Stoichiometry

Name ____ **Period** _______

Unit 6 – Worksheet 1 (Goal 1 - 2)

1. For each of the following reactions, solve the problem:

   a. How many moles of $KClO_3$ are needed to produce 0.366 moles of O_2?

   $$2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$$

   $$0.366\ mol\ O_2\left(\frac{2\ mol\ KClO_3}{3\ mol\ O_2}\right) = 0.244\ mol\ KClO_3$$

   b. How many moles of H_2O are produced from 9.45 moles of NH_4NO_3?

   $$NH_4NO_3 \rightarrow N_2O + 2\ H_2O$$

   $$9.45\ mol\ NH_4NO_3\left(\frac{2\ mol\ H_2O}{1\ mol\ NH_4NO_3}\right) = 18.9\ mol\ H_2O$$

2. Aluminum sulfate, $Al_2(SO_4)_3$ is used in fireproofing fabrics and the manufacture of antiperspirants.

   $$Al_2O_3(s) + 3\ H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3\ H_2O(l)$$

   a. How many moles of $Al_2(SO_4)_3$ would be produced if 6 mol of H_2SO_4 reacted with excess Al_2O_3?

   $$6\text{ mol }H_2SO_4\left(\frac{1\ mol\ Al_2(SO_4)_3}{3\ mol\ H_2SO_4}\right) = 2\ mol\ Al_2(SO_4)_3$$

   b. How many moles of Al_2O_3 are required to make 2 mol of H_2O?

   $$2\text{ mol }H_2O\left(\frac{1\ mol\ Al_2O_3}{3\ mol\ H_2O}\right) = 0.7\ mol\ Al_2O_3$$

3. Copper (II) nitrate, $Cu(NO_3)_2$, is used to give a dark finish to items made o f copper metal, making them appear antique. Using the balanced equation, complete the following table:

$$3\ Cu(s) + 8\ HNO_3(aq) \rightarrow 3\ Cu(NO_3)_2(aq) + 4\ H_2O(l) + 2\ NO(g)$$

Equation	Cu	HNO_3	$Cu(NO_3)_2$	H_2O	NO
# of moles	3	8	3	4	2
Molar Mass	63.6 g/mol	63.0 g/mol	187.6 g/mol	18.0 g/mol	30.0 g/mol
Total Mass	3 x molar mass 191 g	8 x molar mass 504 g	3 x molar mass 563 g	4 x molar mass 72 g	2 x molar mass 60 g
State of Matter	Solid	Aqueous	Aqueous	Liquid	Gas

What is the total mass of the reactants?695 g

What is the total mass of the products? 695 g

What law does the comparison of the mass of the reactants and products follow?

Conservation of Mass

Make sure each equation is BALANCED before working on the Stoichiometry problem!

1. "Baking Powder" consists of a mixture of "Baking Soda" (sodium bicarbonate, NaHCO3) and some solid acid so that the moistened mixture will react to form CO_2 gas. When sodium dihydrogen phosphate, NaH_2PO_4, is used in this reaction, the following reaction occurs,

$$NaHCO_3 + NaH_2PO_4 \rightarrow Na_2HPO_4 + H_2O + CO_2$$

What mass of sodium dihydrogen phosphate (NaH_2PO_4) must be used to completely react with 0.65 mole of "baking soda."

$$0.65\ mol\ NaHCO_3 \left(\frac{1\ mol\ NaH_2PO_4}{1\ mol\ NaHCO_3}\right)\left(\frac{120.0\ g\ NaH_2PO_4}{1\ mol\ NaH_2PO_4}\right) = 78\ g\ NaH_2PO_4$$

2. Calcium cyanide powder is used by beekeepers to destroy a colony of diseased bees. This powder must be stored in a closed container, since moist air decomposes it, according to the equation:

$$Ca(CN)_2 + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ HCN$$

Determine the number of moles of water needed to liberate 94.5g of HCN gas.

$$94.5\ g\ HCN \left(\frac{1\ mol\ HCN}{27.0\ g\ HCN}\right)\left(\frac{2\ mol\ H_2O}{2\ mol\ HCN}\right) = 3.50\ mol\ H_2O$$

3. Stannous flouride is a common toothpaste additive as a source of flourideion for retarding tooth decay. It may be manufactured from tin and dry hydrogen flouride gas:

$$Sn + 2\ HF \rightarrow SnF_2 + H_2$$

If 31.4g of SnF_2 are to be produced what mass of hydrogen gas will be liberated?

$$31.4\ g\ SnF_2 \left(\frac{1\ mol\ SnF_2}{156.7\ g\ SnF_2}\right)\left(\frac{1\ mol\ H_2}{1\ mol\ SnF_2}\right)\left(\frac{2.0\ g\ H_2}{1\ mol\ H_2}\right) = 0.401\ g\ H_2$$

4. "Fools gold" is pyrite ore, and it contains beautiful crystals of FeS_2. This is also a source of iron metal, and so is somewhat valuable although it isn't gold. How many grams of this ore must be used to obtain 255 kg of pure iron?

$$4\ FeS_2 \rightarrow 4\ Fe + S_8$$

$$255\ kg\ Fe \left(\frac{1{,}000\ g\ Fe}{1\ kg\ Fe}\right)\left(\frac{1\ mol\ Fe}{55.9\ g\ Fe}\right)\left(\frac{4\ mol\ FeS_2}{4\ mol\ Fe}\right)\left(\frac{120.0\ g\ FeS_2}{1\ mol\ FeS_2}\right) = 5.48\ x\ 10^5\ g\ FeS_2$$

5. How many moles of oxygen are required to produce 242 grams of MgO, magnesium oxide?

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

$$242\ g\ MgO \left(\frac{1\ mol\ MgO}{40.3\ g\ MgO}\right)\left(\frac{1\ mol\ O_2}{2\ mol\ MgO}\right) = 3.00\ mol\ O_2$$

6. Welders use the reaction of Acetylene (C_2H_2) and Oxygen (O_2) to provide energy for their welds. The equation for the reaction is:

$$2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$$

What volume of Oxygen (O_2) will be required to burn 52 grams of Acetylene (C_2H_2)?

$$52\ g\ C_2H_2 \left(\frac{1\ mol\ C_2H_2}{26.0\ g\ C_2H_2}\right)\left(\frac{5\ mol\ O_2}{2\ mol\ C_2H_2}\right)\left(\frac{22.4\ L\ O_2}{1\ mol\ O_2}\right) = 110\ L\ O_2$$

7. Silicon Carbide is one of the hardest substances known to man. It is used extensively in sharpening stones and other tools. Silicon Carbide (SiC) is made by the following reaction.

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

What mass of carbon C is required to produce 5.0 grams of Silicon Carbide?

$$5.0\ g\ SiC \left(\frac{1\ mol\ SiC}{40.1\ g\ SiC}\right)\left(\frac{3\ mol\ C}{1\ mol\ SiC}\right)\left(\frac{12.0\ g\ C}{1\ mol\ C}\right) = 4.5\ g\ C$$

8. The odorous compound Dimethyl Mercapitan (C_2H_6S) is burned to Sulfur Dioxide (SO_2).

$$2\ C_2H_6S + 9\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O + 2\ SO_2$$

What volume of Sulfur Dioxide (SO_2) is produced by each 1.000 kg of Dimethyl Mercapitan (C_2H_6S) burned?

$$1.000\ kg\ C_2H_6S \left(\frac{1{,}000\ g\ C_2H_6S}{1\ kg\ C_2H_6S}\right)\left(\frac{1\ mol\ C_2H_6S}{62.1\ g\ C_2H_6S}\right)\left(\frac{2\ mol\ SO_2}{2\ mol\ C_2H_6S}\right)\left(\frac{22.4\ L\ SO_2}{1\ mol\ SO_2}\right) = 360.7\ L\ SO_2$$

9. An astronaut on the moon missions consumes 1.000 kg units of carbohydrates ($C_6H_{12}O_6$) per day. These react in his body as follows:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

How many grams of Oxygen are required to sustain the astronaut each day?

$$1.000\ kg\ C_6H_{12}O_6\left(\frac{1{,}000g\ C_6H_{12}O_6}{1\ kg\ C_6H_{12}O_6}\right)\left(\frac{1\ mol\ C_6H_{12}O_6}{180.2\ g\ C_6H_{12}O_6}\right)\left(\frac{6\ mol\ O_2}{1\ mol\ C_6H_{12}O_6}\right)\left(\frac{32.0\ g\ O_2}{1\ mol\ O_2}\right) = 1{,}067\ g\ O_2$$

Use the following equation solve the next three stoichiometry problems:

$$Li_3N\ +\ 3\ H_2O\ \rightarrow\ NH_3\ +\ 3\ LiOH$$

10. What mass of water is needed to react with 7.30×10^{24} formula units of Li_3N?

$$7.30\ x\ 10^{24}\ Li_3N\ formula\ units\left(\frac{1\ mol\ Li_3N}{6.02\ x\ 10^{23} Li_3N\ formula\ units}\right)\left(\frac{3\ mol\ H_2O}{1\ mol\ Li_3N}\right)\left(\frac{18.0\ g\ H_2O}{1\ mol\ H_2O}\right) = 655\ g\ H_2O$$

11. When 13.3 ml of NH_3 are produced how many formula units of LiOH are also produced?

$$13.3\ ml\ NH_3\left(\frac{1\ L\ NH_3}{1000\ ml\ NH_3}\right)\left(\frac{1\ mol\ NH_3}{22.4\ L\ NH_3}\right)\left(\frac{3\ mol\ LiOH}{1\ mol\ NH_3}\right)\left(\frac{6.02\ x\ 10^{23}\ LiOH\ formula\ units}{1\ mol\ LiOH}\right)$$
$$= 1.07\ x\ 10^{21}\ LiOH\ formula\ units$$

12. When 4.0×10^{12} molecules of water are used, how many grams of NH_3 are produced?

$$4.0\ x\ 10^{12}\ H_2O\ molecules\left(\frac{1\ mol\ H_2O}{6.02\ x\ 10^{23}\ H_2O\ molecules}\right)\left(\frac{1\ mol\ NH_3}{3\ mol\ H_2O}\right)\left(\frac{17.0\ g\ NH_3}{1\ mol\ NH_3}\right) = 3.8\ x\ 10^{-11}\ g\ NH_3$$

Limiting Reagent and Percent Yield

Name ______________________________ **Period** _______

Unit 6 – Worksheet 2 (Goals 3 – 6)

1. What is a Limiting Reagent?

   The limiting reagent (or reactant) is the reactant that is consumed first in a chemical reaction. This reactant limits how much product can be formed.

2. What is an Excess Reagent?

   The excess reagent (or reactant) is the reactant that remains after all of the limiting reagent has reacted.

3. When solving for an amount of a product formed by stoichiometry, which reagent should be used?

   The limiting reagent must be used to perform stoichiometry because the limiting reagent limits how much product can be produced.

4. Actual Yield –

   The actual yield is the amount of product produced and collected experimentally in a chemical reaction.

5. Theoretical Yield –

   The theoretical yield is the maximum amount of product predicted by stoichiometric calculations.

6. Percent Yield –

   The percent yield calculated using the following relationship: [(actual yield)/(theoretical yield)]x100%

Identify and use the limiting reagent in a reaction to calculate the maximum amount of product(s) produced and the amount of excess reagent.

7. Aluminum (Al) reacts with bromine (Br_2) in a combination reaction to form Aluminum bromide ($AlBr_3$).

   a. Write the balanced equation for this reaction.

   $2\ Al + 3\ Br_2 \rightarrow 2\ AlBr_3$

   b. Identify the limiting reagent and calculate how many grams of product can be made from 2.2 x 10^{24} atoms of aluminum reacting with 500 grams of bromine?

   $$2.2\ x\ 10^{24}\ atoms\ Al\left(\frac{1\ mol\ Al}{6.02\ x\ 10^{23}\ atoms\ Al}\right)\left(\frac{3\ mol\ Br_2}{2\ mol\ Al}\right)\left(\frac{159.8\ g\ Br_2}{1\ mol\ Br_2}\right) = 876\ g\ Br_2$$

   876 g Br_2 is GREATER than the actual 500 g of Br_2, so Br_2 is the LIMITING REAGENT

   $$500\ g\ \mathrm{Br_2}\left(\frac{1\ \mathrm{mol\ Br_2}}{159.8\ \mathrm{g\ Br_2}}\right)\left(\frac{2\ \mathrm{mol\ AlBr_3}}{3\ \mathrm{mol\ Br_2}}\right)\left(\frac{266.68\ \mathrm{g\ AlBr_3}}{1\ \mathrm{mol\ AlBr_3}}\right) = 556\ g\ \mathrm{AlBr_3} \sim 600\ \mathrm{g\ AlBr_3}$$

8. C_3H_7O completely combusts. (remember: H_2O and CO_2?)

   a. Write the balanced equation for this reaction.

   $4\ C_3H_7O + 17\ O_2 \rightarrow 12\ CO_2 + 14\ H_2O$

   b. If 87 Liters of oxygen reacts with 87 grams of C_3H_7O find the limiting reagent. Then calculate the volume of carbon dioxide that can be produced (assume STP)?

   $$87\ L\ O_2\left(\frac{1\ mol\ O_2}{22.4\ L\ O_2}\right)\left(\frac{4\ mol\ C_3H_7O}{17\ mol\ O_2}\right)\left(\frac{59.10\ g\ C_3H_7O}{1\ mol\ C_3H_7O}\right) = 54\ g\ C_3H_7O < 87\ g\ C_3H_7O;\ O_2\ LIMITING$$

   $$87\ L\ O_2\left(\frac{1\ mol\ O_2}{22.4\ L\ O_2}\right)\left(\frac{12\ mol\ CO_2}{17\ mol\ O_2}\right)\left(\frac{22.4\ L\ CO_2}{1\ mol\ CO_2}\right) = 61\ L\ CO_2$$

   c. How many <u>moles</u> of excess reagent are left over, unused?

   $$87\ L\ O_2\left(\frac{1\ mol\ O_2}{22.4\ L\ O_2}\right)\left(\frac{4\ mol\ C_3H_7O}{17\ mol\ O_2}\right) = 0.91\ mol\ C_3H_7O$$

   $$87\ g\ C_3H_7O\left(\frac{1\ mol\ C_3H_7O}{59.10\ g\ C_3H_7O}\right) = 1.5\ mol\ C_3H_7O$$

   $$1.5\ mol\ C_3H_7O - 0.91\ mol\ C_3H_7O = 0.6\ mol\ C_3H_7O$$

Calculate the theoretical yield, actual yield, or percent yield given appropriate information.

9. Silicon dioxide reacts with carbon to produce silicon carbide (SiC) and carbon monoxide.

   a. Write the balanced equation for this reaction.

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

   b. If 75 grams of silicon dioxide is heated with excess of carbon, 31.9 grams of silicon carbide is produced. What is the percent yield of this reaction?

   $$75\ g\ SiO_2\left(\frac{1\ mol\ SiO_2}{60.09\ g\ SiO_2}\right)\left(\frac{1\ mol\ SiC}{1\ mol\ SiO_2}\right)\left(\frac{40.10\ g\ SiC}{1\ mol\ SiC}\right) = 50\ g\ SiC$$

   $$\%\ Yield = \frac{31.9\ g\ SiC}{50\ g\ SiC}\ x\ 100\ \%\ = 64\ \%$$

10. A solution of rubidium carbonate reacts with aqueous magnesium sulfate in a double replacement reaction. Magnesium carbonate is not soluble.

    a. Write the balanced equation for this reaction.

    $Rb_2CO_3 + MgSO_4 \rightarrow Rb_2SO_4 + MgCO_3$

    b. If the reaction proceeds with an 87% yield, how many grams of precipitate are collected when 12 grams of magnesium sulfate reacts with excess rubidium carbonate?

    $$12\ g\ MgSO_4\left(\frac{1\ mol\ MgSO_4}{120.38\ g\ MgSO_4}\right)\left(\frac{1\ mol\ MgCO_3}{1\ mol\ MgSO_4}\right)\left(\frac{84.32\ g\ MgCO_3}{1\ mol\ MgCO_3}\right) = 8.4\ g\ MgCO_3$$

    $$\left(\frac{87}{100}\right)\ x\ 8.4\ g\ MgCO_3 = 7.3\ g\ MgCO_3$$

    c. How many formula units of rubidium carbonate are consumed when the reaction from part b proceeds?

    $$12\ g\ MgSO_4\left(\frac{1\ mol\ MgSO_4}{120.38\ g\ MgSO_4}\right)\left(\frac{1\ mol\ Rb_2CO_3}{1\ mol\ MgSO_4}\right)\left(\frac{6.02\ x\ 10^{23}\ formula\ units\ Rb_2CO_3}{1\ mol\ Rb_2CO_3}\right) = 6.0x10^{22} Formula\ units\ Rb_2CO_3$$

Calculate the % yield of experimental data after identifying the limiting reagent.

11. Write the complete balanced equation for the single replacement reaction between a solution of copper (II) sulfate, $CuSO_4$ and the element aluminum, Al.

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

You dissolve 25.0 grams of copper (II) sulfate, then react it with 5.0 grams of aluminum. Upon collecting the copper produced, you dry it and determine the collected copper's mass to be 9.0 grams.

a. Show your work, and also explain how you know which reactant was the limiting reagent and which was in excess.

$$25.0\ g\ CuSO_4\left(\frac{1\ mol\ CuSO_4}{159.62\ g\ CuSO_4}\right)\left(\frac{2\ mol\ Al}{3\ mol\ CuSO_4}\right)\left(\frac{26.98\ g\ Al}{1\ mol\ Al}\right) = 2.82\ g\ Al$$

$$< 5.0\ g\ Al;\ CuSO_4\ LIMITING;\ \ Al\ Excess$$

b. Show your work for calculating the % yield of this experiment.

$$25.0\ g\ CuSO_4\left|\frac{1\ mol\ CuSO_4}{159.62\ g\ CuSO_4}\right|\frac{3\ mol\ Cu}{3\ mol\ CuSO_4}\left|\frac{63.55\ g\ Cu}{1\ mol\ Cu}\right| = 9.95\ g\ Cu$$

$$\%\ Yield = \left(\frac{9.0\ g\ Cu}{9.95\ g\ Cu}\right)x\ 100\ \% = 90.\ \%$$

c. How many grams of copper (II) sulfate went unreacted?

Trick Question: NONE – Copper (II) sulfate was the LIMITING reagent. All of it reacted!