Chemical Reactions

I. What is a chemical reaction?
   a. A chemical reaction is a chemical change.
   b. The law of conservation of mass.
      i. The mass of the reactants (the mass of everything that you started with) must equal the mass of the products (the mass of the stuff that you made) in any chemical reaction
      ii. The number atoms of each element that exist before a chemical reaction must equal the number of atoms that exist after the chemical reaction

II. What is a chemical equation?
   a. Describing chemical reactions on paper.
      i. Reactants
         1. Starting substance(s)
         2. Left side of arrow
      ii. Products
         1. Ending substance(s)
         2. Right side of arrow
   b. Subscripts and coefficients.
      i. Consider the equation for the reaction of hydrochloric acid with calcium carbonate:

$$2\,HCl\,(aq) + CaCO_3\,(s) \rightarrow H_2O\,(l) + CO_2\,(g) + CaCl_2\,(aq)$$

      ii. The “2” in front of the HCl is a coefficient. A coefficient is a “big” number in a chemical equation in front of a compound or element’s formula. It tells you to multiply every atom in a certain compound by whatever the value of the coefficient is. The “2” in front of HCl tells us that 2 molecules of HCl are required for this reaction to take place. It’s OK to change subscripts in order to balance an equation.
      iii. The “3” in $CaCO_3$ is an example of a subscript. The subscript tells you how many atoms of a particular element there are in a certain compound. It’s not OK to change a subscript in order to balance an equation.
   c. Other fun symbols that we use
      i. The arrow is pronounced “yields”.
         1. The left side of the arrow is called the reactants. HCl and $CaCO_3$ are the reactants in this chemical reaction.
         2. The right side of the equation is called the products. Water, carbon dioxide, and calcium chloride are the products of this chemical reaction.
         3. If heat is required to make the reaction occur, the Greek letter delta is placed above the “yields” arrow.

$$CaCO_3\,(s) \xrightarrow{\Delta} CaO\,(s) + CO_2\,(g)$$

      ii. States of matter and aqueous solutions
         1. Solids: (s)
         2. Liquids: (l)
         3. Gases (g)
         4. Substances dissolved in water (aqueous solutions): (aq)
         5. Precipitates.
            a. A **precipitate** is a substance which, after it is formed in a

reaction, does not dissolve in the solvent (usually water).

b. The precipitate is always a product. It is signified by the letters (ppt) or simply (s). Other times the downward arrow symbol (↓) is used to show which substance is a precipitate.

iii. Reversible reactions

1. Sometimes a reaction is reversible. Reversible reactions occur in the forward and reverse directions simultaneously. A reversible reaction uses a special arrow with two heads: ↔

iv. Catalysts

1. A catalyst is a chemical which speeds up a chemical reaction without being itself consumed or produced.
2. If there is a catalyst in a reaction, the formula of the catalyst is written above the "yields" arrow. The catalyst is neither a reactant nor a product; this is why the catalyst is written on neither the left nor the right of the arrow.
3. An example of a reaction that uses a catalyst is represented below. This equation shows the catalytic decomposition of H_2O_2. We performed this reaction earlier this year when we poured the hydrogen peroxide from the brown bottle into a test tube and then added the black manganese dioxide powder (the catalyst):

$$2H_2O_2\ (aq) \xrightarrow{MnO_2} 2H_2O\ (l) + O_2\ (g)$$

v. Diatomic elements. There are several elements that occur as molecules rather than as single atoms:

1. H_2
2. N_2
3. O_2
4. F_2
5. Cl_2
6. Br_2
7. I_2

III. What are the different types of chemical reactions?

a. Combination reactions (a.k.a. synthesis reactions)
b. Decomposition reactions
c. Single replacement reactions
d. Double replacement reactions
e. Combustion reactions
   i. Always balance these equations in this order: C – H – O
f. Side note: you will learn a different way of classifying reactions when you take AP Chemistry. We will also discuss this classification scheme later in this course. Another (and better) way of classifying reactions is the following:
   i. Acid-Base Reactions
      1. One reactant is an acid and one reactant is a base. The products are usually a salt plus water. Acid-base reactions are sometimes called **neutralization** reactions.
      2. "Usually" = in aqueous solution, which is the only situation that we will consider.
      3. Later, we will study an entire chapter devoted to acid-base chemistry
   ii. Precipitation Reactions. Two solutions are mixed together and as a result an

insoluble compound is formed. This insoluble product is called the **precipitate**.

iii. Redox reactions
    1. A redox reaction ("redox" stands for oxidation-reduction reaction) is a reaction in which one reactant loses electrons and one reactant gains electrons
    2. The reactant that loses electrons is said to be oxidized. The reactant that gains electrons is said to be reduced.
    3. There must always be a transfer of electrons, which means that there is ALWAYS a substance which is oxidized and a substance that is reduced.
    4. The number of electrons gained by the reduced substance= the number of electrons lost by the oxidized substance
    5. How will you recognize a redox reaction? Answer: All reactions are redox reactions except for double replacement reactions. Later, we will study an entire chapter on redox reactions.

IV. How do I balance a chemical equation?
    a. Satisfying the law of conservation of matter is the reason why we balance equations
    b. The number of atoms on the left side of the equation must equal the number of atoms on the right side of the equation
    c. What you CAN change: the coefficients (big numbers in front of chemical formulas)
        i. The coefficients have to go in front of a chemical formula; they cannot go in the middle of a chemical formula.
    d. What you CAN'T change: the subscripts (little numbers of a chemical formula)
    e. The scoreboard method

V. What causes chemical reactions – the simple version.
    a. Formation of a gas
    b. Formation of a liquid
    c. Formation of a solid (a precipitate)

VI. Reaction prediction for chemical reactions in aqueous solution – this is not so simple.
    a. Single replacement reactions
        i. Determine if the metal or the nonmetal is being replaced.
        ii. If a replacement is going to take place,
            1. A metal will replace a metal
            2. A nonmetal will replace a nonmetal
        iii. Use the end-of-course exam reference tables to determine if the single element is MORE active or LESS active than the element in the compound that it is "trying" to replace. Let's use the example of a metal replacing a metal:
            1. If the single element is more active than the metal in the compound, then the reaction WILL take place. The metal in the reactant compound will become the single element on the products side. The single metal on the reactants side will become part of a compound on the products side of the equation.
            2. If the single element is NOT more active than the metal in the compound, then no reaction takes place.
        iv. Use similar logic if there is a nonmetal replacing a nonmetal.
    b. Double replacement reactions
        i. We are only going to consider the reaction of two compounds that are dissolved in water (reactants are both "aq")
        ii. You will either need to have memorized the solubility rules or have handy your EOC reference tables. Look for the section that lists the solubility guidelines

for common substances.

iii. Pretend that the double replacement reaction takes place.
    1. Remember; metals replace metals and nonmetals replace nonmetals

iv. Right down the putative products (write down what you think the products will/might be)

v. Do both of the products dissolve (are they both “aq”)? If so, NO REACTION takes place.
    1. Think about it: you started out with two dissolved compounds which means that you had four ions floating around independently of one another in aqueous solution. You ended up with the exact same thing afterwards.

vi. Is at least one of the products *in*soluble? If so, the reaction DOES take place.
    1. Write down the products with correct formulas
    2. Balance the equation with coefficients
    3. Write “aq” after the product that stays dissolved (therefore it’s not really a product, but more on that later in the chapter on solutions!)
    4. Write “(s)” after the product that is insoluble. This product is called the **precipitate**. Alternatively, you may write “(ppt)” or “(↓)” instead of (s) to indicate the precipitate.
    5. Tip: memorize the solubility rules. Otherwise, use the EOC reference tables to look up the solubility rules.