Chemical Reactions Notes

1. Writing Word Equations
    a. A **word equation** is one way of representing a chemical reaction: it tells you what reacts and what is produced.
    b. Word equations are written in a particular format.
        i. The left side of a word equation lists the names of all the **reactants** (the substances present at the beginning).
        ii. The right side lists the names of all the **products** (the substances present at the end).
        iii. An arrow points from the reactants to the products
    c. For example, when iron is exposed to oxygen, it rusts and the product is iron(III) oxide.
        i. The word equation for this reaction is iron + oxygen → iron(III) oxide

2. In every chemical reaction matter is conserved - mass is neither gained nor lost.
    a. The **Law of Conservation of Mass** (Remember a scientific law is a general statement that sums up the conclusions of many experiments or an observed pattern in nature.)
        i. The Law of Conservation of Mass states that, in a chemical reaction, the total mass of the reactants is always equal to the total mass of the products.
    b. Experiments have shown that atoms in a chemical reaction are not changed. The number of each kind of atom is the same before and after a reaction.
        i. In chemical reactions, the atoms of the reactants are simply rearranged. Compounds may be broken apart and new compounds may be formed, but the atoms in the products are the same atoms that were in the reactants.
        ii. For example, when methane (or natural gas) burns, carbon dioxide and water are formed.
            1. The word equation is methane + oxygen → water + carbon dioxide
            2. The reactants are two molecules of oxygen gas (O_2) and one molecule of methane (CH_4)
            3. The chemical reaction produces two molecules of water (H_2O) and one molecule of carbon dioxide (CO_2). Heat and light are also produced.
            4. Notice all the atoms present at the beginning of the chemical reaction are present after the reaction. The total mass of the atoms in the reactants remains equal to the total mass of the atoms in the products.

3. A **skeleton equation** represents a chemical reaction by showing the formula for each of the reactants connected to the formulas of the products by an arrow.
    a. Let's use our methane burning example again. The word equation was:
       methane + oxygen → carbon dioxide + water
        i. We write a skeleton equation by replacing each name with a formula:
           $CH_4 + O_2 \rightarrow CO_2 + H_2O$
    b. If you count the atoms on each side of the arrow you'll notice a problem. There are different numbers of some of the atoms on each side. This violates the Law of Conservation of Mass. We cannot change the types or formulas of the molecules. So how can we solve this imbalance?
    c. The answer is to change the numbers of molecules. If we add an oxygen molecule to the reactants and a water molecule to the products, the atoms would be **balanced**. Count the atoms on each side to be sure.
       $CH_4 + O_2 + O_2 \rightarrow CO_2 + H_2O + H_2O$

d. An equation in which the reactants and the products contain equal numbers of atoms of each type is a balanced chemical equation. All we have to do is collect similar molecules and write them using a coefficient. A coefficient is a number written in front of a chemical symbol or formula. It indicates the number of atoms or molecules of that substance. The coefficients are shown in red in the following equation.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

e. By balancing the equation, we've made the mass of the reactants equal to the mass of the products.

4. How to Balance an Equation
   a. Let's go back to our example of iron reacting with oxygen to make iron oxide (Fe_3O_4).
      i. Step 1.Write the word equation for the reaction.

         iron + oxygen →magnetic iron oxide

      ii. Step 2. Write the skeleton equation by replacing each name with a correct formula.

         $Fe + O_2 \rightarrow Fe_3O_4$

      iii. Step 3. Count the numbers of atoms of each type in reactants and products.

Type or atom	Reactants	Products
Fe	1	3
O	2	4

      iv. Step 4. Multiply each of the formulas by the appropriate coefficients to balance the numbers of atoms.
         1. To balance the three iron atoms on the right side, multiply the iron atoms on the left side by 3. To balance the four oxygen atoms on the right side, multiply the oxygen atoms on the left side by 2. Check that the atoms on each side are balanced.

            $3Fe + 2O_2 \rightarrow Fe_3O_4$

5. There are different categories of chemical reactions. Most chemical reactions can be grouped into four categories: combustion, synthesis, decomposition, single displacement, double displacement.
   a. **Combustion** is the very rapid reaction of a substance with oxygen to produce compounds called oxides. We often call this process burning.
      i. Combustion reactions have the following general formula:

         fuel + oxygen →oxides + energy

      ii. The energy produced is mainly in the form of heat and light. The fuel can be a variety of elements and compounds.
         1. When butane is allowed to escape the lighter through a valve and a spark ignites it, the following reaction occurs: butane + oxygen →carbon dioxide + water + energy

            $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

      iii. Hydrocarbons sometimes undergo **incomplete combustion**. This occurs when there is not enough oxygen available. The products carbon monoxide (CO) and carbon (C) are produced in addition to carbon dioxide. Carbon monoxide is an odourless, colourless gas that is extremely poisonous. It combines with hemoglobin in the blood to starve the body of oxygen and cause death.

b. **Synthesis** reactions involve the combination of smaller atoms and/or molecules into larger molecules. These reactions are also called combination reactions. Often the reactants are elements that combine chemically to form compounds.

c. Synthesis reactions have the following general formula:

$$A + B \rightarrow AB$$

   i. If you see two things as reactants and one thing as a product, you know the reaction has to be a synthesis reaction.
   ii. For example, when hydrogen and oxygen gases react, the product is water. This reaction can be represented by the equation:

$$2H_2 + O_2 \rightarrow 2H_2O$$

d. **Decomposition** reactions involve the splitting of a large molecule into elements or smaller molecules.
   i. Decomposition reactions have the following general formula:

$$AB \rightarrow A + B$$

   ii. If you see one reactant and more than one product, you know the reaction has to be a decomposition.
   iii. Think of synthesis reactions as putting things together and decomposition reactions as taking things apart.

e. In **single displacement** reactions one element replaces (or displaces) another element from a compound.
   i. Single displacement reactions have the following general formula:

$$Z + AB \rightarrow ZB + A \text{ or } Y + AB \rightarrow AY + B$$

   ii. In the first case, the metal Z has taken the place of element A. In the second case, the nonmetal Y has taken the place of element B.
   iii. How do we decide which element is displaced? In deciding which element is replaced, remember that a metal replaces a metal and a nonmetal replaces a nonmetal.
   iv. For example, consider the reaction that occurs when magnesium is placed in a solution of silver nitrate.

magnesium + silver nitrate →silver + magnesium nitrate

$$Mg + 2AgNO_3 \rightarrow 2Ag + Mg(NO_3)_2$$

   v. Notice that magnesium replaced silver in the compound with nitrate.
   vi. In our example, silver and magnesium are both metals so magnesium displaces the silver and forms a compound of magnesium nitrate.

f. **Double displacement** reactions occur when elements in different compounds exchange places (or displace each other).
   i. Double displacement reactions have the following general formula:

$$AB + XY \rightarrow AY + XB$$

   ii. For example, the reaction of solutions of lead(II) nitrate and potassium iodide can be represented by:
   lead(II) nitrate + potassium iodide →lead(II) iodide + potassium nitrate
   $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$
   iii. The lead and potassium ions switched places.