Chapter 6

Goals:

- ✓ Be able to write a proper balanced chemical equation.
- ✓ Be able to classify reactions as synthesis, decomposition, double displacement, single displacement or combustion.
- ✓ Be able to predict products for double displacement and combustion reactions.
- ✓ Be able to use the solubility chart to determine the precipitate in a double displacement by precipitation reaction.
- ✓ Know Avogadro's number for the mole, and be able to find a mole ratio from a balanced equation.
- ✓ Be able to find the molar mass for any element or compound by using the periodic table.
- ✓ Be able to use molar mass as a conversion factor between grams of a substance and moles of that substance.
- ✓ Be able to use a mole ratio to relate quantities of different substances in an equation (stoichiometry).

Writing Chemical Equations

The law of conservation of mass is based on the concept that atoms are not created or destroyed, but just rearranged in a chemical reaction. It is because of this law that we balance chemical equations so that the number of atoms of each element on the reactant side is equal to that on the product side.

Example: Propane gas reacts with oxygen gas to form carbon dioxide gas and water vapor.

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (g)$$

- Reactants: Propane and oxygen
- Products: Carbon dioxide and water
- Coefficients: 1, 5, 3, 4
- Subscripts: 3, 8, 2, 2, 2

Abbreviations used in reaction:
- +: written between multiple reactants or products
- Δ: written above the arrow to indicate heat added to a reaction
- (s): indicates a substance in the solid state
- (l): indicates a substance in the liquid state
- (g): indicates a substance in the gaseous state
- (aq): indicates a substance dissolved in water

Try Writing Balanced Equations

1. Solid aluminum reacts with hydrochloric acid to form aqueous aluminum chloride and hydrogen gas.
   a. Write the equation: Al (s) + HCl (aq) → $AlCl_3$ (aq) + H_2 (g)
   b. Tally up the number of each atom on the reactant and product side of the quation
   c. Change the coefficients to balance the reactant side with the product side
      i. Do not start with an element that is already balanced
      ii. Do not start with the most difficult element
      iii. When a polyatomic ion appears in the reactant and product, keep that polyatomic ion together and balance it as you would an individual element

2. Solid mercury (II) oxide decomposes upon heating to form liquid mercury and oxygen gas.

3. Sulfuric acid and aqueous sodium hydroxide react to form aqueous sodium sulfate and water.

4. Methane (CH_4) gas reacts with oxygen gas to form carbon dioxide gas and water vapor.

Types of Chemical Reactions

1) Combination (Synthesis) Reaction: Reactants combine to give one product.

$$A + B \rightarrow AB$$

Examples:

$4Fe\ (s) + 3O_2\ (g) \rightarrow 2Fe_2O_3\ (s)$

$2Al\ (s) + 3Br_2\ (l) \rightarrow 2AlBr_3\ (s)$

2) Decomposition Reaction: The reactant is broken down into two or more smaller substances.

$$AB \rightarrow A + B$$

Examples:

$2NaN_3\ (s) \rightarrow 2Na\ (s) + 3N_2\ (g)$

$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$

3) Single-Displacement (Replacement) Reaction: One element replaces another element in a compound so long as the element being replaced is less reactive. Note that one element is oxidized while another is reduced.

$$A + BC \rightarrow AC + B$$

Examples:

$Br_2\ (l) + 2KI\ (aq) \rightarrow I_2\ (s) + 2KBr\ (aq)$; Br is more reactive than I; I is oxidized while Br is reduced

$I_2\ (s) + KBr\ (aq) \rightarrow$ NO REACTION!!!; I is NOT more reactive than Br

4) Double-Displacement (Replacement) Reaction: The cations and anions of two compounds are exchanged to produce two different compounds. Reaction will only occur if a product that is insoluble or molecular is produced.

$$AB + CD \rightarrow AD + CB$$

Examples:

$2AgNO_3(aq) + BaCl_2\ (aq) \rightarrow 2AgCl\ (s) + Ba(NO_3)_2\ (aq)$

$CaCl_2\ (aq) + KNO_3\ (aq) \rightarrow$ NO REACTION!!!

TABLE 6.1 General Solubility Guidelines for Ionic Compounds in Water

SOLUBLE	EXCEPTIONS
Ammonium compounds (NH_4^+)	None
Lithium compounds (Li^+)	None
Sodium compounds (Na^+)	None
Potassium compounds (K^+)	None
Nitrates (NO_3^-)	None
Perchlorates (ClO_4^-)	None
Acetates ($CH_3CO_2^-$)	None
Chlorides (Cl^-)	
Bromides (Br^-)	Ag^+, Hg_2^{2+}, and Pb^{2+} compounds
Iodides (I^-)	
Sulfates (SO_4^{2-})	Ba^{2+}, Hg_2^{2+}, and Pb^{2+} compounds

Types of Chemical Reactions Continued

5) **Combustion Reaction:** The reaction of a compound with molecular oxygen to form products in which all elements are combined with oxygen.

Example:
C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (g)

Neutralization (a special type of DD reaction): The products are a salt and water.
HA(aq) + BOH(aq) → BA (aq or s) + H_2O (l)

Examples:
HCl(aq) + NaOH(aq) → NaCl (aq) + H_2O (l)
H_2SO_4 (aq) + $Al(OH)_3$ (aq) → $Al_2(SO_4)_3$ (aq) + H_2O (l)

NOTE: You should be able to **predict products** for double displacement (precipitation and neutralization) and combustion reactions for this class.

Problems:

1) Aqueous calcium hydroxide reacts with hydrochloric acid.

2) Aqueous sodium sulfate reacts with aqueous barium chloride.

3) Ethane gas (C_2H_6) combusts.

Stoichiometry

Stoichiometry: The branch of chemistry that deals with the quantitative relationship between reactants and products.

Information from chemical equations:

- Tells what is being reacted and formed.
- Tells the ratio of products formed from the reactants. (MOLE RATIO)

Mole ratio: a ratio between the number of moles of any two substances in a chemical reaction.

Atoms and molecules are incredibly small and impossible to count. We use moles to compare the quantity of reactants to products. One mole is equal to 6.022×10^{23} objects just like one dozen is equal to 12 objects. The number for the mole is known as **Avogadro's number**.

One mole of any substance is the same numerical value as the molecular mass or formula mass given in the periodic table, but it is expressed in grams rather than amus. The mass of one mole of a substance is known as the **molar mass**.

Examples:

The atomic mass of Cu is 63.55 amu. This is the mass of one Cu atom.

The molar mass of Cu is 63.55 g/mol. This is the mass of one mole of Cu atoms. More specifically, this is the mass of 6.022×10^{23} Cu atoms.

The formula mass of CuCl is 63.55 amu + 35.45 amu for a total or 99.00 amu. This is the mass of one formula unit of CuCl.

The molar mass of CuCl is 99.00 g/mol. This is the mass of one mole of CuCl formula units.

Molar Mass

Problem:

1) Calculate the molar mass of water:

Molar mass can be used as a conversion factor to convert between grams and moles of any one substance.

Problems:

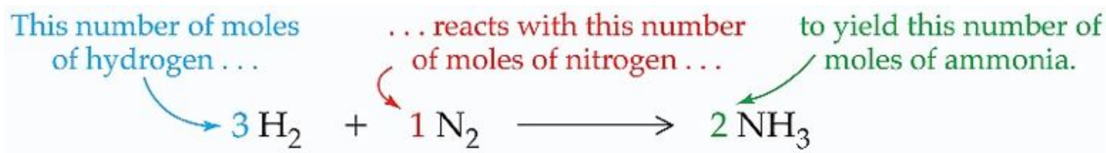
1) A reaction calls for 0.25 moles of water. How many grams of water should be added to the reaction?

2) A reaction uses 27.0 grams of water. How many moles of water does this reaction require?

Mole Ratio

Molar mass only allows us to convert between grams and moles of the *same* substance. How do we relate two *different* substances in an equation? The answer is the **mole ratio**.

The mole ratio can be obtained from a balanced chemical equation. It tells us quantitatively how any two substances in that reaction relate to one another in terms of moles.



Using the above equation, you can see that nitrogen and hydrogen react in a 1:3 ratio. That is, one mole of nitrogen reacts with three moles of hydrogen. This mole ratio can be written as:

$$\frac{3 \text{ mol } H_2}{1 \text{ mol } N_2} \quad \text{OR} \quad \frac{1 \text{ mol } N_2}{3 \text{ mol } H_2}$$

Problems:

1) Find the mole ratio for hydrogen and ammonia.

2) Find the mole ratio for nitrogen and ammonia.

Using the Mole Ratio

The mole ratio can be used as a conversion factor to determine how much of another reactant is needed or how much of a certain product is formed.

Problem:

1) Using the reaction from the last page, determine how many moles of hydrogen are needed to fully react with 2.55 moles of nitrogen.

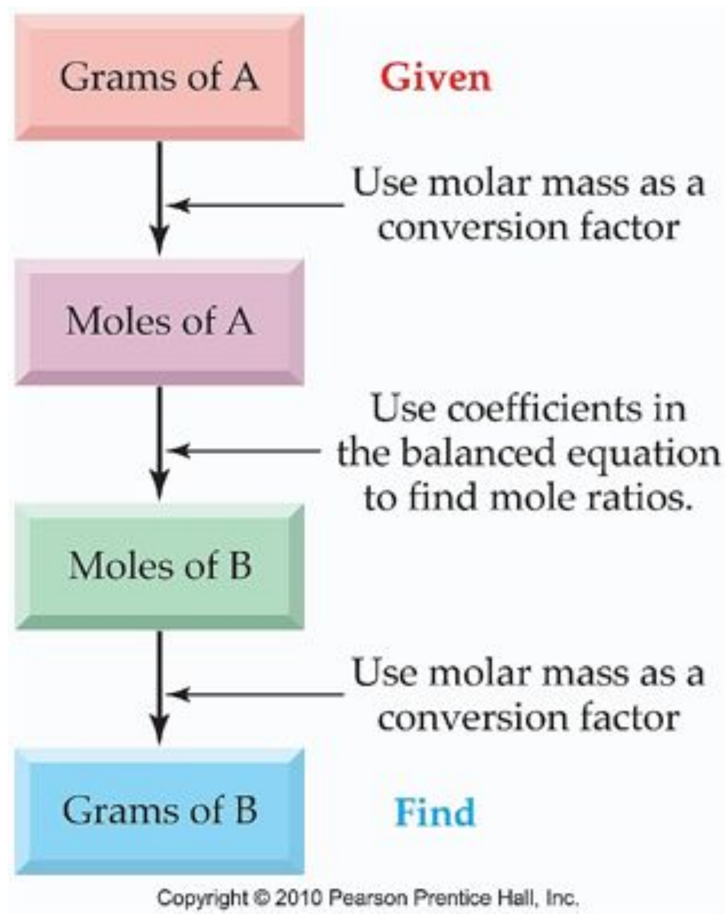
Since we typically measure substances in grams in the lab, it is still necessary to be able to calculate the number of grams formed rather than the number of moles. Remember that you can convert between grams and moles of a substance by using the molar mass.

Problems:

1) Calculate the number of **grams** of hydrogen needed to fully react with 2.55 **moles** of nitrogen.

2) Calculate the number of **grams** of ammonia formed when 3.88 **grams** of hydrogen reacts with excess nitrogen.

Overview of Stoichiometry Calculations



Chapter 6 Problems

1. You need to add 0.433 moles of calcium nitrate to a reaction. How many grams of this solid compound should be added to the reaction?

2. If one aspirin pill contains 250 mg of aspirin ($C_9H_8O_4$), how many moles of aspirin does one aspirin pill contain? Assume 250 mg has 3 sig figs.

3. Hematite (Fe_2O_3) can be used to obtain iron metal. To isolate the free metal, hematite is reacted with carbon monoxide gas in a furnace. The reaction is shown below:

$$Fe_2O_3\ (s) + 3CO\ (g) \rightarrow 2Fe\ (s) + 3CO_2\ (g)$$

   a. find the molar mass of hematite and iron

   b. find the mole ratio of hematite to iron

   c. calculate the number of grams of iron metal that can be produced when 1.00 kg of hematite is reacted with excess carbon monoxide