Unit 9: Stoichiometry

Name:______________________________

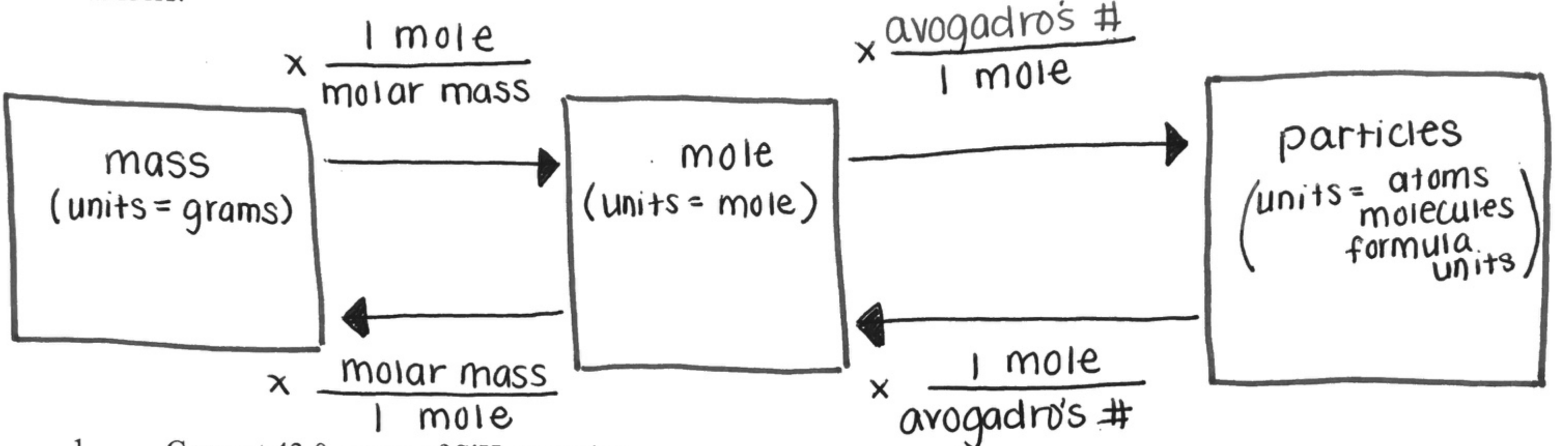
Learning Targets
1. *I CAN write a balanced chemical equation *review*
2. *I CAN convert between mass, moles, and particles of a single substance *review*
3. I CAN identify the mole ratio for two compounds in a chemical equation
4. I CAN convert between moles of two compounds involved a chemical reaction (mole to mole stoich)
5. I CAN convert between masses of two compounds involved in a reaction (mass to mass stoich)
6. I CAN define the limiting reactant in a chemical reaction
7. I CAN identify the limiting reactant in a chemical reaction using conversions
8. I CAN define the theoretical yield in a chemical reaction
9. I CAN identify the theoretical yield in a chemical reaction using conversions
10. Given the amount of product wanted, I CAN determine the amounts of reactant(s) needed
11. I CAN calculate the percent error of a chemical reaction
12. I CAN calculate the percent yield of a chemical reaction

Chemistry Important Dates!

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
April 17	18	19	20	21	22	23
24	25	26	27	28	29	30
1	2	3	4	5	6	7

Review of Mole Calculations **SHOW ALL WORK. Sig figs and units!**

In the space below, draw a mole road with direction arrows. Include conversions factors and any relevant numbers.



1. Convert 43.0 grams of SiH_4 to moles.

$43.0\ g\ SiH_4 \times \frac{1\ mol\ SiH_4}{32.13 g\ SiH_4} = \boxed{1.34\ mol\ SiH_4}$

2. Convert 7.680 moles of PtSe to grams.

$7.680\ mol\ PtSe \times \frac{274.04 g\ PtSe}{1\ mol\ PtSe} = \boxed{2105\ g\ PtSe}$

3. Convert 0.400 moles of BF_3 to molecules.

$0.400\ mol\ BF_3 \times \frac{6.02 \times 10^{23}\ mc\ BF_3}{1\ mol\ BF_3} = \boxed{2.41 \times 10^{23}\ mc\ BF_3}$

4. Convert 4.36×10^{25} molecules of CH_3OH to moles.

$4.36 \times 10^{25}\ mc\ CH_3OH \times \frac{1\ mole\ CH_3OH}{6.02 \times 10^{23}\ mc\ CH_3OH} = \boxed{0.724\ mol\ CH_3OH}$

5. Convert 7.41×10^{24} molecules of C_2H_2 to grams.

$7.41 \times 10^{24}\ mc\ C_2H_2 \times \frac{1\ mol\ C_2H_2}{6.02 \times 10^{23}\ mc\ C_2H_2} \times \frac{26.04\ g\ C_2H_2}{1\ mol\ C_2H_2} = \boxed{32.1 g\ C_2H_2}$

6. Convert 66.3 grams of SiS_2 to molecules.

$66.3 g\ SiS_2 \times \frac{1 mol\ SiS_2}{92.23 g\ SiS_2} \times \frac{6.02 \times 10^{23} mc\ SiS_2}{1 mol\ SiS_2} = \boxed{4.33 \times 10^{23}\ mc\ SiS_2}$

Introduction to Stoichiometry: McDonald's Problem

Remember to show all of your work in order to receive credit!

You have just purchased the McDonald's franchise in Mt. Pleasant and are going to make Big Macs. The world famous McDonald's Big Mac is made with "two all beef patties, special sauce, lettuce, cheese, pickles, and onions on a sesame seed bun." You check the storeroom and see that you have a large surplus of special sauce, lettuce, pickles, and onions. However, you have a limited amount of hamburger patties, cheese slices, and buns.

1. If each Big Mac has 2 hamburger (Ha) patties, 3 buns (Bu) and 2 slices of cheese (Ch), write a **balanced chemical equation** for the formation of a Big Mac from these ingredients using the symbols (Ha, Bu, Ch).

$$2Ha + 3Bu + 2Ch \longrightarrow Ha_2Bu_3Ch_2$$

2. You inventory your supplies and total 500 hamburger patties, 600 slices of cheese, and 650 hamburger buns. How many Big Macs can you make with these ingredients?

$$500\ Ha \times \frac{1\ Ha_2Bu_3Ch_2}{2\ Ha} = 250\ Ha_2Bu_3Ch_2$$

$$600\ Ch \times \frac{1\ Ha_2Bu_3Ch_2}{2\ Ch} = 300\ Ha_2Bu_3Ch_2$$

$$650\ Bu \times \frac{1\ Ha_2Bu_3Ch_2}{3\ Bu} = \boxed{217\ Ha_2Bu_3Ch_2}$$

↑ Theoretical yield = the maximum amount of product that can be made with the given reactants.

3. Which is your limiting factor? How much of each ingredient will be left over?

The limiting factor is buns. There will be no extras of this!

$$217\ Ha_2Bu_3Ch_2 \times \frac{2\ Ha}{1\ Ha_2Bu_3Ch_2} = 434\ Ha \text{ used up}$$

$$500\ Ha - 434\ Ha = \boxed{66\ Ha \text{ left over}}$$

$$217\ Ha_2Bu_3Ch_2 \times \frac{2\ Ch}{1\ Ha_2Bu_3Ch_2} = 434\ Ch \text{ used up}$$

$$600\ Ch - 434\ Ch = \boxed{166 \text{ left over.}}$$

Notes on Determining the Mole Ratio

Using the Mole Ratio

1. Give the mole ratio of each of the following chemical combinations for the reaction:

$$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(l) + \text{heat}$$

Chemical combination	Equality	Conversion factors
EXAMPLE: Hydrogen (H_2) to oxygen (O_2)	2 moles H_2 : 1 mole O_2	$\frac{2\ mol\ H_2}{1\ mol\ O_2}$ or $\frac{1\ mol\ O_2}{2\ mol\ H_2}$
Hydrogen (H_2) to water (H_2O)	2 mol H_2 : 2 mol H_2O	$\frac{2\ mol\ H_2}{2\ mol\ H_2O}$ or $\frac{2\ mol\ H_2O}{2\ mol\ H_2}$
Oxygen (O_2) to water (H_2O)	1 mol O_2 : 2 mol H_2O	$\frac{1\ mol\ O_2}{2\ mol\ H_2O}$ or $\frac{2\ mol\ H_2O}{1\ mol\ O_2}$

For the following, **use conversion factors** from the table above to convert from moles of one substance to moles of another. **REMEMBER TO SHOW ALL OF YOUR WORK!**

2. 1.0 mol H_2 = 0.50 mol O_2 — $1.0\ mol\ H_2 \times \frac{1\ mol\ O_2}{2\ mol\ H_2} = \boxed{0.50\ mol\ O_2}$

3. 1.0 mol O_2 = 2.0 mol H_2O — $1.0\ mol\ O_2 \times \frac{2\ mol\ H_2O}{1\ mol\ O_2} = \boxed{2.0\ mol\ H_2O}$

4. 1.0 mol H_2 = 1.0 mol H_2O — $1.0\ mol\ H_2 \times \frac{2\ mol\ H_2O}{2\ mol\ H_2} = \boxed{1.0\ mol\ H_2O}$

Stoichiometry (Mole Relationships)

Chemical reactions are like recipes: two of these, one of those make 4 servings, and so on. If you want the recipe to come out right, you need to start with the right ratio of ingredients. You can make a bigger or smaller recipe, but you have to keep the *ratios* the same. Otherwise, you will get a gloppy cake or a hard cookie. As you work through the following questions, keep the idea of a recipe in mind.

Balance the following reaction:

$$\underline{1}\ N_{2(g)} + \underline{3}\ H_{2(g)} \rightarrow \underline{2}\ NH_{3(g)}$$

Remember that in any chemical equation:
Subscripts represent the number of atoms in a compound (molecule)

Coefficients represent the number of molecules of each compound in a reaction

Using conversions, fill in the following table:

Situation	N_2	H_2	NH_3	Ratio of all three
For a single recipe, how many molecules would you need (or make)?	1	3	2	1 : 3 : 2
If you made the recipe 538 times, how many molecules would you need (or make)?	538	1614	1076	1 : 3 : 2
If you made the recipe 6.02 x 10^{23} times, how many molecules would you need (or make)?	6.02×10^{23}	1.806×10^{24}	1.204×10^{24}	1 : 3 : 2
Since it is hard to count molecules, how many moles of each would you need (or make) for the previous situation?	1	3	2	1 : 3 : 2
What masses of each reactant would you need to make this recipe a mole number of times?	28.02	6.06	34.08	23 : 5 : 28

1. What did you find to be true about the mole ratios in your table? Do they always hold true? Explain mathematically why or why not. Compare the mole ratios to the coefficients in the chemical reaction.

The mole ratio holds true for everything EXCEPT mass. The ratios come from the coefficients in a chemical reaction.

2. Was the last ratio in the table the same as the ones above it? Why or Why not?

No! Every element has a different mass, so they cannot be used to compare substances.

Notes on Stoichiometry Moles-to-Moles **(Include all three steps!)**

Stoichiometry Practice (mole-to-mole)

Balance the following chemical reaction:

$\underline{\ 1\ } N_{2(g)} + \underline{\ 3\ } H_{2(g)} \longrightarrow \underline{\ 2\ } NH_{3(g)}$

How many moles of ammonia, NH_3, are formed when 2.0 moles of nitrogen, N_2, react with excess hydrogen, H_2?

$$2.0 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = \boxed{4.0 \text{ mol } NH_3}$$

How many moles of ammonia, NH_3, are formed when 1.0 mole of hydrogen, H_2, reacts with excess nitrogen, N_2?

$$1.0 \text{ mol } H_2 \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = \boxed{0.67 \text{ mol } NH_3}$$

How many moles of nitrogen ***and*** hydrogen are needed to make 3.0 moles of NH_3?

$$3.0 \text{ mol } NH_3 \times \frac{1 \text{ mol } N_2}{2 \text{ mol } NH_3} = \boxed{0.67 \text{ mol } N_2}$$

$$3.0 \text{ mol } NH_3 \times \frac{3 \text{ mol } H_2}{2 \text{ mol } NH_3} = \boxed{4.5 \text{ mol } H_2}$$

Stoichiometry Practice (mole-to-mole)

Balance the following chemical reaction:

$$\underline{16}\ Al_{(s)} + \underline{3}\ S_{8\,(g)} \longrightarrow \underline{8}\ Al_2S_{3\,(s)}$$

How many moles of aluminum sulfide, Al_2S_3, are formed when 2.0 moles of aluminum, Al, react with sulfur, S_8?

$$2.0\ \text{mol Al} \times \frac{8\ \text{mol}\ Al_2S_3}{16\ \text{mol Al}} = \boxed{1.0\ \text{mol}\ Al_2S_3}$$

How many moles of aluminum sulfide, Al_2S_3, are formed when 1.0 mole of sulfur, S_8, reacts with aluminum, Al?

$$1.0\ \text{mol}\ S_8 \times \frac{8\ \text{mol}\ Al_2S_3}{3\ \text{mol}\ S_8} = \boxed{2.7\ \text{mol}\ Al_2S_3}$$

How many moles of aluminum and sulfur are needed to make 3.0 moles of Al_2S_3?

$$3.0\ \text{mol}\ Al_2S_3 \times \frac{16\ \text{mol Al}}{8\ \text{mol}\ Al_2S_3} = \boxed{6.0\ \text{mol Al}}$$

$$3.0\ \text{mol}\ Al_2S_3 \times \frac{3\ \text{mol}\ S_8}{8\ \text{mol}\ Al_2S_3} = \boxed{1.1\ \text{mol}\ S_8}$$

Notes on Stoichiometry Grams-to-Grams **(Include all three steps!)**

Stoichiometry Practice (grams-to-grams)

Balance the following chemical reaction:

1 $N_{2(g)}$ + 3 $H_{2(g)} \longrightarrow$ 2 $NH_{3(g)}$

How many grams of NH_3 are formed when 56g of N_2 react with hydrogen?

1. Convert from grams to moles of N_2

$$56\text{ g } N_2 \times \frac{1\text{ mol } N_2}{28.02\text{ g } N_2} = 2.0\text{ mol } N_2$$

2. Convert from moles of N_2 to moles of NH_3

$$2.0\text{ mol } N_2 \times \frac{2\text{ mol } NH_3}{1\text{ mol } N_2} = 4.0\text{ mol } NH_3$$

3. Convert from moles to grams of NH_3

$$4.0\text{ mol } NH_3 \times \frac{17.04\text{ g } NH_3}{1\text{ mol } NH_3} = \boxed{68\text{ g } NH_3}$$

How many grams of NH_3 are formed when 6 g of H_2 react with nitrogen?

$$6\text{ g } H_2 \times \frac{1\text{ mol } H_2}{2.02\text{ g } H_2} \times \frac{2\text{ mol } NH_3}{3\text{ mol } H_2} \times \frac{17.04\text{ g } NH_3}{1\text{ mol } NH_3} = \boxed{30\text{ g } NH_3}$$

Balance the following chemical reaction:

16 $Al_{(s)}$ + 3 $S_{8\,(g)} \longrightarrow$ 8 $Al_2S_{3\,(s)}$

How many grams of **Al_2S_3** are formed when 56g of **Al** react with sulfur?

$$56\text{ g Al} \times \frac{1\text{ mol Al}}{26.98\text{ g Al}} \times \frac{8\text{ mol } Al_2S_3}{16\text{ mol Al}} \times \frac{150.17\text{ g } Al_2S_3}{1\text{ mol } Al_2S_3} = \boxed{160\text{ g } Al_2S_3}$$

How many grams of **Al_2S_3** are formed when 6g of **S_8** react with aluminum?

$$6\text{ g } S_8 \times \frac{1\text{ mol } S_8}{256.56\text{ g } S_8} \times \frac{8\text{ mol } Al_2S_3}{3\text{ mol } S_8} \times \frac{150.17\text{ g } Al_2S_3}{1\text{ mol } Al_2S_3} = \boxed{9\text{ g } Al_2S_3}$$

Simple Stoichiometry Practice (MIXED mole-to-mole AND gram-to gram)

Remember to show all of your work. Use unit conversions to solve.

1. How many moles of $NaNO_3$ will be produced from 2.3 moles of Na_2CO_3 in the following reaction:

$$Na_2CO_3\,(aq) + Ca(NO_3)_2\,(aq) \rightarrow CaCO_3\,(s) + 2NaNO_3\,(aq)$$

$$2.3 \text{ mol } Na_2CO_3 \times \frac{2 \text{ mol } NaNO_3}{1 \text{ mol } Na_2CO_3} = \boxed{4.6 \text{ mol } NaNO_3}$$

2. How many moles of O_2 are needed to produce 0.85 moles of P_2O_5?

$$4P\,(s) + 5O_2\,(g) \rightarrow 2P_2O_5\,(s)$$

$$0.85 \text{ mol } P_2O_5 \times \frac{5 \text{ mol } O_2}{2 \text{ mol } P_2O_5} = \boxed{2.1 \text{ mol } O_2}$$

3. If 10.0 g of zinc reacts with an HCl solution, how many moles of hydrogen gas will be released?

$$Zn\,(s) + 2HCl\,(aq) \rightarrow H_2\,(g) + ZnCl_2\,(aq)$$

$$10.0\text{g } Zn \times \frac{1 \text{ mol } Zn}{65.39\text{g } Zn} \times \frac{1 \text{ mol } H_2}{1 \text{ mol } Zn} = \boxed{0.153 \text{ mol } H_2}$$

4. How many moles of hydrogen gas are needed to react completely with 15.1 g of chlorine gas to produce hydrogen chloride?

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$$

$$15.1\text{g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.9\text{g } Cl_2} \times \frac{1 \text{ mol } H_2}{1 \text{ mol } Cl_2} = \boxed{0.213 \text{ mol } H_2}$$

5. Gasoline (C_8H_{18}) burns in your car engine to form the normal combustion reaction. If 9.0×10^3 g of gasoline are burned, how many grams of CO_2 are produced?

$$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$$

$$9.0 \times 10^3\text{g } C_8H_{18} \times \frac{1 \text{ mol } C_8H_{18}}{114.26\text{g } C_8H_{18}} \times \frac{16 \text{ mol } CO_2}{2 \text{ mol } C_8H_{18}} \times \frac{44.01\text{g } CO_2}{1 \text{ mol } CO_2} = \boxed{28{,}000 \text{ g } CO_2}$$

6. How many grams of aluminum are required to produce 410. g of aluminum oxide through a reaction with oxygen gas?

$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

$$410.\text{g } Al_2O_3 \times \frac{1 \text{ mol } Al_2O_3}{101.96\text{g } Al_2O_3} \times \frac{4 \text{ mol } Al}{2 \text{ mol } Al_2O_3} \times \frac{26.98\text{g } Al}{1 \text{ mol } Al} = \boxed{217 \text{ g } Al}$$

Simple Stoichiometry Practice (MIXED mole-to-mole AND gram-to gram)

Remember to show all of your work. Use unit conversions to solve.

1. How many moles of $NaNO_3$ will be produced from 2.3 moles of Na_2CO_3 in the following reaction:

$$Na_2CO_3\ (aq) + Ca(NO_3)_2\ (aq) \rightarrow CaCO_3\ (s) + 2NaNO_3\ (aq)$$

$$2.3\ mol\ Na_2CO_3 \times \frac{2\ mol\ NaNO_3}{1\ mol\ Na_2CO_3} = \boxed{4.6\ mol\ NaNO_3}$$

2. How many moles of O_2 are needed to produce 0.85 moles of P_2O_5?

$$4P\ (s) + 5O_2\ (g) \rightarrow 2P_2O_5\ (s)$$

$$0.85\ mol\ P_2O_5 \times \frac{5\ mol\ O_2}{2\ mol\ P_2O_5} = \boxed{2.1\ mol\ O_2}$$

3. If 10.0 g of zinc reacts with an HCl solution, how many moles of hydrogen gas will be released?

$$Zn\ (s) + 2HCl\ (aq) \rightarrow H_2\ (g) + ZnCl_2\ (aq)$$

$$10.0g\ Zn \times \frac{1\ mol\ Zn}{65.39g\ Zn} \times \frac{1\ mol\ H_2}{1\ mol\ Zn} = \boxed{0.153\ mol\ H_2}$$

4. How many moles of hydrogen gas are needed to react completely with 15.1 g of chlorine gas to produce hydrogen chloride?

$$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$$

$$15.1g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.9g\ Cl_2} \times \frac{1\ mol\ H_2}{1\ mol\ Cl_2} = \boxed{0.213\ mol\ H_2}$$

5. Gasoline (C_8H_{18}) burns in your car engine to form the normal combustion reaction. If 9.0×10^3 g of gasoline are burned, how many grams of CO_2 are produced?

$$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$$

$$9.0 \times 10^3 g\ C_8H_{18} \times \frac{1\ mol\ C_8H_{18}}{114.26g\ C_8H_{18}} \times \frac{16\ mol\ CO_2}{2\ mol\ C_8H_{18}} \times \frac{44.01g\ CO_2}{1\ mol\ CO_2} = \boxed{28{,}000\ g\ CO_2}$$

6. How many grams of aluminum are required to produce 410. g of aluminum oxide through a reaction with oxygen gas?

$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

$$410.\ g\ Al_2O_3 \times \frac{1\ mol\ Al_2O_3}{101.96g\ Al_2O_3} \times \frac{4\ mol\ Al}{2\ mol\ Al_2O_3} \times \frac{26.98g\ Al}{1\ mol\ Al} = \boxed{217\ g\ Al}$$

Limiting Reagent (definition):

Excess Reagent (definition):

$$N_{2(g)} \quad + \quad 3\ H_{2(g)} \longrightarrow 2\ NH_{3(g)}$$

1. How much NH_3 will be formed when 6 moles of N_2 and 6 moles of H_2 are reacted?

$6 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } NH_3} = 10 \text{ mol } NH_3$

$6 \text{ mol } H_2 \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = \boxed{4 \text{ mol } NH_3}$

Limiting Reagent – H_2

Excess Reagent – N_2

2. How much NH_3 will be formed when 10 moles of H_2 and 5 moles of N_2 are reacted?

$10 \text{ mol } H_2 \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = \boxed{7 \text{ mol } NH_3}$

$5 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = 10 \text{ mol } NH_3$

3. How much NH_3 will be formed when 3 moles of N_2 react with 6 moles of H_2?
   a. How many moles of ammonia, NH_3 are formed?

$3 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = 6 \text{ mol } NH_3$ $\quad$ $6 \text{ mol } H_2 \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = \boxed{4 \text{ mol } NH_3}$

   b. What is the limiting reactant?

$\boxed{H_2}$

   c. What is the excess reactant?

$\boxed{N_2}$

4. How much NH_3 will be formed when 10 grams of H_2 and 5 grams of N_2 are reacted?

$10 g\ H_2 \times \frac{1 \text{ mol } H_2}{2.02 g\ H_2} \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = 3 \text{ mol } NH_3$

$5 g\ N_2 \times \frac{1 \text{ mol } N_2}{28.02 g\ N_2} \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = \boxed{0.4 \text{ mol } NH_3}$

Stoichiometry Practice (Limiting and Excess Problems)
Remember to show all of your work. Use conversions to solve.

1. Sodium chloride can be prepared by the reaction of sodium metal and chlorine gas. If 6.70 moles of Na react with 3.20 moles of Cl_2,
   a. How many moles of NaCl are produced?
   b. What is the limiting reactant?

$$2Na_{(s)} + Cl_{2\,(g)} \rightarrow 2NaCl_{(s)}$$

$$6.70 \text{ mol Na} \times \frac{2 \text{ mol NaCl}}{2 \text{ mol Na}} = \boxed{6.70 \text{ mol NaCl}}$$

Na is the limiting reactant.

$$3.20 \text{ mol } Cl_2 \times \frac{2 \text{ mol NaCl}}{1 \text{ mol } Cl_2} = 6.40 \text{ mol NaCl}$$

2. Hydrogen gas can be produced in the laboratory by the reaction of magnesium metal with hydrochloric acid. How many grams of hydrogen can be produced when 6.00 g of HCl is added to 5.00 g of Mg?

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + MgCl_{2\,(aq)}$$

$$6.00 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.46 \text{ g HCl}} \times \frac{1 \text{ mol } H_2}{2 \text{ mol HCl}} \times \frac{2.02 \text{ g } H_2}{1 \text{ mol } H_2} = \boxed{0.166 \text{ g } H_2}$$

$$5.00 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} \times \frac{1 \text{ mol } H_2}{1 \text{ mol Mg}} \times \frac{2.02 \text{ g } H_2}{1 \text{ mol } H_2} = 0.415 \text{ g } H_2$$

3. If 19 g of zinc are reacted with 19 g of magnesium chloride, zince chloride and magnesium are formed.
   a. Calculate the mass of the zinc chloride produced.
   b. Which reactant will be in excess?

$$Zn + MgCl_2 \rightarrow ZnCl_2 + Mg$$

$$19 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.39 \text{ g Zn}} \times \frac{1 \text{ mol } ZnCl_2}{1 \text{ mol Zn}} \times \frac{136.29 \text{ g } ZnCl_2}{1 \text{ mol } ZnCl_2} = 40. \text{ g } ZnCl_2$$

$$19 \text{ g } MgCl_2 \times \frac{1 \text{ mol } MgCl_2}{95.21 \text{ g } MgCl_2} \times \frac{1 \text{ mol } ZnCl_2}{1 \text{ mol } MgCl_2} \times \frac{136.29 \text{ g } ZnCl_2}{1 \text{ mol } ZnCl_2} = \boxed{27 \text{ g } ZnCl_2}$$

Stoichiometry Practice (Yields and Errors)
Remember to show all of your work. Use unit conversions to solve.

1. Calcium carbonate is decomposed by heating to form calcium oxide and carbon dioxide gas.
   a. What is the theoretical yield of CaO?
   b. What is the percent yield of this reaction if 24.8 g of $CaCO_3$ is heated to give 13.1 g of CaO?
   c. What is the percent error of the experiment?

$$CaCO_3 \rightarrow CaO + CO_2$$

$$24.8\text{ g } CaCO_3 \times \frac{1\text{ mol } CaCO_3}{100.09\text{ g } CaCO_3} \times \frac{1\text{ mol CaO}}{1\text{ mol } CaCO_3} \times \frac{56.08\text{ g CaO}}{1\text{ mol CaO}} = \boxed{13.9\text{ g CaO}}$$

$$\frac{13.1\text{ g CaO}}{13.9\text{ g CaO}} \times 100 = \boxed{94.2\%\text{ yield}} \qquad \frac{|13.1\text{ g} - 13.9\text{ g}|}{13.1\text{ g}} \times 100 = \boxed{6.10\%\text{ error}}$$

2. Nitrogen gas can be prepared by passing gaseous ammonia over solid copper (II) oxide at high temperatures. The other products of the reaction are solid copper and water vapor. If a sample containing 18.1 g of NH_3 is reacted with 90.4 g of CuO,
   a. How many grams of N_2 will be formed?
   b. Which is the limiting reactant?
   c. If only 8.2 grams of N_2 are actually formed during the experiment, what is the percent yield?
   d. What is the percent error of the experiment?

$$2NH_{3(g)} + 3CuO_{(s)} \rightarrow N_{2(g)} + 3Cu_{(s)} + 3H_2O_{(g)}$$

$$18.1\text{ g } NH_3 \times \frac{1\text{ mol } NH_3}{17.04\text{ g } NH_3} \times \frac{1\text{ mol } N_2}{2\text{ mol } NH_3} \times \frac{28.02\text{ g } N_2}{1\text{ mol } N_2} = 14.9\text{ g } N_2$$

$$90.4\text{ g CuO} \times \frac{1\text{ mol CuO}}{79.55\text{ g CuO}} \times \frac{1\text{ mol } N_2}{3\text{ mol CuO}} \times \frac{28.02\text{ g } N_2}{1\text{ mol } N_2} = \boxed{10.6\text{ g } N_2 \text{ Theoretical Yield}} \quad \boxed{\text{LR is CuO}}$$

$$\frac{8.2\text{ g } N_2}{10.6\text{ g } N_2} \times 100 = \boxed{77\%\text{ yield}} \qquad \frac{|8.2\text{ g} - 10.6\text{ g}|}{10.6\text{ g}} \times 100 = \boxed{2.3\%\text{ error}}$$

3. Methanol (CH_3OH), also called methyl alcohol, is the simplest alcohol. It is used as a fuel in race cars and is a potential replacement for gasoline. Methanol can be manufactured by reacting gaseous carbon monoxide with hydrogen gas. Suppose 68.5 kg CO is reacted with 8.60 kg H_2,
   a. Calculate the theoretical yield of methanol.
   b. If 3.57×10^4 g CH_3OH is actually produced, what is the percent yield of methanol?
   c. What is the percent error of the experiment?

$$CO + 2H_2 \rightarrow CH_3OH$$

$$68.5\text{ kg CO} \times \frac{1000\text{ g CO}}{1\text{ kg CO}} \times \frac{1\text{ mol CO}}{28.01\text{ g CO}} \times \frac{1\text{ mol } CH_3OH}{1\text{ mol CO}} \times \frac{32.05\text{ g } CH_3OH}{1\text{ mol } CH_3OH} = 78{,}400\text{ g } CH_3OH$$

$$8.60\text{ kg } H_2 \times \frac{1000\text{ g } H_2}{1\text{ kg } H_2} \times \frac{1\text{ mol } H_2}{2.02\text{ g } H_2} \times \frac{1\text{ mol } CH_3OH}{2\text{ mol } H_2} \times \frac{32.05\text{ g } CH_3OH}{1\text{ mol } CH_3OH} = \boxed{68{,}200\text{ g } CH_3OH}$$

$$\frac{3.57 \times 10^4\text{ g } CH_3OH}{68{,}200\text{ g } CH_3OH} = \boxed{52.3\%\text{ yield}} \qquad \frac{|3.57 \times 10^4\text{ g} - 68{,}200\text{ g}|}{68{,}200\text{ g}} \times 100 = \boxed{47.7\%\text{ err}}$$

Stoichiometry Practice Test

1. In the reaction: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ How many moles of CH_4 react with 6 moles of O_2?

2. How many moles of silver can be produced from 0.10 moles of tin and excess $AgNO_3$ in the following reaction? $Sn + AgNO_3 \rightarrow Ag + Sn(NO_3)_2$

3. How many moles of chlorine gas are needed to react with 3.20 moles of sodium to produce sodium chloride?

4. Hydrochloric acid reacts with calcium carbonate to produce H_2CO_3 and calcium chloride. How many moles of HCl are required to react completely with 25g of $CaCO_3$?

5. How many grams of aluminum chloride are produced when 32.0g of Al react with an excess of HCl? (Hydrogen gas is the other product).

6. What mass of zinc reacts completely with 18.0g of copper(II) nitrate?

7. How many grams of FeI_3 can be produced when 25.7g of Fe react with excess I_2?

8. A chemist reacts 140.g of calcium oxide with water. Calculate the percent yield if she produces only 150.g of the only product, calcium hydroxide.

9. Ammonia (NH_3) is formed through the synthesis of nitrogen and hydrogen gas. If 1.25 moles of nitrogen gas are combined with 4.00 moles of hydrogen:
    a. Which reactant is the limiting reacant?
    b. How many moles of ammonia are produced?

10. When aluminum metal is placed in copper(II) nitrate, a single replacement reaction occurs. If the solution is made by dissolving 52.5g of copper(II) nitrate, and 2.7g of aluminum is placed in the solution.
    a) How many grams of copper metal will be produced?
    b) How many grams of aluminum metal will be left over?

11. If 25.0g of zinc metal are reacted with 30.0g of lead(II) chloride, zinc chloride and lead metal are formed:
    a) Which reactant will be in excess?
    b) Calculate the mass of the excess reactant that will remain.
    c) Calculate the mass of zinc chloride produced.
    d) If a 90.0% yield of is produced, how much zinc chloride will there be in grams?

12. A student intended to make a salt solution with a concentration of 10.0 grams of solute per liter of solution. When the student's solution was analyzed, it was found to contain 8.90 grams of solute per liter of solution. What was the percent error in the concentration of the solution?

13. When performing the Copper and Silver Nitrate lab the following data was produced:

    Data: Mass of clean, dry 100mL beaker 32.43 g
    Mass of copper wire before reaction 1.50 g
    Mass of copper wire after reaction .25g
    Mass of silver plus beaker at end of experiment 36.67 g

    How many grams of Silver Nitrate reacted? (Assume copper forms a +2 ox # in the product)

Answers: 1. **3 mol CH_4** 2. **0.20 mol Ag** 3. **1.60 mol Cl_2** 4. **0.50 mol HCl**
5. **158g $AlCl_3$** 6. **6.28g Zn** 7. **201g FeI_3** 8. **81.1% yield** 9. a. **N_2** b. **2.50 mol NH_3**
10. a. **9.5g Cu** b. **None** 11. a. **Zinc** b. **17.9g Zn** c. **14.7g $ZnCl_2$** d. **13.2 g** 12. **11.0%** 13. **6.68 g**