Name ____________________ **Honors Chemistry** **___/___/___**

Limiting Reagent, Excess Reagent and Percent Yield

Limiting Reagent Problems

In a limiting reagent problem you will be given amounts of **two of your reagents**. The goal is to determine which you will run out of first. The one you run out of first is your **limiting reagent**. The other reagent, the one you will have extra of when finished, is your **excess reagent**.

- One way to **determine the limiting reagent** is to solve the stoichiometry problem **twice** using each reagent and its value to solve for the same product in moles.

  Example: (This reaction is the same for all examples shown.)

  Nitrogen gas reacts with hydrogen gas to form gaseous ammonia, NH_3. If you are given 45.5 liters of hydrogen and 23.1 grams of nitrogen, what is the limiting reagent?

  $$N_2 + 3H_2 \rightarrow 2NH_3$$

  $$\frac{45.5 \text{ L } H_2}{1} \times \frac{1 \text{ mole } H_2}{22.4 \text{ L } H_2} \times \frac{2 \text{ moles } NH_3}{3 \text{ mole } H_2} = 1.35 \text{ mol } NH_3$$

  $$\frac{23.1 \text{ g } N_2}{1} \times \frac{1 \text{ mole } N_2}{28.0 \text{ g } N_2} \times \frac{2 \text{ moles } NH_3}{1 \text{ mole } N_2} = 1.65 \text{ mol } NH_3$$

  Since $\mathbf{H_2}$ produced less NH_3 it is the **limiting reagent**. $\mathbf{N_2}$ produced more NH_3 than possible so it is the **excess reagent**.

- Another way to **determine the limiting reagent** is to solve the stoichiometry problem **once** using one reactant and solving for the other substance. You then make a comparison between the amount needed and the amount available of the other substance.

  Example: (Same data and reaction as above.)

  $$\frac{45.5 \text{ L } H_2}{1} \times \frac{1 \text{ mole } H_2}{22.4 \text{ L } H_2} \times \frac{1 \text{ moles } N_2}{3 \text{ mole } H_2} \times \frac{28.0 \text{ g } N_2}{1 \text{ mole } N_2} = 19.0 \text{ g } N_2$$

  If you were to use up all of your H_2 you would only need 19.0 grams of N_2. Since you have more than that N_2 is the excess reagent and H_2 is your limiting reagent.

- Another calculation you will be asked to make is the **amount of excess that remains**. In this type of problem you will have to use your limiting reagent and solve for your excess reagent to determine the amount of the excess needed. Once you know how much of your excess reagent is needed you can subtract from the amount of excess reagent given to determine the amount of excess that remains.

  Example: (Same data and reaction as above.)

  $$\frac{45.5 \text{ L } H_2}{1} \times \frac{1 \text{ mole } H_2}{22.4 \text{ L } H_2} \times \frac{1 \text{ moles } N_2}{3 \text{ mole } H_2} \times \frac{28.0 \text{ g } N_2}{1 \text{ mole } N_2} = 19.0 \text{ g } N_2$$

  23.1 g N_2 (given) – 19.0 g N_2 (needed) = 4.1 g N_2 in excess

- Another calculation you will be required to make is **percent yield**. Percent yield is used to determine the efficiency of a chemical procedure. When you perform a percent yield calculation you will be comparing how much product you **actually** produce in a lab situation with how much should theoretically be produced if the situation was ideal. The **theoretical yield** is what you determine in a **stoichiometry problem**. The percent yield equation is listed below.

  $$\text{Percent Yield} = \frac{\text{Experimental Yield}}{\text{Theoretical Yield}} \times 100$$

  Example: (Same data and reaction as above.)

  Additional information: If 18.4 grams of NH_3 are actually produced, what is your percent yield?

  - **Use your limiting reagent to solve for the substance you are measuring, in this case, mass of NH_3.**

  $$\frac{45.5 \text{ L } H_2}{1} \times \frac{1 \text{ mole } H_2}{22.4 \text{ L } H_2} \times \frac{2 \text{ moles } NH_3}{3 \text{ mole } H_2} \times \frac{17.0 \text{ g } NH_3}{1 \text{ mole } NH_3} = 23.0 \text{ g } NH_3$$ **←This is your theoretical yield.**

  - Use the percent yield formula to solve the problem.

  $$\textbf{Percent Yield} = \frac{18.4\text{g}}{23.0\text{g}} \times 100$$

  Percent Yield = 80.0%

Homework:

1. $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Iron reacts with oxygen to produce iron(III) oxide, as represented by the equation above. A 75.0 g sample of Fe(*s*) is mixed with 11.5 L of $O_2(g)$ at STP.
(a) Identify the limiting reactant when the mixture is heated to produce $Fe_2O_3(s)$. Support your answer with calculations.
(b) Determine the amount of excess that remains.
(c) Calculate the mass of $Fe_2O_3(s)$ produced when the reaction proceeds to completion.
(d) If 42.3 grams of Fe_2O_3 are actually produced, what is the percent yield?

2. $N_2 + 3H_2 \rightarrow 2NH_3$

Nitrogen gas reacts with hydrogen gas to form ammonia, NH_3, gas. 50.0 liters of hydrogen gas and 18.0 liters of nitrogen gas react.
(a) Identify the limiting reactant when the mixture is heated to produce $NH_3(g)$. Support your answer with calculations.
(b) How many liters of excess reagent remain?
(c) Calculate the volume of NH_3 produced.
(d) Calculate the percent yield if 20.0 liters of NH_3 is actually produced?

3. $2Cu + S \rightarrow Cu_2S$

Solid copper reacts with solid sulfur to form solid cuprous sulfide. 80.0 grams of copper and 25.0 grams of sulfur are reacted.
(a) Identify the limiting reactant when the mixture is heated to produce Cu_2S. Support your answer with calculations.
(b) How many grams of excess reagent remain?
(c) Calculate the mass of Cu_2S produced.
(d) Calculate the percent yield if 87.3 grams of Cu_2S is actually produced?

4. $2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$

Solid aluminum reacts with aqueous copper(II) sulfate in a single displacement reaction. 1.87 grams of aluminum reacts with 2.50 grams of $CuSO_4$.
(a) Identify the limiting reactant when the mixture is heated to produce Cu. Support your answer with calculations.
(b) How many grams of excess reagent remain?
(c) Calculate the mass of Cu produced.
(d) Calculate the percent yield if 0.65 grams of Cu actually produced?

5. $2CH_3OH + O_2 \rightarrow 2H_2CO + 2H_2O$

Methanol, CH_3OH, reacts with oxygen to produce formaldehyde, H_2CO and water according to the following equation:
The above reaction is carried out in a laboratory and 270.0 grams of methanol and 48.6 liters of oxygen at STP.
(a) Identify the limiting reactant. Support your answer with calculations.
(b) How much of the excess reagent remains?
(c) Calculate the mass of H_2CO produced.
(d) If 82.34 grams of formaldehyde are actually produced, what is the percent yield?

6. $C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$

Nitrobenzene is used in the production of perfumes. Nitrobenzene, $C_6H_5NO_2$, along with water, is produced by reacting benzene, C_6H_6, with nitric acid, HNO_3. 109.5 grams of C_6H_6 and 102.2 grams of HNO_3 react.
(a) Identify the limiting reactant. Support your answer with calculations.
(b) How much of the excess reagent remains?
(c) Calculate the mass of Nitrobenzene, $C_6H_5NO_2$ produced.
(d) If 159.7 grams of $C_6H_5NO_2$ are actually produced, what is the percent yield?

7. $2Al + 3CrO \rightarrow Al_2O_3 + 3Cr$

Aluminum oxide is produced in a single replacement reaction between aluminum and chromium(II) oxide. 225.0 grams of chromium(II) oxide reacted with 125.0 grams of aluminum.
(a) Identify the limiting reactant. Support your answer with calculations.
(b) How much of the excess reagent remains?
(c) Calculate the mass of aluminum oxide produced.
(d) If 100.0 grams of aluminum oxide are actually produced, what is the percent yield?

5. Solid silicon dioxide, SiO_2, reacts with solid carbon, C, to produce solid silicon carbide, SiC, and carbon monoxide gas, CO. If 50.0 grams of silicon dioxide **actually** produce 32.2 grams of silicon carbide, what is the percent yield?

$SiO_2 + 3C \rightarrow SiC + 2CO$

4. Solid nitroglycerine, $C_3H_5N_3O_9$, decomposes to form nitrogen gas, carbon dioxide gas, liquid water and oxygen gas:

$4C_3H_5N_3O_9 \rightarrow 6N_2 + 12CO_2 + 10H_2O + O_2$

a. If 49.0 grams of $C_3H_5N_3O_9$ are used, how many grams of water will be produced?

b. If only 6.9 grams of water are actually captured, what is the percent yield?

3. Solid magnesium reacts with aqueous hydrogen chloride to produce aqueous magnesium chloride and hydrogen gas. If Shannon is given 6.00 grams of hydrogen chloride and 5.00 grams of magnesium, what is her limiting reagent? What is her excess reagent? What is the greatest amount of hydrogen gas (in liters) she can produce at STP? What amount of excess reagent remains?

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

4. Solid sodium reacts with chlorine gas to form solid sodium chloride. If Lily is given 6.10 grams of sodium and 3.00 liters of chlorine gas, what is her limiting reagent? What is her excess reagent? How many grams of sodium chloride can be produced? What amount of excess reagent remains?

$2Na + Cl_2 \rightarrow 2NaCl$

5. Liquid hydrazine, N_2H_4, reacts with oxygen gas to produce nitrogen gas and water vapor. How many liters of nitrogen gas form when Julie reacts 1.000 **kg** of hydrazine with 700.0 liters of oxygen gas at STP? What amount of excess reagent remains?

$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$

6. Hydrogen sulfide gas reacts with aqueous sodium hydroxide to produce aqueous sodium sulfide and water. If Sarah is given 2.5 liters of hydrogen sulfide and 1.85 grams of sodium hydroxide, how many grams of sodium sulfide can she produce at STP? What amount of excess reagent remains?

$H_2S + 2NaOH \rightarrow Na_2S + 2H_2O$

7. Solid iron reacts with oxygen gas to form solid ferrous oxide. Determine the mass of ferrous oxide produced if Anne Marie is given 30.0 grams of iron and 6.25 liters of oxygen at STP. What amount of excess reagent remains?

$2Fe + O_2 \rightarrow 2FeO$

8. Determine the volume of water vapor and carbon dioxide gas produced if Katie is given 33.0 liters of oxygen gas and 21.0 liters of propane gas, C_3H_8 at STP. What amount of excess reagent remains?

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

9. Concentrated sulfuric acid solution reacts with calcium carbonate producing water, carbon dioxide and aqueous calcium sulfate. If 45.0 mL of sulfuric acid is poured on 18.0 grams of solid calcium carbonate, what volume of carbon dioxide would be produced at STP? What amount of excess reagent remains? The density of sulfuric acid is 1.84 g/mL.

$H_2SO_4 + CaCO_3 \rightarrow H_2O + CO_2 + CaSO_4$