RbOH, CsOH)
Hydrobromic, HBr	
Hydrochloric, HCl	
Hydroiodic, HI	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Nitric, HNO_3	
Perchloric, $HClO_4$	
Sulfuric, H_2SO_4	

Salts

-**Salts**: ionic compounds that can be formed by replacing one or more of the hydrogen ions of an acid by a different positive ion. *Almost all salts are STRONG electrolytes. The only exceptions are some salts of the heavy metals, such as mercury and lead.*

Identifying Strong and Weak Electrolytes

1. Most *salts* are strong electrolytes
2. Most *acids* are weak electrolytes. However, HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_3$, and $HClO_4$ are strong acids
3. The common strong *bases* are the hydroxides of the alkali metals and the heavy alkaline-earths. Ammonia, NH_3, is a weak electrolyte
4. Most other substances are nonelectrolytes

Neutralization Reactions

-**Neutralization reactions**: occurs when and acid is mixed with a solution of base. *In general, a neutralization reaction between an acid and a metal hydroxide produces water and salt*

4.4 Ionic Equations

-**Molecular equation**: equation showing the complete chemical formulas of the reactants and the products
-**Net ionic equation**: includes ions and molecules that are directly involved in the reaction
-**Spectator ions**: ions that appear in identical form on both sides of the equation

Only soluble strong electrolytes are written in ionic form. Soluble weak electrolytes, soluble nonelectrolytes, and insoluble substances are written in "molecular" form.

4.5 Metathesis Reactions

-**Metathesis reactions**: aka **double-replacement reactions**; cations and anions exchange partners
Driving forces are chemical processes that can remove ions from a solution. Below are the three chemical processes, known as driving forces:

1. The formation of an insoluble solid (called a precipitate)
2. The formation of either a soluble weak electrolyte or a soluble nonelectrolyte
3. The formation of a gas that escapes from solution

Precipitation Reactions

-**Precipitation reactions**: metathesis reactions that result in the formation of a precipitate
-**Solubility**: amount of a substance that can be dissolved in a given quantity of solvent

Solubility Rules

Memorize those from the summer packet

Reactions in which a Weak Electrolyte or Nonelectrolyte Forms

-Ions can react to form weak electrolytes or nonelectrolytes that remain dissolved in the solution. *Acid-base neutralization reactions, in which H^+ and OH^- ions react to form water, are the most common reactions of this type.* Even water-insoluble hydroxides react with acids:

$$Mg(OH)_{2\,(s)} + 2HCl_{\,(aq)} \rightarrow MgCl_{2\,(aq)} + 2H_2O_{\,(l)}$$

Insoluble metal oxides can also react with acids because the oxide ion can combine with two H^+ ions to give water :

Molecular Equation: $NiO_{\,(s)} + 2HNO_{3\,(aq)} \rightarrow Ni(NO_3)_{2\,(aq)} + H_2O_{\,(l)}$
Net Ionic Equation: $NiO_{\,(s)} + 2H^+_{\,(aq)} \rightarrow Ni^{2+}_{\,(aq)} + 2H_2O_{\,(l)}$

A net reaction will also occur when ions are removed from solution by the formation of a weak electrolyte, such as a weak acid.

Molecular Equation: $HCl_{(aq)} + NaC_2H_3O_{2\ (aq)} \rightarrow HC_2H_3O_{2\ (aq)} + NaCl_{(aq)}$
Net Ionic Equation: $H^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2\ (aq)}$

4.6 Reactions of Metals

Oxidation and Reduction

-**Oxidation**: loss of electrons by a substance, making it more positive
-**Reduction**: gain of electrons by a substance, making it more negative

Oxidation of Metals by Acids and Salts

-*Many metals react with acids to form salts and hydrogen gas.*

Ex. $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\ (aq)} + H_{2\ (g)}$

The metal is oxidized by the acid to form the metal cation; the H^+ ion of the acid is reduced to form H_2. *Whenever one substance is oxidized, some other substance must be reduced.*

The Activity Series

-**Activity series**: list of metals arranged in order of decreasing ease of oxidation

4.7 Solution Stoichiometry

Titrations

-**Standard solution**: solution of known concentration; used to determine the concentration of another solution
-**Titration**: reaction in which the standard solution undergoes a reaction of known stoichiometry with a solution of unknown concentration, in order to determine the unknown concentration
-**Equivalence point**: the point at which stoichiometrically equivalent quantities are brought together

During a titration, color change of the indicator indicates the end point of the titration.