Key

Ch 9 –Stoichiometry

Mole Review!!

1. Convert the following into moles:
   a. 75.6g of NO_2

$$\frac{75.6\,\cancel{g\,NO_2}}{1} \times \frac{1\,mol\,NO_2}{46.01\,\cancel{g\,NO_2}} = \boxed{1.64\ mol\ NO_2}$$

   b. 90.0g of H_2O

$$\frac{90.0\,\cancel{g\,H_2O}}{1} \times \frac{1\,mol\,H_2O}{18.016\,\cancel{g\,H_2O}} = \boxed{5.00\ mol\ H_2O}$$

Sig Figs!

2. Convert the following into grams:
   a. 4.30 mol H_2O

$$\frac{4.3\,\cancel{mol\,H_2O}}{1} \times \frac{18.016\,g\,H_2O}{1\,\cancel{mol\,H_2O}} = \boxed{77.5\ g\ H_2O}$$

   b. 0.20 mol NO_2

$$\frac{0.20\,\cancel{mol\,NO_2}}{1} \times \frac{46.01\,g\,NO_2}{1\,\cancel{mol\,NO_2}} = \boxed{9.2\ g\ NO_2}$$

Mole Ratios and Mole-Mole Conversions

3. Carbon monoxide + hydrogen → methanol

   a. Write and balance the equation:

$$CO + 2H_2 \longrightarrow CH_3OH$$

   b. What is the ratio of carbon monoxide to methanol? Hydrogen to methanol?

1 : 1 2 : 1

   c. If 4.00 moles of CO react with an excess of H_2, how many moles of CH_3OH would be made?

$$\frac{4.00\,\cancel{mol\,CO}}{1} \times \frac{1\,mol\,CH_3OH}{1\,\cancel{mol\,CO}} = \boxed{4.00\ mol\ CH_3OH}$$

   d. If 4.00 moles of H_2 react with an excess of CO, how many moles of CH_3OH would be made?

$$\frac{4.00\,\cancel{mol\,H_2}}{1} \times \frac{1\,mol\,CH_3OH}{2\,\cancel{mol\,H_2}} = \boxed{2.00\ mol\ CH_3OH}$$

4. Calculate the number of moles of oxygen required to react exactly with 4.30 mol of C_3H_8.
   1 C_3H_8 (g) + 5 O_2 (g) → 3 CO_2 + 4 H_2O

$$\frac{4.30\,\cancel{mol\,C_3H_8}}{1} \times \frac{5\,mol\,O_2}{1\,\cancel{mol\,C_3H_8}} = \boxed{21.5\ mol\ O_2}$$

5. When 4.30 moles of C_3H_8 reacts with an excess of oxygen, how many moles of CO_2 are formed?

$$\frac{4.30\,\cancel{mol\,C_3H_8}}{1} \times \frac{3\,mol\,CO_2}{1\,\cancel{mol\,C_3H_8}} = \boxed{12.9\ mol\ CO_2}$$

6. How many moles of hydrogen are needed to prepare 312 moles of NH_3? Assume you have an excess of nitrogen.

$$3H_2\,(g) + N_2\,(g) \rightarrow 2NH_3\,(g)$$

$$\frac{312\ \cancel{mol\ NH_3}}{1} \times \frac{3\ mol\ H_2}{2\ \cancel{mol\ NH_3}} = \boxed{468\ mol\ H_2}$$

7. How many moles of NH_3 can be made from 2.00 moles of N_2 if you have excess H_2?

$$\frac{2.00\ \cancel{mol\ N_2}}{1} \times \frac{2\ mol\ NH_3}{1\ \cancel{mol\ N_2}} = \boxed{4.00\ mol\ NH_3}$$

Mole-Gram Problems

8. How many grams of aluminum are needed to completely react with 135 g iron (III) oxide?

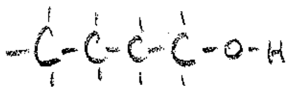
$$2\,Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Fe$$

$$\frac{135\ \cancel{g\ Fe_2O_3}}{1} \times \frac{1\ \cancel{mol\ Fe_2O_3}}{159.7\ \cancel{g\ Fe_2O_3}} \times \frac{2\ \cancel{mol\ Al}}{1\ \cancel{mol\ Fe_2O_3}} \times \frac{26.98\ g\ Al}{1\ \cancel{mol\ Al}} = \boxed{45.6\ g\ Al}$$

9. How many moles of iron are made when 100.0 g aluminum is reacted with excess iron (III) oxide?

$$\frac{100.0\ \cancel{g\ Al}}{1} \times \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g}\ Al} \times \frac{2\ mol\ Fe}{2\ \cancel{mol\ Al}} = \boxed{3.706\ mol\ Fe}$$

10. How many grams of water are made when 3.00 moles of butanol is combusted?



$-C-C-C-C-O-H$

$$C_4H_{10}O + 6O_2 \longrightarrow 4CO_2 + 5H_2O$$

$$\frac{3.00\ \cancel{mol\ C_4H_{10}O}}{1} \times \frac{5\ \cancel{mol\ H_2O}}{1\ \cancel{mol\ C_4H_{10}O}} \times \frac{18.016\ g\ H_2O}{1\ \cancel{mol\ H_2O}} = \boxed{270.\ g\ H_2O}$$

Gram-Gram Conversions

1. Sodium hydroxide + sulfuric acid → $\overset{5.00\,g}{2NaOH} + \overset{?\,g}{H_2SO_4} \longrightarrow 2H_2O + Na_2SO_4$

Calculate the number of grams of [redacted] that can react completely with 5.00 g sodium hydroxide.
Sulfuric acid

$$\frac{5.00\,g\,\cancel{NaOH}}{1} \times \frac{1\,mol\,\cancel{NaOH}}{40.008\,g\,\cancel{NaOH}} \times \left(\frac{1\,mol\,\cancel{H_2SO_4}}{2\,mol\,\cancel{NaOH}}\right) \times \frac{98.086\,g\,H_2SO_4}{1\,mol\,\cancel{H_2SO_4}} = \boxed{6.13\,g\,H_2SO_4}$$

2. nitrogen + magnesium $\overset{?\,g}{N_2} + \overset{10.0\,g}{3Mg} \longrightarrow Mg_3N_2$

a. What mass of nitrogen is required to react completely with 10.0 g of magnesium?

$$\frac{10.0\,g\,\cancel{Mg}}{1} \times \frac{1\,mol\,\cancel{Mg}}{24.31\,g\,\cancel{Mg}} \times \left(\frac{1\,mol\,\cancel{N_2}}{3\,mol\,\cancel{Mg}}\right) \times \frac{28.02\,g\,N_2}{1\,mol\,\cancel{N_2}} = \boxed{3.84\,g\,N_2}$$

b. What mass of product is produced from 10.0 g of nitrogen and excess magnesium?

$$\frac{10.0\,g\,\cancel{N_2}}{1} \times \frac{1\,mol\,\cancel{N_2}}{28.02\,g\,\cancel{N_2}} \times \left(\frac{1\,mol\,\cancel{Mg_3N_2}}{1\,mol\,\cancel{N_2}}\right) \times \frac{100.95\,g\,Mg_3N_2}{1\,mol\,\cancel{Mg_3N_2}} = \boxed{36.0\,g\,Mg_3N_2}$$

3. Nitric acid + calcium → $2HNO_3 + \overset{2300.0\,g}{Ca} \longrightarrow \overset{?\,g}{Ca(NO_3)_2} + H_2$

What mass of calcium [redacted] can be produced from 2300.0 g calcium and excess nitric acid?
nitrate

$$\frac{2300.0\,g\,\cancel{Ca}}{1} \times \frac{1\,mol\,\cancel{Ca}}{40.08\,g\,\cancel{Ca}} \times \left(\frac{1\,mol\,\cancel{Ca(NO_3)_2}}{1\,mol\,\cancel{Ca}}\right) \times \frac{164.1\,g\,Ca(NO_3)_2}{1\,mol\,\cancel{Ca(NO_3)_2}} = \boxed{9416.9\,g\,Ca(NO_3)_2}$$

4. Carbon monoxide + hydrogen → methanol $CO + 2H_2 \longrightarrow CH_3OH$

What mass of carbon monoxide **AND** what mass of hydrogen are needed in order to make 600.0 g methanol? Hint: Solve this like two separate problems, one for each reactant.

CO/

$$\frac{600.0\,g\,\cancel{CH_3OH}}{1} \times \frac{1\,mol\,\cancel{CH_3OH}}{32.042\,g\,\cancel{CH_3OH}} \times \left(\frac{1\,mol\,\cancel{CO}}{1\,mol\,\cancel{CH_3OH}}\right) \times \frac{28.01\,g\,CO}{1\,mol\,\cancel{CO}} = \boxed{524.5\,g\,CO}$$

H_2/

$$\frac{600.0\,g\,\cancel{CH_3OH}}{1} \times \frac{1\,mol\,\cancel{CH_3OH}}{32.042\,g\,\cancel{CH_3OH}} \times \left(\frac{2\,mol\,\cancel{H_2}}{1\,mol\,\cancel{CH_3OH}}\right) \times \frac{2.016\,g\,H_2}{1\,mol\,\cancel{H_2}} = \boxed{75.50\,g\,H_2}$$

5. magnesium + oxygen → $\overset{50.0g}{2Mg} + \overset{excess}{O_2} \longrightarrow \overset{?g}{2MgO}$

How many grams of magnesium oxide are made when 50.0 g magnesium reacts with excess oxygen?

$$\frac{50.0\,\cancel{g\,Mg}}{1} \times \frac{1\,\cancel{mol\,Mg}}{24.31\,\cancel{g\,Mg}} \times \left(\frac{2\,\cancel{mol\,MgO}}{2\,\cancel{mol\,Mg}}\right) \times \frac{40.31\,g\,MgO}{1\,\cancel{mol\,MgO}} = \boxed{82.9\,g\,MgO}$$

6. aluminum + chlorine → $2Al + 3Cl_2 \longrightarrow 2AlCl_3$

How many grams of aluminum chloride are made when 12.0 g aluminum reacts with excess chlorine gas?

$$\frac{12.0\,\cancel{g\,Al}}{1} \times \frac{1\,\cancel{mol\,Al}}{26.98\,\cancel{g\,Al}} \times \left(\frac{2\,\cancel{mol\,AlCl_3}}{2\,\cancel{mol\,Al}}\right) \times \frac{133.33\,g\,AlCl_3}{1\,\cancel{mol\,AlCl_3}} = \boxed{59.3\,g\,AlCl_3}$$

7. Calcium carbonate → $\overset{?g}{CaCO_3} \longrightarrow \overset{50.0g}{CaO} + CO_2$

If 50.0 g of calcium oxide were produced, how many grams of calcium carbonate reacted?

$$\frac{50.0\,\cancel{g\,CaO}}{1} \times \frac{1\,\cancel{mol\,CaO}}{56.08\,\cancel{g\,CaO}} \times \left(\frac{1\,\cancel{mol\,CaCO_3}}{1\,\cancel{mol\,CaO}}\right) \times \frac{100.9\,g\,CaCO_3}{1\,\cancel{mol\,CaCO_3}} = \boxed{89.2\,g\,CaCO_3}$$

8. Lithium + copper (III) phosphate → $3Li + CuPO_4 \longrightarrow Li_3PO_4 + Cu$

If 47.0 g of lithium are reacted with excess copper (II) phosphate, how many grams of copper are produced?

$$\frac{47.0\,\cancel{g\,Li}}{1} \times \frac{1\,\cancel{mol\,Li}}{6.94\,\cancel{g\,Li}} \times \left(\frac{1\,\cancel{mol\,Cu}}{3\,\cancel{mol\,Li}}\right) \times \frac{63.55\,g\,Cu}{1\,\cancel{mol\,Cu}} = \boxed{143\,g\,Cu}$$

9. Potassium + gold (IV) permanganate → $4K + Au(MnO_4)_4 \longrightarrow 4KMnO_4 + Au$

If 32.0g of gold (IV) permanganate is reacted with excess potassium, how many grams of gold are produced?

$$\frac{32.0\,g\,Au(MnO_4)_4}{1} \times \frac{1\,mol\,Au(MnO_4)_4}{672.76\,g\,Au(MnO_4)_4} \times \left(\frac{1\,mol\,Au}{1\,mol\,Au(MnO_4)_4}\right) \times \frac{197\,g\,Au}{1\,mol\,Au} = \boxed{9.37\,g\,Au}$$

10. Mercury (II) + bromine → $Hg + Br_2 \longrightarrow HgBr_2$

What mass of product can be made from 2kg of mercury reacting with excess bromine?

$$\frac{2\,kg\,Hg}{1} \times \frac{1000\,g\,Hg}{1\,kg\,Hg} \times \frac{1\,mol\,Hg}{200.6\,g\,Hg} \times \left(\frac{1\,mol\,HgBr_2}{1\,mol\,Hg}\right) \times \frac{360.4\,g\,HgBr_2}{1\,mol\,HgBr_2} = 3593\,g\,HgBr_2$$

↓

1 sig fig → $\boxed{4000\,g\,HgBr_2}$

$$\% \text{ Yield} = \frac{\text{Actual}}{\text{Theoretical}} \times 100$$

Percent Yield

Actual Yield

1. If 5.00g of potassium chlorate is decomposed in an experiment to form 1.25g of oxygen, what is the percent yield of the reaction?

$$2\overset{5.00g}{KClO_3} \rightarrow 2KCl + 3O_2$$

$$\frac{5.00\,g\,KClO_3}{1} \times \frac{1\,mol\,KClO_3}{122.55\,g\,KClO_3} \times \left(\frac{3\,mol\,O_2}{2\,mol\,KClO_3}\right) \times \frac{32\,g\,O_2}{1\,mol\,O_2} = 1.96\,g\,O_2$$

$$\frac{1.25}{1.96} \times 100 = \boxed{63.8\%}$$

2. If 40.0g of magnesium is reacted with excess nitrous acid, and 1.70g of hydrogen is actually produced, what is the percent yield of the reaction?

$$Mg + 2HNO_2 \rightarrow Mg(NO_2)_2 + H_2$$

$$\frac{40.0\,g\,Mg}{1} \times \frac{1\,mol\,Mg}{24.31\,g\,Mg} \times \left(\frac{1\,mol\,H_2}{1\,mol\,Mg}\right) \times \frac{2.016\,g\,H_2}{1\,mol\,H_2} = 3.32\,g\,H_2 \text{ theoretically}$$

$$\frac{1.70}{3.32} \times 100 = \boxed{51.2\% \text{ Yield}}$$

* 3. If 10.0g of aluminum chloride is decomposed, what is the percent yield if [redacted] of chlorine are produced?
2.10g

$$2AlCl_3 \rightarrow 2Al + 3Cl_2$$

$$\frac{10.0\,g\,AlCl_3}{1} \times \frac{1\,mol\,AlCl_3}{133.33\,g\,AlCl_3} \times \left(\frac{3\,mol\,Cl_2}{2\,mol\,AlCl_3}\right) \times \frac{70.9\,g\,Cl_2}{1\,mol\,Cl_2} = 7.98\,g\,Cl_2 \text{ theoretically}$$

$$\frac{2.10\,g}{7.98\,g} \times 100 = \boxed{26.3\% \text{ Yield}}$$

* 4. What is the percent yield of oxygen gas if [redacted] of oxygen is produced by the decomposition of 120.0 g of carbon monoxide?
65.0g

$$2CO \rightarrow 2C + O_2$$

$$\frac{120.0\,g\,CO}{1} \times \frac{1\,mol\,CO}{28.01\,g\,CO} \times \left(\frac{1\,mol\,O_2}{2\,mol\,CO}\right) \times \frac{32\,g\,O_2}{1\,mol\,O_2} = 68.55\,g\,O_2 \text{ theoretically}$$

$$\frac{65.0}{68.55} \times 100 = \boxed{94.8\%}$$

* 5. How many grams of fluorine are needed to react with excess sodium [redacted] to actually produce 120.0 g of sodium fluoride if the reaction has 78.1% yield?
Chloride

$$F_2 + \overset{xs}{2NaCl} \rightarrow \overset{153.6g}{2NaF} + Cl_2$$

$$\frac{120.0\,g}{T} \times 100 = 78.1$$

$$T = 153.6\,g\,NaF$$

$$\frac{153.6\,g\,NaF}{1} \times \frac{1\,mol\,NaF}{42\,g\,NaF} \times \left(\frac{1\,mol\,F_2}{2\,mol\,NaF}\right) \times \frac{38\,g\,F_2}{1\,mol\,F_2} = \boxed{69.5\,g\,F_2}$$

6. Ammonia + oxygen + methane → hydrogen cyanide + water
If 5.00 kg of ammonia is reacted with excess oxygen and methane, how many grams of water would actually be made if the reaction is 82.0% yield?

$$2NH_3 + 3O_2 + 2CH_4 \rightarrow 2HCN + 6H_2O$$

$$\frac{5000\,g\,NH_3}{1} \times \frac{1\,mol\,NH_3}{17.034\,g\,NH_3} \times \left(\frac{6\,mol\,H_2O}{2\,mol\,NH_3}\right) \times \frac{18.016\,g\,H_2O}{1\,mol\,H_2O} = \underset{\uparrow \text{ 3 sig figs}}{15900}\,g\,H_2O$$

$$.82 = \frac{A}{15900}$$

3 sig figs ↓

$$\boxed{A = 1.30 \times 10^4\,g\,H_2O}$$

Limiting Reactant Problems

1. How many atoms of silver will be produced from combining 100.0 g of copper (II) with 200.0 g of silver nitrate?

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

$$\frac{100.0\text{ g Cu}}{1} \times \frac{1\text{ mol Cu}}{63.55\text{ g Cu}} \times \left(\frac{2\text{ mol Ag}}{1\text{ mol Cu}}\right) \times \frac{6.02\times10^{23}\text{ atoms Ag}}{1\text{ mol Ag}} = 1.895\times10^{24}\text{ atoms Ag}$$

$$\boxed{LR} \rightarrow \frac{200.0\text{ g }AgNO_3}{1} \times \frac{1\text{ mol }AgNO_3}{169.91\text{ g }AgNO_3} \times \left(\frac{2\text{ mol Ag}}{2\text{ mol }AgNO_3}\right) \times \frac{6.02\times10^{23}\text{ atoms Ag}}{1\text{ mol Ag}} = \boxed{7.086\times10^{23}\text{ atoms Ag}}$$

2. What mass of "laughing gas" (dinitrogen monoxide) will be produced from 50.0 g of nitrogen gas and 75.0 g of oxygen gas?

$$2N_2 + O_2 \rightarrow 2N_2O$$

$$\boxed{LR} \rightarrow \frac{50.0\text{ g }N_2}{1} \times \frac{1\text{ mol }N_2}{28.02\text{ g }N_2} \times \left(\frac{2\text{ mol }N_2O}{2\text{ mol }N_2}\right) \times \frac{44.02\text{ g }N_2O}{1\text{ mol }N_2O} = \boxed{78.6\text{ g }N_2O}$$

$$\frac{75.0\text{ g }O_2}{1} \times \frac{1\text{ mol }O_2}{32\text{ g }O_2} \times \left(\frac{2\text{ mol }N_2O}{1\text{ mol }O_2}\right) \times \frac{44.02\text{ g }N_2O}{1\text{ mol }N_2O} = 206\text{ g }N_2O$$

3. Carbon monoxide (CO) can be combined with hydrogen gas (H_2) to produce methanol, CH_3OH. If you had 152.5 g of carbon monoxide and 24.5 g of hydrogen gas, how many grams of methanol could be produced?

$$\_\_\_CO + \underline{2}H_2 \rightarrow \_\_\_CH_3OH$$

$$\boxed{LR} \rightarrow \frac{152.5\text{ g CO}}{1} \times \frac{1\text{ mol CO}}{28.01\text{ g CO}} \times \left(\frac{1\text{ mol }CH_3OH}{1\text{ mol CO}}\right) \times \frac{32.042\text{ g }CH_3OH}{1\text{ mol }CH_3OH} = \boxed{174.5\text{ g }CH_3OH}$$

$$\frac{24.5\text{ g }H_2}{1} \times \frac{1\text{ mol }H_2}{2.016\text{ g }H_2} \times \left(\frac{1\text{ mol }CH_3OH}{2\text{ mol }H_2}\right) \times \frac{32.042\text{ g }CH_3OH}{1\text{ mol }CH_3OH} = 194.7\text{ g }CH_3OH$$

4. How many grams of water will be produced from 50.0 g of hydrogen gas and 100.0 g of oxygen gas?

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

$$\frac{50.0\text{ g }H_2}{1} \times \frac{1\text{ mol }H_2}{2.016\text{ g }H_2} \times \left(\frac{2\text{ mol }H_2O}{2\text{ mol }H_2}\right) \times \frac{18.016\text{ g }H_2O}{1\text{ mol }H_2O} = 447\text{ g }H_2O$$

$$\boxed{LR} \rightarrow \frac{100.0\text{ g }O_2}{1} \times \frac{1\text{ mol }O_2}{32\text{ g }O_2} \times \left(\frac{2\text{ mol }H_2O}{1\text{ mol }O_2}\right) \times \frac{18.016\text{ g }H_2O}{1\text{ mol }H_2O} = \boxed{112.6\text{ g }H_2O}$$

5. An unbalanced chemical equation is given as: $\underline{2}\,N_2H_4(l) + \underline{\quad}\,N_2O_4(l) \rightarrow \underline{3}\,N_2(g) + \underline{4}\,H_2O(l)$.

If you begin with 400.0 g of N_2H_4 and 900.0 g of N_2O_4...

A. Find the number of grams of water produced, assuming the reaction goes to completion.

LR

$$\frac{400.0\text{ g } N_2H_4}{1} \times \frac{1\text{ mol } N_2H_4}{32.052\text{ g } N_2H_4} \times \left(\frac{4\text{ mol } H_2O}{2\text{ mol } N_2H_4}\right) \times \frac{18.016\text{ g } H_2O}{1\text{ mol } H_2O} = \boxed{449.7\text{ g } H_2O}$$

$$\frac{900.0\text{ g } N_2O_4}{1} \times \frac{1\text{ mol } N_2O_4}{92.02\text{ g } N_2O_4} \times \left(\frac{4\text{ mol } H_2O}{1\text{ mol } N_2O_4}\right) \times \frac{18.016\text{ g } H_2O}{1\text{ mol } H_2O} = 704.8\text{ g } H_2O$$

B. Find the number of grams of nitrogen produced, assuming the reaction goes to completion.

LR

$$\frac{400.0\text{ g } N_2H_4}{1} \times \frac{1\text{ mol } N_2H_4}{32.052\text{ g } N_2H_4} \times \left(\frac{3\text{ mol } N_2}{2\text{ mol } N_2H_4}\right) \times \frac{28.02\text{ g } N_2}{1\text{ mol } N_2} = \boxed{524.5\text{ g } N_2}$$

6. An unbalanced chemical equation is given as: sodium (s) + oxygen (g) →

If you have 100.0 g of sodium and 60.0 g of oxygen...

$$4\,Na + O_2 \longrightarrow 2\,Na_2O$$

A. What is the limiting reactant?

$$\frac{100.0\text{ g Na}}{1} \times \frac{1\text{ mol Na}}{23\text{ g Na}} \times \left(\frac{2\text{ mol } Na_2O}{4\text{ mol Na}}\right) = 2.174\text{ mol } Na_2O \longrightarrow \boxed{Na}$$

$$\frac{60.0\text{ g } O_2}{1} \times \frac{1\text{ mol } O_2}{32\text{ g } O_2} \times \left(\frac{2\text{ mol } Na_2O}{1\text{ mol } O_2}\right) = 3.75\text{ mol } Na_2O$$

B. Find the number of moles of sodium oxide produced.

$$\boxed{2.174\text{ mol } Na_2O}$$

7. Calcium hydroxide, used to neutralize acid spills, reacts with hydrochloric acid.

$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$$

(a)If you have spilled 6.3 mol of hydrochloric acid and put 2.8 mol of calcium hydroxide on it, which substance is the limiting reactant?

$$\frac{6.3\text{ mol }HCl}{1} \times \left(\frac{1\text{ mol }CaCl_2}{2\text{ mol }HCl}\right) = 3.15\text{ mol }CaCl_2$$

$$\boxed{Ca(OH)_2}$$

$$\frac{2.8\text{ mol }Ca(OH)_2}{1} \times \left(\frac{1\text{ mol }CaCl_2}{1\text{ mol }Ca(OH)_2}\right) = 2.8\text{ mol }CaCl_2$$

(b)How many grams of the excess reactant remain?

* * * *
* Don't worry *
about
* sig figs on *
this one *
* * *

$$\frac{2.8\text{ mol }Ca(OH)_2}{1} \times \left(\frac{2\text{ mol }HCl}{1\text{ mol }Ca(OH)_2}\right) = 5.6\text{ mol }HCl\text{ used up}$$

$$\begin{array}{r} 6.3 \\ -\,5.6 \\ \hline 0.7\text{ mol }HCl \\ \text{left} \end{array}$$

$$\frac{0.7\text{ mol }HCl}{1} \times \frac{35.458\text{ g }HCl}{1\text{ mol }HCl} = \boxed{25.5\text{ g } HCl\text{ left}}$$

8. Heating zinc sulfide in the presence of oxygen yields the following:

$\underline{2}$ ZnS + $\underline{3}$ O_2 → $\underline{2}$ ZnO + $\underline{2}$ SO_2

(a)If 1.72 mol of ZnS is heated in the presence of 3.04 mol of O_2, which is the limiting reactant?

$$\frac{1.72\text{ mol }ZnS}{1} \times \left(\frac{2\text{ mol }ZnO}{2\text{ mol }ZnS}\right) : 1.72\text{ mol }ZnO \qquad \boxed{ZnS}$$

$$\frac{3.04\text{ mol }O_2}{1} \times \left(\frac{2\text{ mol }ZnO}{3\text{ mol }O_2}\right) = 2.03\text{ mol }ZnO$$

(b)How many grams of the excess reactant remain?

$$\frac{1.72\text{ mol }ZnS}{1} \times \left(\frac{3\text{ mol }O_2}{2\text{ mol }ZnS}\right) : 2.58\text{ mol }O_2\text{ used up}$$

$$\begin{array}{r} 3.04 \\ -\,2.58 \\ \hline 0.46\text{ mol }O_2\text{ left} \end{array}$$

$$\frac{0.46\text{ mol }O_2}{1} \times \frac{32\text{ g }O_2}{1\text{ mol }O_2} = 14.72\text{ g }O_2 \longrightarrow \boxed{15\text{ g }O_2}$$

9. Chlorine can replace bromine in bromide compounds forming a chloride compound and elemental bromine. The following equation is an example of the reaction:

$\underline{2}\,KBr(aq) + \underline{\quad}\,Cl_2(aq) \rightarrow Br_2 + 2KCl$

(a)When 0.855g of Cl_2 and 3.205g of KBr are mixed in solution, which is the limiting reactant?

$$\frac{0.855\text{g } Cl_2}{1} \times \frac{1\text{ mol } Cl_2}{70.9\text{ g } Cl_2} \times \left(\frac{1\text{ mol } Br_2}{1\text{ mol } Cl_2}\right) \times \frac{159.8\text{ g } Br_2}{1\text{ mol } Br_2} = 1.93\text{ g } Br_2$$

Cl_2

$$\frac{3.205\text{g } KBr}{1} \times \frac{1\text{ mol } KBr}{119\text{ g } KBr} \times \left(\frac{1\text{ mol } Br_2}{2\text{ mol } KBr}\right) \times \frac{159.8\text{ g } Br_2}{1\text{ mol } Br_2} = 2.15\text{ g } Br_2$$

(b)How many grams of each product are theoretically formed?

1.93 g Br_2

$$\frac{0.855\text{g } Cl_2}{1} \times \frac{1\text{ mol } Cl_2}{70.9\text{ g } Cl_2} \times \left(\frac{2\text{ mol } KCl}{1\text{ mol } Cl_2}\right) \times \frac{74.55\text{ g } KCl}{1\text{ mol } KCl} = 1.80\text{ g } KCl$$

10. Zirconium metal can be produced from the mineral zirconium (IV) orthosilicate, $ZrSiO_4$, reacting with chlorine gas to form zirconium (IV) chloride, silicon dioxide, and oxygen.

$$ZrSiO_4 + 2Cl_2 \longrightarrow ZrCl_4 + SiO_2 + O_2$$

What mass of zirconium (IV) chloride can be produced if 862g of $ZrSiO_4$ and 950.0 g of chlorine are available? (You must first determine limiting reactant).

$$\frac{862\text{g } ZrSiO_4}{1} \times \frac{1\text{ mol } ZrSiO_4}{183.31\text{ g } ZrSiO_4} \times \left(\frac{1\text{ mol } ZrCl_4}{1\text{ mol } ZrSiO_4}\right) \times \frac{233.02\text{ g } ZrCl_4}{1\text{ mol } ZrCl_4} = 1096\text{ g } ZrCl_4$$

↳ 1100 g $ZrCl_4$

$$\frac{950.0\text{ g } Cl_2}{1} \times \frac{1\text{ mol } Cl_2}{70.9\text{ g } Cl_2} \times \left(\frac{1\text{ mol } ZrCl_4}{2\text{ mol } Cl_2}\right) \times \frac{233.02\text{ g } ZrCl_4}{1\text{ mol } ZrCl_4} = 1561\text{ g } ZrCl_4$$

11. Huge quantities of sulfur dioxide are produced from zinc sulfide by means of the following reaction.

$\underline{2}\,ZnS(s) + \underline{3}\,O_2(g) \rightarrow \underline{2}\,ZnO(s) + \underline{2}\,SO_2(g)$

If the typical yield is 86.78%, how much SO_2 should be expected if 4897g of ZnS are used?

$$\frac{4897\text{g } ZnS}{1} \times \frac{1\text{ mol } ZnS}{97.46\text{ g } ZnS} \times \left(\frac{2\text{ mol } SO_2}{2\text{ mol } ZnS}\right) \times \frac{64.07\text{ g } SO_2}{1\text{ mol } SO_2} = 3219\text{ g } SO_2$$

$$.8678 = \frac{A}{3219} = \boxed{2794\text{ g } SO_2}$$

12. Aspirin, $C_9H_8O_4$, is synthesized by the reaction of salicylic acid, $C_7H_6O_3$, with acetic anhydride, $C_4H_6O_3$.

$\underline{2}\,C_7H_6O_3 + \_\_\_C_4H_6O_3 \rightarrow \underline{2}\,C_9H_8O_4 + \_\_\_H_2O$

a. When 20.0 g of $C_7H_6O_3$and 20.0g of $C_4H_6O_3$ react, which is the limiting reagent? $\boxed{C_7H_6O_3}$

$$\frac{20.0g\ C_7H_6O_3}{1} \times \frac{1 mol\ C_7H_6O_3}{138.118g\ C_7H_6O_3} \times \left(\frac{2 mol\ C_9H_8O_4}{2 mol\ C_7H_6O_3}\right) \times \frac{180.154g\ C_9H_8O_4}{1 mol\ C_9H_8O_4} = 26.1 g\ C_9H_8O_4$$

$$\frac{20.0g\ C_4H_6O_3}{1} \times \frac{1 mol\ C_4H_6O_3}{102.088g\ C_4H_6O_3} \times \left(\frac{2 mol\ C_9H_8O_4}{1 mol\ C_4H_6O_3}\right) \times \frac{180.154g\ C_9H_8O_4}{1 mol\ C_9H_8O_4} = \cancel{70.6g}\ C_9H_8O_4$$

b. What mass in grams of aspirin are theoretically formed?

$\boxed{26.1 g\ C_9H_8O_4}$

13. Dichlorine monoxide, Cl_2O is sometimes used as a powerful chlorinating agent in research. It can be produced by passing chlorine gas over heated mercury (II) oxide according to the following equation:

$\_\_\_HgO + \_\_\_Cl_2 \rightarrow \_\_\_HgCl_2 + \_\_\_Cl_2O$

What is the percent yield, if the quantity of the reactants is sufficient to produce 0.86g of Cl_2O but only 0.71 g is obtained? $\frac{0.71}{0.86} \times 100 = \boxed{83\%}$

14. In the commercial production of the element arsenic, arsenic(III) oxide is heated with carbon, which reduces the oxide to the metal according to the following equation:

$\underline{2}\,As_2O_3 + \underline{3}\,C \rightarrow \underline{3}\,CO_2 + \underline{4}\,As$

a. If 8.87g of As_2O_3 is used in the reaction and 5.33 g of As is produced, what is the percent yield?

$$\frac{8.87g\ As_2O_3}{1} \times \frac{1 mol\ As_2O_3}{197.84 g\ As_2O_3} \times \left(\frac{4 mol\ As}{2 mol\ As_2O_3}\right) \times \frac{74.92 g\ As}{1 mol\ As} = 6.72 g\ As$$

$$100 \times \frac{5.33}{6.72} = \boxed{79.3\%}$$

b. If 67.0 g of carbon is used up in a different reaction and 425 g of As is produced, calculate the percent yield of this reaction.

$$\frac{67.0 g C}{1} \times \frac{1 mol\ C}{12.01g C} \times \left(\frac{4 mol\ As}{3 mol\ C}\right) \times \frac{74.92 g\ As}{1 mol\ As} = 557 g\ As$$

$$\frac{425}{557} \times 100 = \boxed{76.3\%}$$

Chemistry Review Name ______________________________

Chapter 9 - Stoichiometry Period _______ Date _______________

I. Mole Ratios

The number of moles of substances involved in a reaction, when compared, yield a mole ratio. For example, given the equation: $2 H_2 + O_2 \rightarrow 2 H_2O$, the mole ratio of H_2 to O_2 is 2 to 1 , or 2:1.

II. Stoichiometry Calculations

1. What mass of $ZnSO_4$ is produced when 10.0 grams of zinc (II) reacts with sulfuric acid?

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

$$\frac{10.0g\ Zn}{1} \times \frac{1\ mol\ Zn}{65.38g\ Zn} \times \left(\frac{1\ mol\ ZnSO_4}{1\ mol\ Zn}\right) \times \frac{161.46\ g\ ZnSO_4}{1\ mol\ ZnSO_4} = \boxed{24.7g\ ZnSO_4}$$

2. What mass of iron (III) nitrate is needed to produce 17.8 grams of ammonium nitrate in a reaction with ammonium hydroxide?

$$Fe(NO_3)_3 + 3NH_4OH \rightarrow 3NH_4NO_3 + Fe(OH)_3$$

$$\frac{17.8g\ NH_4NO_3}{1} \times \frac{1\ mol\ NH_4NO_3}{80.052g\ NH_4NO_3} \times \left(\frac{1\ mol\ Fe(NO_3)_3}{3\ mol\ NH_4NO_3}\right) \times \frac{241.88\ g\ Fe(NO_3)_3}{1\ mol\ Fe(NO_3)_3} = \boxed{17.9g\ Fe(NO_3)_3}$$

3. How many moles of calcium oxide are produced when 36.5 grams of calcium reacts with oxygen gas?

$$2Ca + O_2 \rightarrow 2CaO$$

$$\frac{36.5\ g\ Ca}{1} \times \frac{1\ mol\ Ca}{40.08g\ Ca} \times \left(\frac{2\ mol\ CaO}{2\ mol\ Ca}\right) = \boxed{0.911\ mol\ CaO}$$

4. What mass of iodine is produced by the decomposition of 25.4 grams of aluminum iodide?

$$2AlI_3 \rightarrow 2Al + 3I_2$$

$$\frac{25.4\ g\ AlI_3}{1} \times \frac{1\ mol\ AlI_3}{407.68\ g\ AlI_3} \times \left(\frac{3\ mol\ I_2}{2\ mol\ AlI_3}\right) \times \frac{253.8g\ I_2}{1\ mol\ I_2} = \boxed{23.7\ g\ I_2}$$

$$MgO + K_2SO_4 \longrightarrow MgSO_4 + K_2O$$

5. What mass of magnesium oxide is needed to react with 77.0 grams of potassium sulfate?

$$\frac{77.0\,g\,K_2SO_4}{1} \times \frac{1\,mol\,K_2SO_4}{174.27\,g\,K_2SO_4} \times \left(\frac{1\,mol\,MgO}{1\,mol\,K_2SO_4}\right) \times \frac{40.31\,g\,MgO}{1\,mol\,MgO} = \boxed{17.8\,g\,MgO}$$

III. Limiting Reactants

1. When 8.51 grams of hydrogen reacts with 9.25 grams of oxygen, how many grams of water are produced?

$$2H_2 + O_2 \rightarrow 2H_2O \qquad \boxed{10.4\,g\,H_2O}$$

What is the limiting reactant? O_2

What mass of the excess reactant left unreacted? 7.34 g H_2

$$\frac{8.51\,g\,H_2}{1} \times \frac{1\,mol\,H_2}{2.016\,g\,H_2} \times \left(\frac{2\,mol\,H_2O}{2\,mol\,H_2}\right) \times \frac{18.016\,g\,H_2O}{1} = 76.0\,g\,H_2O$$

$$\begin{array}{r} 8.51\,g\,H_2 \\ -1.17\,g\,H_2 \\ \hline \boxed{7.34\,g\,H_2} \end{array}$$

$$\frac{9.25\,g\,O_2}{1} \times \frac{1\,mol\,O_2}{32\,g\,O_2} \times \left(\frac{2\,mol\,H_2O}{1\,mol\,O_2}\right) \times \frac{18.016\,g\,H_2O}{1\,mol\,H_2O} = 10.4\,g\,H_2O$$

$$\frac{9.25\,g\,O_2}{1} \times \frac{1\,mol\,O_2}{32\,g\,O_2} \times \left(\frac{2\,mol\,H_2}{1\,mol\,O_2}\right) \times \frac{2.016\,g\,H_2}{1\,mol\,H_2} = 1.17\,g\,H_2 \text{ used}$$

2. What mass of carbonic acid is produced when 40.0 grams of calcium carbonate reacts with 6.0 grams of sulfuric acid?

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2CO_3 \qquad \boxed{3.79\,g\,H_2CO_3}$$

What is the limiting reactant? H_2SO_4

What mass of the excess reactant left unreacted? 33.9 g $CaCO_3$

$$\frac{40.0\,g\,CaCO_3}{1} \times \frac{1\,mol\,CaCO_3}{100.09\,g\,CaCO_3} \times \left(\frac{1\,mol\,H_2CO_3}{1\,mol\,CaCO_3}\right) \times \frac{62.026\,g\,H_2CO_3}{1\,mol\,H_2CO_3} = 24.8\,g\,H_2CO_3$$

$$\frac{6.0\,g\,H_2SO_4}{1} \times \frac{1\,mol\,H_2SO_4}{98.086\,g\,H_2SO_4} \times \left(\frac{1\,mol\,H_2CO_3}{1\,mol\,H_2SO_4}\right) \times \frac{62.026\,g\,H_2CO_3}{1\,mol\,H_2CO_3} = 3.79\,g\,H_2CO_3$$

$$\frac{6.0\,g\,H_2SO_4}{1} \times \frac{1\,mol\,H_2SO_4}{98.086\,g\,H_2SO_4} \times \left(\frac{1}{1}\right) \times \frac{100.09\,g\,CaCO_3}{1\,mol} = 6.1\,g\,CaCO_3$$

$$\begin{array}{r} 40.0 \\ -6.1 \\ \hline \boxed{33.9\,g\,CaCO_3 \text{ left}} \end{array}$$

3. What mass of zinc is produced when 5.0 grams of aluminum react with 4.0 grams of zinc (II) sulfide? $\boxed{2.7\,g\,Zn}$

What is the limiting reactant? ZnS

$$2Al + 3ZnS \rightarrow 3Zn + Al_2S_3$$

What mass of the excess reactant left unreacted? 4.3 g Al left (4.26g)

$$\frac{5.0\,g\,Al}{1} \times \frac{1\,mol\,Al}{26.98\,g\,Al} \times \left(\frac{3\,mol\,Zn}{2\,mol\,Al}\right) \times \frac{65.39\,g\,Zn}{1\,mol\,Zn} = \cancel{18\,g\,Zn}$$

$$\frac{4.0\,g\,ZnS}{1} \times \frac{1\,mol\,ZnS}{97.46\,g\,ZnS} \times \left(\frac{2\,mol\,Al}{3\,mol\,ZnS}\right) \times \frac{26.98\,g\,Al}{1\,mol\,Al} = 0.74\,g\,Al \text{ used}$$

$$\frac{4.0\,g\,ZnS}{1} \times \frac{1\,mol\,ZnS}{97.46\,g\,ZnS} \times \left(\frac{3\,mol\,Zn}{3\,mol\,ZnS}\right) \times \frac{65.39\,g\,Zn}{1\,mol\,Zn} = 2.7\,g\,Zn$$

$$\begin{array}{r} 5.0 \\ -0.74 \\ \hline \boxed{4.3\,g\,Al} \end{array}$$

IV. Percent Yield

1. Fill in the table below:

ACTUAL YIELD	THEORETICAL YIELD	PERCENT YIELD
15.8 g	25.0 g	63.2%
2.5 g	3.8	65 %
110.9	135.0 g	82.15 %
.0054 g	.0115 g	47 %

2. What is the percent yield for the production of magnesium oxide where 50.0 grams of oxygen react with excess magnesium? The actual yield was found to be 100.0 g of magnesium oxide.

$$2Mg + O_2 \longrightarrow 2MgO$$

$$\frac{50.0g\ O_2}{1} \times \frac{1\ mol\ O_2}{32g\ O_2} \times \left(\frac{2\ mol\ MgO}{1\ mol\ O_2}\right) \times \frac{40.31g\ MgO}{1\ mol\ MgO} = 126g\ MgO$$

$$\frac{100.0g\ MgO}{126\ g\ MgO} = \boxed{79.4\%}$$