Unit 4: Days 1 - 13

STOICHIOMETRY

A) Formulas/Nomenclature
   1. Oxidation numbers
   2. Solubility Rules
   3. Common Ions
   4. Chemical symbols, formulas and names

B) Mass Relationships/Mathematical skills
   1. Calculating average atomic mass
   2. Molar mass and Avogadro's number
   3. Conversion Map
   4. Determining Percent composition
   5. Determining empirical formula from percent composition
   6. Determining a molecular formula from the empirical formula

C) Balancing equations

D) Stoichiometry
   1. The "Mole Method"
   2. Limiting Reactants
   3. Percent Yield

Note to Teacher: The following daily plans are based on my average experience teaching AP Chemistry. Some days move faster than other, some students move faster than others. I've tried to include some flexibility. Have the students read the appropriate chapter(s) from the text you are using.

Stoichiometry is often viewed as a difficult section—some students pick up quickly and other don't. I tend to be very flexible here and leave just open time—it shouldn't take more than 10 classes to get through the stoichiometry. The best way is to just run through sample problems with the students. Remind them of these critical facts:

1) If the reaction is not properly balanced, the stoichiometry will not work! (In fact, I tell my students that I won't even look at the rest of their answer)
2) For the reaction to be properly balanced, make sure you have the correct chemical formula--- if that is wrong, the stoichiometry will definitely not work!
3) Dimensional analysis can be a life-saver. If the student is stuck—tell them to look at the units, perform mathematical function that will give the correct

units—units don't lie and this often gives the students at least a lead in finding the answer.

4) Analysis of the problem before any attempt to solve it will pay off—understand what is going on in the problem and what is being asked!
5) For every problem, I have the students make a list of "givens" (information that is presented in the problem) and "solve fors" (whatever is being asked). This helps organize the information and, in later units will help determine the equation to be used.
6) Depending on your school's curriculum, the students may or may not have been required to know rules for oxidation numbers, solubility rules, the names and charges on polyatomic ions: in AP Chemistry, they <u>need</u> to have these memorized. Even if this constitutes a review, make sure they know them!

Unit 4: Days 1 – 13

OVERALL OBJECTIVES:

1) To ensure that the students become familiar with and comfortable in using the basic formulas and nomenclature of chemistry.
2) To ensure the students have a basic understanding of in the use of oxidation numbers.
3) To ensure that the students become familiar with and comfortable determining the solubility of reactants and products.
4) To ensure that the students are comfortable with chemical conversions.
5) To ensure that the students become familiar with and comfortable with the basic mathematical and chemical concepts of percent composition, and empirical and molecular formulas.
6) To ensure that the students are comfortable and familiar with balancing chemical reactions.
7) To ensure that the students are comfortable and familiar with basic principals of stoichiometry.

Unit 4:Day 1: CN: 4:1: A-F PowerPoint Slides #167-178 Homework: Unit 4:1-3

FORMULAS AND NOMENCLATURE:

The students need to memorize a number of things:

1) Rules to determine oxidation numbers
2) Solubility rules to determine the phase of reactants and products
3) Charges on polyatomic ions (these can be used to help in determining oxidation numbers (rule # 8)

- Rules to determine Oxidation numbers (oxidation states): Oxidation numbers are essentially a book-keeping method—a method of keeping the number of electrons involved straight. For covalent compounds with identical elements, the electrons are split equally. In a compound where two different elements are involved, the electrons are assigned completely to the more electronegative element. These rules are a hierarchy--the rules are listed in order of importance. When determining oxidation numbers, the higher order rules take precedence over the lesser rules—i.e. rule #3 is more important than rule #6. In some ways, rule #8 is most useful, however.

Oxidation Numbers:

1) Free elements or elements in a diatomic form (H_2, O_2, N_2 , Cl_2, Br_2, I_2, F_2) have an oxidation number of 0.
2) Monoatomic ions have an oxidation number equal to their charge.
3) Alkali metals have an oxidation number of +1

4) Alkaline earth metals have an oxidation number of +2
5) The oxidation number of oxygen in compounds other than peroxides (eg H_2O_2) and superoxides (KO_2) is –2.
   - In peroxides the oxidation number of oxygen is –1.
   - In superoxides, the oxidation number of oxygen is –1/2
6) The oxidation number of hydrogen in compounds other than binary metal hydrides is +1. The oxidation number of hydrogen in the binary metal hydrides (e.g. LiH, NaH) is –1.
7) The oxidation number of fluorine is –1. The oxidation number of other halogens are negative except in combination with oxygen, where they are positive (because rule #3 applies)
8) In a neutral molecule, the sum of the oxidation numbers is 0. In a polyatomic ion, the sum of the oxidation numbers equals the charge of the ion.

Examples:

CO_2: Rule #5 takes precedence: The oxidation number for O is –2
Rule#8: The sum of the oxidation numbers is 0, so C is +4
[2 x (-2) =-4, and the oxidation number of C + (-2)=0]

NO_3^-: Rule #5 takes precedence: The oxidation number for O is –2
Rule#8: The sum of the oxidation numbers of the polyatomic ion is -1, so N is +5
[3 x (-2) =-6, and the oxidation number of N + (-6)=-1]

H_2SO_4: Split the compound into its polyatomic anion and monoatomic cations first.
SO_4^{2-}: Rule #5 takes precedence: The oxidation number for O is –2
Rule#8: The sum of the oxidation numbers of the polyatomic ion is -2, so S is +6.
[4 x (-2) =-8, and the oxidation number of S + (-8)=-2]
Rule#8: The sum of the oxidation numbers is 0, so the 2 H's are +1 each (also Rule #6)

Unit 4:Day 2: CN: 4:2: A-G PowerPoint Slides #179-198

The solubility rules

These are important in determining the phase of products or reactants.

SOLUBILITY RULES

SOLUBLE COMPOUNDS	**EXCEPTIONS**
Compounds containing alkali metal ions: Li^+, Na^+, K^+, Rb^+, Cs^+ Compounds containing the ammonium ion: NH_4^+	NONE
Nitrates (NO_3^-), Bicarbonates (CO_3^-), and chlorates (ClO_3^-)	NONE
Halides (F^-, Cl^-, Br^-, I^-)	Halides of Ag^+ Hg_2^{2+} and Pb^{2+}
Sulfates(SO_4^{2-})	Sulfates of Ag^+, Ca^{2+}, Ba^{2+},$Hg^{2+}$and Pb^{2+}
INSOLUBLE COMPOUNDS	**EXCEPTIONS**
Carbonates (CO_3^{2-}), phosphates (PO_4^{3-}) and chromates (CrO_4^{2-}) and sulfides (S^{2-})	Compounds containing the alkali metal ions ammonium ion.
Hydroxides (OH^-)	Compounds containing alkali metal ions. Those containing Ba^{2+}, Sr^{2+} and Ca^{2+} are somewhat soluble.

Common Mono/Polyatomic Ions

Cations:

Ammonium; NH_4^+
Hydronium: H_3O^+
Mercury (I) Mercurous: Hg_2^{2+}
Mercury (II) Mercuric: Hg^{2+}
Nitride: N^{3+}

Anions: (1-)

Acetate: CH_3COO^- (or $C_2H_3O_2^-$)
Cyanide: CN^-
Hydrogen carbonate: HCO_3^-
Dihydrogen phosphate: $H_2PO_4^-$
Hydrogen sulfate (bisulfate): HSO_4^-
Hydrogen sulfide: HS^-
Bisulfite: HSO_3^-
Hydroxide: OH^-
Nitrate: NO_3^-
Nitrite: NO_2^-
Permanganate: MnO_4^-
Perchlorate: ClO_4^-
Chlorate: ClO_3^-
Chlorite: ClO_2^-
Hypochlorite: ClO^-

Anions: (2-)

Carbonate: CO_3^{2-}
Chromate: CrO_4^{2-}
Dichromate: $Cr_2O_7^{2-}$
Hydrogen phosphate: HPO_4^{2-}
Oxalate: $C_2O_4^{2-}$
Sulfate: SO_4^{2-}
Sulfite: SO_3^{2-}
Oxide: O^{2-}
Sulfide: S^{2-}

Anions: (3-)

Arsenate: AsO_4^{3-}
Borate: BO_3^{3-}
Phosphate: PO_4^{3-}
Phosphide: P^{3-}

CHEMICAL SYMBOLS, FORMULAS AND NAMES:

Most of the following is extremely basic—it pays to briefly review it as some things that are "basic" need to be emphasized from time to time.

1. **Symbols for elements**: Each element has a one or two-letter symbol. Often, these are the first letter(s) of the name of the element. Examples include: Oxygen (O), Hydrogen (H), Carbon (C) , Neon (Ne) and Lithium (Li). Sometimes, the symbol is based on the Latin name of the element. Examples of this include Sodium (Natrium, Na), Gold (Aurum= Au) and Tin (Stannum=Sn).

2. **Formulas of the Elements**: An element is defined as a pure substance that cannot be decomposed by chemical means.
    a. Monoatomic: Many elements have chemical formulas that are also the symbols for the elements—that is when they can exist by themselves. Metals such as Au (gold), Ca (calcium), Al (aluminum) and Ni (nickel) are examples of these. Some non- metals such as the elements known as the Noble Gases [Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn)] can exist alone.
    b. Diatomic: Some elements exist naturally in groups of 2 ("di" =2) atoms. Examples are H_2 (hydrogen), O_2 (oxygen), N_2 (nitrogen), Cl_2 (chlorine), Br_2 (bromine), I_2 (iodine) and F_2(fluorine) [HONClBrIF—I use it as a mnemonic] Also note that with the exception of Hydrogen, all the diatomics form an "L" at the upper right of the periodic table.
    c. Polyatomic: Some elements exist naturally in groups of 3 or more atoms ("poly" = many). Examples are O_3 (ozone), P_4 (white phosphorus), P_8 (red phosphorus), S_8 (sulfur) and C_{60} (fullerenes)

3. **Formulas for compounds**: A compound is defined as two or more elements chemically combined in definite proportions. The number, written as a subscript to the lower right of an element represents the number of atoms or moles of each element in the compound.

    Examples:
    a. H_2O is the chemical formula for water. Water is composed of 2 atoms of Hydrogen and one atom of Oxygen. AND: Water is composed of 2 **moles** of Hydrogen atoms and one **mole** of Oxygen atoms.
    b. HCl is the formula for hydrochloric acid. Hydrochloric acid is composed of one H and one Cl atom. AND: Hydrochloric acid is composed of one **mole** of H atoms and one **mole** of Cl atoms.
    c. H_2SO_4 is the formula for sulfuric acid. It is composed of 2 H atoms, 1 S atom and 4 O atoms. AND: Sulfuric acid is composed of 2 **moles** of H atoms, 1 **mole** of S atoms and 4 **moles** of O atoms.

d. $C_6H_{12}O_6$ is the formula for glucose. It is composed of 6 C's, 12 H's and 6 O's. AND: It is composed of 6 **moles** of Carbon atoms, 12 **moles** of Hydrogen atoms and 6 **moles** of Oxygen atoms..

4. **Writing and naming compounds**: The simple criss-cross method can be used:

❖ The signs of the oxidation numbers/ ion charge are dropped and switched to the opposite element/polyatomic ion. The formulas are simplified mathematically as long as they are not covalent compounds. (ex: Fe $^{+2}$ and $SO_4^{2-} \rightarrow Fe_2(SO_4)_2$ is written $FeSO_4$ but N_2O_2 is not simplified because it is a covalent compound)

a. **Simple binary compounds**: Binary compounds contain only 2 elements. The one with a positive oxidation number (the cation) is written first, and the one with the negative oxidation number (the anion) is written second.

To name these compounds, name the cation first, then the anion—the cation keeps the element name while the anion gets an "ide" ending.

b. **The Stock System**: Some elements have more than one positive oxidation number and can form more than one binary compound. In this case, the Stock system for naming is used. The Stock system replaces the positive oxidation number used with the Roman numeral.

Example: Fe has two oxidation numbers, +2 and +3. Fe can form 2 different compounds with oxygen:

FeO where the Fe has a +2 oxidation number. The name is Iron (II) oxide
Fe_2O_3 where the Fe has a +3 oxidation number. The name is Iron (III) oxide

Example: Cu has two oxidation numbers, +1 and +2. Cu can form 2 different compounds with oxygen:

Cu_2O where the Cu has a +1 oxidation number. The name is copper (I) oxide
CuO where the Cu has a +2 oxidation number. The name is copper (II) oxide.

Example: Au has two oxidation numbers, +1 and +3. Au can form 2 different compounds with chlorine.

AuCl where the Au has a +1 oxidation number. The name is gold (I) chloride
$AuCl_3$ where the Au has a +3 oxidation number. The name is gold (III) chloride

c. **Compounds containing polyatomic anions**: The criss-cross method is still used. The polyatomic anions are listed above. Use the oxidation numbers listed to criss-cross. Naming: Name the cation first and then simply the name of the polyatomic ion.

Example: Na^{+1} and ClO_3^{1-}
The criss-cross gives us: $NaClO_3$ and the name is sodium chlorate

Example: Li^{+1} and NO_3^{1-}
The criss-cross gives us: $LiNO_3$ and the name is lithium nitrate

Example: K^{+1} and MnO_4^{1-}
The criss-cross gives us: $KMnO_4$ and the name is potassium permanganate

Example: K^{+1} and MnO_4^{2-}
The criss-cross gives us: K_2MnO_4 and the name is potassium manganate

- Again, some elements have more than one positive oxidation number and can form more than one binary compound. In this case, the Stock system for naming is used. The Stock system replaces the positive oxidation number used with the Roman numeral.

Example: Fe and SO_4^{2-}
If Fe has the +2 oxidation state, the compound is $FeSO_4$ and is named iron (II) sulfate.
If Fe has the +3 oxidation state, the compound is $Fe_2(SO_4)_3$ and is named iron (III)sulfate

d. **Molecular Compounds** (covalent molecules):
1) The less electronegative atom is listed and named first.
2) Use prefixes to indicate the number of atoms in the formula: (if the first atom is mono, the prefix is omitted)

Mono- 1	*Hexa*- 6
Di- 2	*Hepta*- 7
Tri- 3	*Octa*- 8
Tetra- 4	*Nona*- 9
Penta- 5	*Deca*- 10

3) The more electronegative atom, written last, has the *-ide* ending

Examples:
CO_2: Carbon dioxide
CO: Carbon monoxide
N_2O_4: Dinitrogen tetroxide
PCl_3: Phosphorus trichloride

The Stock System can be used here as well:
N_2O_4: Dinitrogen tetroxide is also name Nitrogen (IV) oxide
CO: Carbon monoxide is also named Carbon (II) oxide

e. Acids:
1) The name of the acid is based on the anion
2) The acid will end in *-ic or -ous* depending on the anion from which it is derived

3) If the anion ends in *-ide*, the acid will end in *-ic*
4) If the anion ends in *-ate*, the acid will end in *-ic*
5) If the anion ends in *-ite*, the acid will end in *-ous*
6) The anion is preceded by *hydro-*

Examples: **HCl** is hydrochloric acid
$HClO_4$ is perchloric acid, **$HClO_3$** is chloric acid, **$HClO_2$** is chlorous acid and **$HClO$** is hypochlorous acid.
H_2SO_3 is sulfurous acid and **H_2SO_4** is sulfuric acid
HNO_2 is nitrous acid and **HNO_3** is nitric acid

f. **Other systems:** The older system for naming is still in use. In this case, if the cation has the lower oxidation number, the suffix "ous" is used. If the higher oxidation number is used, the suffix "ic" is used. Usually the Latin stems are used.

Examples:

$FeSO_4$:	Ferrous sulfate (iron (II) sulfate)
$Fe_2(SO_4)_3$:	Ferric sulfate (iron (III) sulfate)
SnF_2:	Stannous fluoride (tin (II) fluoride)
SnF_4:	Stannic fluoride (tin (IV) fluoride)
$AuCl_3$:	Auric chloride (Gold (III) chloride
$PbSO_4$:	Plumbous sulfate (Lead(II) sulfate)
$Pb(SO_4)_2$:	Plumbic sulfate (Lead (IV) sulfate)

Figure 1:Overview of Naming: