Corrections to key.

p. 10 1c should be Carbor

~~p. 9 4 should be 50g~~

p. 12 6c should add ~~.55g~~ 0.553g

p. 16 4b 87%

p 16 4c 230g

Mass Relationships in Chemical Reactions

Key

①. $2Li + 2H_2O \longrightarrow 2LiOH + H_2$

$$\frac{6.23\text{ mol Li}}{} \left| \frac{1\text{ mol }H_2}{2\text{ mol Li}} \right. = \boxed{3.12\text{ mol }H_2}$$

② $$\frac{80.57\text{ g Li}}{} \left| \frac{1\text{ mol Li}}{6.94\text{ g Li}} \right| \frac{1\text{ mol }H_2}{2\text{ mol Li}} \left| \frac{2.02\text{ g }H_2}{1\text{ mol }H_2} \right. = \boxed{11.73\text{ g }H_2}$$

③ $2NO + O_2 \longrightarrow 2NO_2$

$$\frac{0.254\text{ mol }O_2}{} \left| \frac{2\text{ mol }NO_2}{1\text{ mol }O_2} \right. = \boxed{0.508\text{ mol }NO_2}$$

④. $$\frac{1.44\text{ g NO}}{} \left| \frac{1\text{ mol NO}}{30.01\text{ g NO}} \right| \frac{2\text{ mol }NO_2}{2\text{ mol NO}} \left| \frac{46.01\text{ g }NO_2}{1\text{ mol }NO_2} \right. = \boxed{2.21\text{ g }NO_2}$$

⑤. $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$

$$\frac{856\text{ g }C_6H_{12}O_6}{} \left| \frac{1\text{ mol }C_6H_{12}O_6}{\begin{array}{c}\cancel{116.06}\text{ g }C_6H_{12}O_6\\ 180.16\text{ g }C_6H_{12}O_6\end{array}} \right| \frac{6\text{ mol }CO_2}{1\text{ mol }C_6H_{12}O_6} \left| \frac{44.01\text{ g }CO_2}{1\text{ mol }CO_2} \right. = \boxed{[illegible]}$$

1250 g CO_2

⑥. $2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$

$$\frac{209\text{ g }CH_3OH}{} \left| \frac{1\text{ mol }CH_3OH}{32.01\text{ g }CH_3OH} \right| \frac{3\text{ mol }O_2}{2\text{ mol }CH_3OH} \left| \frac{32.00\text{ g }O_2}{1\text{ mol }O_2} \right. = \boxed{313\text{ g }O_2}$$

⑦ $$\frac{209\text{ g }CH_3OH}{} \left| \frac{1\text{ mol }CH_3OH}{32.01\text{ g }CH_3OH} \right| \frac{2\text{ mol }CO_2}{2\text{ mol }CH_3OH} \left| \frac{44.01\text{ g }CO_2}{1\text{ mol }CO_2} \right. = \boxed{287\text{ g }CO_2}$$

STOICHIOMETRY:
MOLE-MOLE PROBLEMS

Name ________________

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

How many moles of hydrogen are needed to completely react with two moles of nitrogen?

$$\begin{array}{c|c} 2\text{ mol } N_2 & 3\text{ mol } H_2 \\ \hline & 1\text{ mol } N_2 \end{array}$$

$6\text{ mol } H_2$

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

How many moles of oxygen are produced by the decomposition of six moles of potassium chlorate?

$$\begin{array}{c|c} 6\text{ mol } KClO_3 & 3\text{ mol } \overset{O_2}{\cancel{KClO_3}} \\ \hline & 2\text{ mol } KClO_3 \end{array} \; s$$

$9 \; \cancel{18} \text{ mol } O_2$

3. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

How many moles of hydrogen are produced from the reaction of three moles of zinc with an excess of hydrochloric acid?

$$\begin{array}{c|c} 3\text{ mol } Zn & 1\text{ mol } H_2 \\ \hline & 1\text{ mol } Zn \end{array}$$

$3\text{ mol } H_2$

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

How many moles of oxygen are necessary to react completely with four moles of propane (C_3H_8)?

$$\begin{array}{c|c} 4\text{ mol } C_3H_8 & 5\text{ mol } O_2 \\ \hline & 1\text{ mol } C_3H_8 \end{array} \; s$$

$20\text{ mol } O_2$

5. $K_3PO_4 + Al(NO_3)_3 \rightarrow 3KNO_3 + AlPO_4$

How many moles of potassium nitrate are produced when two moles of potassium phosphate react with two moles of aluminum nitrate?

$$\begin{array}{c|c} 2\text{ mol } K_3PO_4 & 3\text{ mol } KNO_3 \\ \hline & 1\text{ mol } K_3PO_4 \end{array}$$

$6\text{ mol } KNO_3$

TOICHIOMETRY:
O ME-VOLUME PROBLEMS

Name ____________________

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

What volume of hydrogen is necessary to react with five liters of nitrogen to produce ammonia? (Assume constant temperature and pressure.)

$$\begin{array}{c|c} 5\text{ L }\cancel{N_2} & 3\text{ mol }H_2 \\ \hline & 1\text{ mol }\cancel{N_2} \end{array} = 15\text{ L }H_2$$

$$\begin{array}{c|c|c|c} 5\text{ L }N_2 & \cancel{1\text{ mol }N_2} & 3\text{ mol }H_2 & \cancel{22.4\text{ L }H_2} \\ \hline & \cancel{22.4\text{ L }N_2} & 1\text{ mol }N_2 & \cancel{1\text{ mol }H_2} \end{array}$$

15 L H_2

2. What volume of ammonia is produced in the reaction in Problem 1?

$$\begin{array}{c|c} 5\text{ L }N_2 & 2\text{ mol }NH_3 \\ \hline & 1\text{ mol }N_2 \end{array} =$$

10 L NH_3

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

If 20 liters of oxygen are consumed in the above reaction, how many liters of carbon dioxide are produced?

$$\begin{array}{c|c} 20\text{ L }O_2 & 3\text{ mol }CO_2 \\ \hline & 5\text{ mol }O_2 \end{array} =$$

12 L CO_2

4. $2H_2O \rightarrow 2H_2 + O_2$

If 30 mL of hydrogen are produced in the above reaction, how many milliliters of oxygen are produced?

$$\begin{array}{c|c} 30\text{ mL }H_2 & 1\text{ mol }O_2 \\ \hline & 2\text{ mol }H_2 \end{array} =$$

15 mL O_2

5. $2CO + O_2 \rightarrow 2CO_2$

How many liters of carbon dioxide are produced if 75 liters of carbon monoxide are burned in oxygen? How many liters of oxygen are necessary?

$$\begin{array}{c|c} 75\text{ L }CO & 2\text{ mol }CO_2 \\ \hline & 2\text{ mol }CO \end{array}$$

$$\begin{array}{c|c} 75\text{ L }CO & 1\text{ mol }O_2 \\ \hline & 2\text{ mol }CO \end{array}$$

75
~~150~~ L CO_2
38 L O_2

Sec 3.9 Limiting Reactants

③ $\underline{2}\,NH_3\,(g) + \_\_CO_2\,(g) \rightarrow \_\_(NH_2)_2CO\,(s) + \_\_H_2O\,(l)$

637.2g   1142g   x g

$637.2g\ NH_3 \times \frac{1\ mol\ NH_3}{17.03g} = 37.42\ moles\ NH_3$

$1142g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01g} = 25.95\ moles\ CO_2$

$25.95\ mol\ CO_2 \times \frac{2\ mol\ NH_3}{1\ mol\ CO_2} = 51.90\ mol\ NH_3$ needed to react with all of the CO_2.

b) LR is NH_3 because < 51.90 moles is available

a) $37.42\ mol\ NH_3 \times \frac{1\ mol\ (NH_2)_2CO}{2\ mol\ NH_3} \times \frac{60.06g}{1\ mol\ (NH_2)_2CO} = \boxed{1124g\ (NH_2)_2CO}$

c) Excess reactant is CO_2

$37.42\ moles\ NH_3 \times \frac{1\ mole\ CO_2}{2\ mol\ NH_3} = 18.71\ moles\ CO_2$ react

$25.95 - 18.71 = 7.24\ mol\ CO_2 \times \frac{44.01g\ CO_2}{1\ mole}$

$= \boxed{318g\ CO_2\ \text{remain}}$

④ $\underline{2}Al_{(s)} + Fe_2O_{3\,(s)} \rightarrow Al_2O_{3\,(s)} + Fe_{(s)}$

124g   601g   x g

$$124g\,Al \times \frac{1mol\,Al}{26.98g} \times \frac{2mol\,Fe}{2mol\,Al} \times \frac{55.85g\,Fe}{1mole\,Fe} = 257g\,Fe$$

$$601g\,Fe_2O_3 \times \frac{1mol\,Fe_2O_3}{159.7g} \times \frac{2\,mol\,Fe}{1mol\,Fe_2O_3} \times \frac{55.85g\,Fe}{1mole\,Fe} = 420g\,Fe$$

a) Smaller amount is the maximum amount that can be produced. $\boxed{257g\,Fe}$

b) Limiting Reactant is Aluminum. When 257 g of iron have been produced, the Aluminum is used up and the reaction stops.

c) $$124g\,Al \times \frac{1mol\,Al}{26.98\,g} \times \frac{1mol\,Fe_2O_3}{2mol\,Al} \times \frac{159.7g\,Fe_2O_3}{1mol}$$

$= 367g\,Fe_2O_3$ reacts

$601 - 367 = \boxed{234g \text{ of } Fe_2O_3 \text{ remain}}$

①a) $$\begin{array}{l|l|l|l} 55.6\text{ g H}_2 & 1\text{ mol H}_2 & 2\text{ mol NH}_3 & 17.04\text{ g NH}_3 \\ \hline & 2.02\text{ g H}_2 & 3\text{ mol H}_2 & 1\text{ mol NH}_3 \end{array} = 312.68 \sim \boxed{313\text{ g}}$$

b) $$\frac{159\text{ g}}{313\text{ g}} \times 100 = \boxed{50.5\%}$$

②a) $$\begin{array}{l|l|l|l} 1.20\text{ g H}_2 & 1\text{ mol H}_2 & 1\text{ mol CH}_3\text{OH} & 32.05\text{ g CH}_3\text{OH} \\ \hline & 2.02\text{ g H}_2 & 2\text{ mol H}_2 & 1\text{ mol CH}_3\text{OH} \end{array} = 9.52\text{ g CH}_3\text{OH}$$

$$\begin{array}{l|l|l|l} 7.45\text{ g CO} & 1\text{ mol CO} & 1\text{ mol CH}_3\text{OH} & 32.05\text{ g CH}_3\text{OH} \\ \hline & 28.01\text{ g CO} & 1\text{ mol CO} & 1\text{ mol CH}_3\text{OH} \end{array} = \boxed{8.52\text{ g CH}_3\text{OH}}$$

b) CO

c) $$\begin{array}{l|l|l|l} 7.45\text{ g CO} & 1\text{ mol CO} & 2\text{ mol H}_2 & 2.02\text{ g H}_2 \\ \hline & 28.01\text{ g CO} & 1\text{ mol CO} & 1\text{ mol H}_2 \end{array} = 1.07\text{ g H}_2$$

$$1.20\text{ g} - 1.07 = \boxed{0.13\text{ g H}_2}$$

d) $$\frac{7.52\text{ g}}{8.52\text{ g}} \times 100 = \boxed{88.3\%}$$

③a) $$\begin{array}{l|l} 1.25\text{ L C}_2\text{H}_4 & 2\text{ mol H}_2\text{O} \\ \hline & 1\text{ mol C}_2\text{H}_4 \end{array} = \boxed{2.50\text{ L H}_2\text{O}}$$

b) $$\frac{2.58\text{ L}}{2.50\text{ L}} \times 100 = \boxed{103\%}$$

④a) $$\begin{array}{l|l|l|l} 125\text{ g HC}_2\text{H}_3\text{O}_2 & 1\text{ mol HC}_2\text{H}_3\text{O}_2 & 1\text{ mol Al(C}_2\text{H}_3\text{O}_2)_3 & \overset{204.13}{\cancel{86.03}}\text{ g Al(C}_2\text{H}_3\text{O}_2)_3 \\ \hline & 60.06\text{ g HC}_2\text{H}_3\text{O}_2 & 3\text{ mol HC}_2\text{H}_3\text{O}_2 & 1\text{ mol Al(C}_2\text{H}_3\text{O}_2)_3 \end{array} \boxed{= 142\text{ g Al(C}_2\text{H}_3\text{O}_2)_3}$$

$$\begin{array}{l|l|l|l} 275\text{ g Al(OH)}_3 & 1\text{ mol Al(OH)}_3 & 1\text{ mol Al(C}_2\text{H}_3\text{O}_2)_3 & 204.13\text{ g Al(C}_2\text{H}_3\text{O}_2)_3 \\ \hline & 78.01\text{ g Al(OH)}_3 & 1\text{ mol Al(OH)}_3 & 1\text{ mol Al(C}_2\text{H}_3\text{O}_2)_3 \end{array} = 720\text{ g Al(C}_2\text{H}_3\text{O}_2)_3$$

b) $HC_2H_3O_2$

$$\begin{array}{l|l|l|l} 125\text{ g HC}_2\text{H}_3\text{O}_2 & 1\text{ mol HC}_2\text{H}_3\text{O}_2 & 1\text{ mol Al(OH)}_3 & 78.01\text{ g Al(OH)}_3 \\ \hline & 60.06\text{ g HC}_2\text{H}_3\text{O}_2 & 3\text{ mol HC}_2\text{H}_3\text{O}_2 & 1\text{ mol Al(OH)}_3 \end{array} = 54.1\text{ g Al(OH)}_3$$

$$275\text{ g} - 54.1\text{ g} = \boxed{221\text{ g Al(OH)}_3}$$

3.10 % Yield

① $TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$

$3.54 \times 10^7 g$ $\quad 1.13 \times 10^7 g$ $\qquad\qquad x\ g$

$$3.54 \times 10^7 g\ TiCl_4 \times \frac{1\ mole\ TiCl_4}{189.68g} \times \frac{1\ mol\ Ti}{1\ mol\ TiCl_4} \times \frac{47.88g\ Ti}{1\ mole}$$

$= 8.94 \times 10^6 g$ Ti possible

$$1.13 \times 10^7 g\ Mg \times \frac{1\ mol\ Mg}{24.31g} \times \frac{1\ mol\ Ti}{2\ mol\ Mg} \times \frac{47.88g\ Ti}{1\ mole}$$

$= 1.11 \times 10^7 g$ Ti possible

a) Theoretical yield $= 8.94 \times 10^6 g$ Ti because when this is produced, the reaction will stop since all of the $TiCl_4$ is used up.

b. $$\% \text{ Yied} = \frac{\text{Actual}}{\text{Theoretical}} \times 100 = \frac{7.91 \times 10^6 g\ Ti}{8.94 \times 10^6 g\ \text{possible}} \times 100$$

$$= \boxed{88.5\%}$$

② $\underline{5}\,Ca + V_2O_5 \rightarrow \underline{5}\,CaO + \underline{2}\,V$

$1.96 \times 10^3\,g$ $1.54 \times 10^3\,g$ $x\,g$

$$1.96 \times 10^3\,g\ Ca \times \frac{1\ mol\ Ca}{40.08\,g} \times \frac{2\ mol\ V}{5\ mol\ Ca} \times \frac{50.94\,g\ V}{1\ mole}$$

$= 9.96 \times 10^2\,g$ V possible

$$1.54 \times 10^3\,g\ V_2O_5 \times \frac{1\ mol\ V_2O_5}{[illegible]1.88\,g} \times \frac{2\ mol\ V}{1\ mol\ V_2O_5} \times \frac{50.94\,g\ V}{1\ mol}$$

181.

= [illegible] 862 g V possible

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a) Theoretical yield = 862 [illegible] g V because when this is produced, all of the V_2O_5 is used up.

b) % Yield $= \frac{803\,g}{862\,g} \times 100 = \boxed{93.2\%}$

Limiting Reactants

Limiting reactant –

Excess reactant-

Assume all gases are at STP.

1. Carbon reacts with oxygen to produce carbon dioxide.

   a. Write the balanced equation showing physical states

   $$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$

   b. How many grams of CO_2 are formed if 10.0 g of carbon are burned in 20.0 L of O_2?

If C is LR

$$\begin{array}{l|l|l|l} 10.0\text{ g C} & 1\text{ mol C} & 1\text{ mol CO}_2 & 44.01\text{ g CO}_2 \\ \hline & 12.01\text{ g C} & 1\text{ mol C} & 1\text{ mol CO}_2 \end{array} = \boxed{36.6\text{ g CO}_2}$$

If O_2 is LR

$$\begin{array}{l|l|l|l} 20.0\text{ L O}_2 & 1\text{ mol O}_2 & 1\text{ mol CO}_2 & 44.01\text{ g CO}_2 \\ \hline & 22.4\text{ L O}_2 & 1\text{ mol O}_2 & 1\text{ mol CO}_2 \end{array} = 39.3\text{ g}$$

   c. What is the limiting reactant?

   Carbon

2. Calcium reacts with water to produce solid calcium hydroxide, $Ca(OH)_2$, and hydrogen gas.

   a. Write the balanced equation showing physical states

   $$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + 1H_{2(g)}$$

   b. What volume of hydrogen is formed when 15.0 g of calcium reacts with 10.0 g of water?

If Ca is LR

$$\begin{array}{l|l|l|l} 15.0\text{ g Ca} & 1\text{ mol Ca} & 1\text{ mol H}_2 & 22.4\text{ L H}_2 \\ \hline & 40.08\text{ g Ca} & 1\text{ mol Ca} & 1\text{ mol H}_2 \end{array} = 8.38\text{ L H}_2$$

If H_2O is LR

$$\begin{array}{l|l|l|l} 10.0\text{ g H}_2\text{O} & 1\text{ mol H}_2\text{O} & 1\text{ mol H}_2 & 22.4\text{ L H}_2 \\ \hline & 18.02\text{ g H}_2\text{O} & 2\text{ mol H}_2\text{O} & 1\text{ mol H}_2 \end{array} = \boxed{6.22}\text{ L H}_2$$

   c. What is the limiting reactant?

   Water

2

3. Sodium metal reacts with chlorine to produce crystalline sodium chloride, NaCl.

a. Write the balanced equation showing physical states

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

b. How much sodium chloride is produced when 2.50g of sodium reacts with 2.5 L of chlorine gas?

if Na is LR

$$\begin{array}{l|l|l} 2.50\text{ g Na} & 1\text{ mol Na} & 2\text{ mol NaCl} \\ \hline & 22.99\text{ g Na} & 2\text{ mol Na} \end{array} = \boxed{\begin{array}{l} 0.109\text{ mol} \\ \text{mol NaCl} \end{array}}$$

if Cl_2 is LR

$$\begin{array}{l|l|l} 2.5\text{ L }Cl_2 & 1\text{ mol }Cl_2 & 2\text{ mol NaCl} \\ \hline & 22.4\text{ L }Cl_2 & 1\text{ mol }Cl_2 \end{array} = \cancel{0.22\text{ mol NaCl}}$$

c. What is the limiting reactant?

~~Chlorine gas~~ Sodium

4. Glucose, $C_6H_{12}O_6$ (s), undergoes combustion to form the same products as a hydrocarbon.

a. Write the balanced equation showing physical states.

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6H_2O_{(g)} + 6CO_{2(g)}$$

b. What mass of carbon dioxide is formed when 85.0 g of glucose combines with 75.0 L of oxygen?

if glucose is LR

$$\begin{array}{l|l|l|l} 85.0\text{ g }C_6H_{12}O_6 & 1\text{ mol }C_6H_{12}O_6 & 6\text{ mol }CO_2 & 44.01\text{ g }CO_2 \\ \hline & 180.2\text{ g }C_6H_{12}O_6 & 1\text{ mol }C_6H_{12}O_6 & 1\text{ mol }CO_2 \end{array} = \boxed{125\text{ g }CO_2}$$

if O_2 is LR

$$\begin{array}{l|l|l|l} 75.0\text{ L }O_2 & 1\text{ mol }O_2 & 6\text{ mol }CO_2 & \overset{44.01\text{ g}}{\cancel{22.4\text{ L}}}\ CO_2 \\ \hline & 22.4\text{ L }O_2 & 6\text{ mol }O_2 & 1\text{ mol }CO_2 \end{array} = 147\text{ g }CO_2$$

c. What volume does the carbon dioxide occupy?

$$\begin{array}{l|l|l} 125\text{ g }CO_2 & 1\text{ mol }CO_2 & 22.4\text{ L }CO_2 \\ \hline & 44.01\text{ g }CO_2 & 1\text{ mol }CO_2 \end{array} = \boxed{63.6\text{ L }CO_2}$$

d.. What is the limiting reactant?

glucose

5. Hydrogen sulfide reacts with an aqueous solution of iodine to produce hydroiodic acid, HI (aq) and sulfur.

a. Write the balanced equation showing physical states

$H_2S_{(g)} + I_{2(aq)} \longrightarrow 2HI_{(aq)} + S_{(s)}$

b. What mass of sulfur is produced by 4.11g of iodine and 317 mL of hydrogen sulfide?

if I_2 is LR

$$\frac{4.11\,g\ I_2}{} \cdot \frac{1\ mol\ I_2}{253.8\,g\ I_2} \cdot \frac{1\ mol\ S}{1\ mol\ I_2} \cdot \frac{32.07\,g\ S}{1\ mol\ S} = 0.519\ g\ S$$

if H_2S is LR

$$\frac{317\ mL\ H_2S}{} \cdot \frac{1\ L\ H_2S}{1000\ mL\ H_2S} \cdot \frac{1\ mol\ H_2S}{22.4\ L\ H_2S} \cdot \frac{1\ mol\ S}{1\ mol\ H_2S} \cdot \frac{32.07\,g\ S}{1\ mol\ S} = \boxed{0.454\,g\ S}$$

c. What is the limiting reactant?

H_2S

6. Chlorine combines with hydrogen bromide to produce bromine vapor and hydrogen chloride.

a. Write the balanced equation showing physical states

$Cl_{2(g)} + 2HBr_{(g)} \longleftrightarrow Br_{2(g)} + 2HCl_{(g)}$

b. What volume of bromine gas is produced when 212 mL and chlorine reacts with 155 mL of hydrogen bromide?

if Cl_2 is LR

$$\frac{212\ mL\ Cl_2}{} \cdot \frac{1\ L\ Cl_2}{1000\ mL\ Cl_2} \cdot \frac{1\ mol\ Cl_2}{22.4\ L\ Cl_2} \cdot \frac{1\ mol\ Br_2}{1\ mol\ Cl_2} \cdot \frac{22.4\ L\ Br_2}{1\ mol\ Br_2} = .212\ L\ Br_2$$

if HBr is LR

$$\frac{155\ mL\ HBr}{} \cdot \frac{1\ L\ HBr}{1000\ mL\ HBr} \cdot \frac{1\ mol\ HBr}{22.4\ L\ HBr} \cdot \frac{1\ mol\ Br_2}{2\ mol\ HBr} \cdot \frac{22.4\ L\ Br_2}{1\ mol\ Br_2} = \boxed{0.0775\ L\ Br_2}$$

c. What is the mass of this volume of bromine?

$$\frac{0.0775\ L\ Br_2}{} \cdot \frac{1\ mol\ Br_2}{22.4\ L\ Br_2} \cdot \frac{159.8\,g\ Br_2}{1\ mol\ Br_2} = \boxed{0.553\,g\ Br_2}$$

d. What is the limiting reactant?

HBr

e. What volume of the excess reactant remains?

$$\frac{155\ \cancel{mL\ HBr}}{} \cdot \frac{1\ \cancel{L\ HBr}}{1000\ \cancel{mL\ HBr}} \cdot \frac{1\ \cancel{mol\ HBr}}{22.4\ \cancel{L\ HBr}} \cdot \frac{1\ \cancel{mol}\ Cl_2}{2\ \cancel{mol\ HBr}} \cdot \frac{22.4\ \cancel{L}\ Cl_2}{1\ \cancel{mol\ Cl_2}} \cdot \frac{1000\ mL\ Cl_2}{1\ \cancel{L\ Cl_2}} = 77.5\ mL\ Cl_2$$

$212\ mL - 77.5\ mL = 134.5\ mL \sim \boxed{135\ mL\ Cl_2}$

7. 725 mL of ethane gas, C_2H_6, undergoes combustion in the presence of 3.5 L of oxygen.

a. Write the balanced equation showing physical states

$$2C_2H_{6(g)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 6H_2O_{(g)}$$

b. What volume of carbon dioxide is formed if the reaction goes to completion?

if C_2H_6 is LR

$$\frac{.725\text{ L }C_2H_6}{} \left| \frac{1\text{ mol }C_2H_6}{22.4\text{ L }C_2H_6} \right| \frac{4\text{ mol }CO_2}{2\text{ mol }C_2H_6} \left| \frac{22.4\text{ L }CO_2}{1\text{ mol }CO_2} \right. = \boxed{1.45\text{ L }CO_2}$$

if O_2 is LR

$$\frac{3.5\text{ L }O_2}{} \left| \frac{1\text{ mol }O_2}{22.4\text{ L }O_2} \right| \frac{4\text{ mol }CO_2}{7\text{ mol }O_2} \left| \frac{22.4\text{ L }CO_2}{1\text{ mol }CO_2} \right. = 2.0\text{ L }CO_2$$

c. What is the limiting reactant?

ethane

d. What volume of the excess reactant remains?

$$\frac{.725\text{ L }C_2H_6}{} \left| \frac{1\text{ mol }C_2H_6}{22.4\text{ L }C_2H_6} \right| \frac{7\text{ mol }O_2}{2\text{ mol }C_2H_6} \left| \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} \right. = 2.54\text{ L }O_2$$

$$3.5\text{ L} - 2.54\text{ L} = 0.96 \sim \boxed{1.0\text{ L }O_2\text{ remains}}$$

8. Zinc sulfide, ZnS(s) reacts with oxygen to produce zinc oxide, ZnO(s) and sulfur dioxide.

a. Write the balanced equation showing physical states.

$$2ZnS_{(s)} + 3O_{2(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2(g)}$$

b. What mass of zinc oxide could be produced from 418 g of zinc sulfide and 185 L of oxygen?

if ZnS is LR

$$\frac{418\text{ g ZnS}}{} \left| \frac{1\text{ mol ZnS}}{97.46\text{ g ZnS}} \right| \frac{2\text{ mol ZnO}}{2\text{ mol ZnS}} \left| \frac{81.39\text{ g ZnO}}{1\text{ mol ZnO}} \right. = \boxed{349\text{ g ZnO}}$$

if O_2 is LR

$$\frac{185\text{ L }O_2}{} \left| \frac{1\text{ mol }O_2}{22.4\text{ L }O_2} \right| \frac{2\text{ mol ZnO}}{3\text{ mol }O_2} \left| \frac{81.39\text{ g ZnO}}{1\text{ mol ZnO}} \right. = 448\text{ g ZnO}$$

c. What is the limiting reactant?

ZnS

d. How much of the excess reactant remain?

$$\frac{418\text{ g ZnS}}{} \left| \frac{1\text{ mol ZnS}}{97.46\text{ g ZnS}} \right| \frac{3\text{ mol }O_2}{2\text{ mol ZnS}} \left| \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} \right. = 144\text{ L }O_2$$

$$185\text{ L} - 144\text{ L} = \boxed{41\text{ L }O_2}$$

9. Use the same equation in #8 above to answer the questions below.

a. What volume, at STP, of sulfur dioxide would be produced from 4.66g of zinc sulfide and 1250 mL of oxygen?

if ZnS is LR

$$\begin{array}{l|l|l|l} 4.66\text{ g ZnS} & 1\text{ mol ZnS} & 2\text{ mol SO}_2 & 22.4\text{ L SO}_2 \\ \hline & 97.46\text{ g ZnS} & 2\text{ mol ZnS} & 1\text{ mol SO}_2 \end{array} = 1.07\text{ L SO}_2$$

if O_2 is LR

$$\begin{array}{l|l|l|l} 1.25\text{ L O}_2 & 1\text{ mol O}_2 & 2\text{ mol SO}_2 & 22.4\text{ L SO}_2 \\ \hline & 22.4\text{ L O}_2 & 3\text{ mol O}_2 & 1\text{ mol SO}_2 \end{array} = \boxed{0.833\text{ L SO}_2}$$

b. What is the limiting reactant?

Oxygen

c. How much excess reactant remains?

$$\begin{array}{l|l|l|l} 1.25\text{ L O}_2 & 1\text{ mol O}_2 & 2\text{ mol ZnS} & 97.46\text{ g ZnS} \\ \hline & 22.4\text{ L O}_2 & 3\text{ mol O}_2 & 1\text{ mol ZnS} \end{array} = 3.63\text{ g ZnS}$$

$$4.66\text{ g} - 3.63\text{ g} = \boxed{1.03\text{ g ZnS}}$$

10. 8.4 grams of cyclopropane gas, C_3H_6, undergoes combustion. If 5.5 L of oxygen is available for this reaction:

a. Write the balanced equation showing physical states.

$$2C_3H_{6(g)} + 9O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$$

b. What is the limiting reactant?

Oxygen.

c. What is the excess reactant?

C_3H_6

d. What mass of carbon dioxide is formed?

if C_3H_6 is LR

$$\begin{array}{l|l|l|l} 8.4\text{ g C}_3\text{H}_6 & 1\text{ mol C}_3\text{H}_6 & 6\text{ mol CO}_2 & 44.01\text{ g CO}_2 \\ \hline & 42.08\text{ g C}_3\text{H}_6 & 2\text{ mol C}_3\text{H}_6 & 1\text{ mol CO}_2 \end{array} = 26\text{ g CO}_2$$

if O_2 is LR

$$\begin{array}{l|l|l|l} 5.5\text{ L O}_2 & 1\text{ mol O}_2 & 6\text{ mol CO}_2 & 44.01\text{ g CO}_2 \\ \hline & 22.4\text{ L O}_2 & 9\text{ mol O}_2 & 1\text{ mol CO}_2 \end{array} = \boxed{7.2\text{ g CO}_2}$$

d. How much of the excess reactant remains?

$$\begin{array}{l|l|l|l} 5.5\text{ L O}_2 & 1\text{ mol O}_2 & 2\text{ mol C}_3\text{H}_6 & 42.08\text{ g C}_3\text{H}_6 \\ \hline & 22.4\text{ L O}_2 & 9\text{ mol O}_2 & 1\text{ mol C}_3\text{H}_6 \end{array} = 2.3\text{ g C}_3\text{H}_6$$

$$8.4 - 2.3 = \boxed{6.1\text{ g C}_3\text{H}_6}$$

L

Percent Yield

The percentage yield of a product is the actual amount of product expressed as a percentage of the calculated theoretical yield of that product.

Actual yield – the amount actually produced by the reaction
Theoretical yield – the calculated amount from the balanced equation. Assumes that the reaction goes to completion, that all of the reactants react, that all of the product is recovered and that there are no side reactions.

$$\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

1. Oil of wintergreen (methyl salicylate) is used in a variety of commercial products for its flavor and aroma. It is made by heating salicylic acid with methanol.

   $C_7H_6O_3 + CH_3OH \rightarrow C_8H_8O_3 + H_2O$

   A chemist starts with 1.75g of salicylic acid and excess methanol and calculates the maximum possible yield to be 1.93 g. However, after the reaction is run, the chemist finds that the amount of methyl salicylate produced and isolated is only 1.42 g. What is the percentage yield of the process?

   $\frac{1.42g}{1.93g} \times 100 = 73.6\%$ methyl salicylate

2. The actual amount of product in a reaction is 39.7 g although a mass- mass calculation predicted 65.6 g. What is the percent yield of this product?

   $\frac{39.7g}{65.6g} \times 100 = 60.5\%$

3. What is the percentage yield if 5.50 g of hydrogen react with excess nitrogen to form 20.4 g of ammonia? Write the balanced equation before you begin.

   $3H_2 + N_2 \rightarrow 2NH_3$

   $\frac{5.50g\ H_2}{} \cdot \frac{1\ mol\ H_2}{2.02g\ H_2} \cdot \frac{2\ mol\ NH_3}{3\ mol\ H_2} \cdot \frac{17.04\ g\ NH_3}{1\ mol\ NH_3} = 30.9\ g\ NH_3$

   $= \frac{20.4g}{30.9g} \times 100$

   $66.0\%\ NH_3$

4. The decomposition of potassium chlorate, $KClO_3$ (s), is used by many laboratories to produce oxygen. The other product is potassium chloride, KCl(s).

   a. Write the balanced equation for the reaction

   $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

   b. If 75.6 g $KClO_3$ are decomposed in the lab producing 21L O_2 what is the percent yield?

   $\frac{75.6g\ KClO_3}{} \cdot \frac{1\ mol\ KClO_3}{122.55\ g\ KClO_3} \cdot \frac{3\ mol\ O_2}{2\ mol\ KClO_3} \cdot \frac{22.4L\ O_2}{1\ mol\ O_2} = 20.7L\ O_2$

   $\frac{21}{0.7} = 101\%$

   c. Using the percent yield you calculated above, how much $KClO_3$ must be decomposed to produce 54 L of oxygen?

   $1.01 = \frac{54L}{x}$

   $\frac{53.5L\ O_2}{} \cdot \frac{1\ mol\ O_2}{22.4L\ O_2} \cdot \frac{2\ mol\ KClO_3}{3\ mol\ O_2} \cdot \frac{122.55\ KClO_3}{1\ mol\ KClO_3} = 195g\ KClO_3$