Review Package #2

Percentage Composition, Empirical and Molecular Formulae:

1. Write the empirical formula for each of the following compounds.

a) P_4O_{10} — P_2O_5
b) Mg_2Cl_4 — $MgCl_2$
c) $Pb_2(CO_3)_4$ — $Pb(CO_3)_2$
d) N_2O_2 — NO

2. Calculate the percentage composition by mass of each of the following compounds. a) CO_2 b) C_4H_8O

CO_2 MM = 44.0 g/mol

$\%C = \frac{12.0\ g/mol}{44.0\ g/mol} \times 100\% = 27.3\%$

$\%O = \frac{32.0\ g/mol}{44.0\ g/mol} \times 100\% = 72.7\%$

C_4H_8O MM = 72.0 g/mol

$\%C = \frac{48.0\ g/mol}{72.0\ g/mol} \times 100\% = 66.7\%$

$\%O = \frac{16.0\ g/mol}{72.0\ g/mol} \times 100\% = 22.2\%$

$\%H = \frac{8.0\ g/mol}{72.0\ g/mol} \times 100\% = 11.1\%$

3. Calculate the percentage composition of the bold species in each of the following compounds. a) $Cu(\mathbf{NO_3})_2$ b) $NaSCN \cdot 5\mathbf{H_2O}$

$Cu(NO_3)_2$ MM =

$\%\ NO_3 = \frac{124.0\ g/mol}{187.6\ g/mol} \times 100\% = 66.12\%$

$NaSCN \cdot 5H_2O$ MM

$\%\ H_2O = \frac{90.0\ g/mol}{171.1\ g/mol} \times 100\% = 52.6\%$

4. a) A compound has the following composition: 24.24% C, 4.04% H and 71.72% Cl. What is the empirical formula of the compound?

$?\ mol\ C = 24.24\ g \times \frac{1\ mol}{12.0\ g} = 2.02\ mol$; 1 mol

$?\ mol\ H = 4.04\ g \times \frac{1\ mol}{1.0\ g} = 4.04\ mol$; 2 mol

$?\ mol\ C = 71.72\ g \times \frac{1\ mol}{35.5\ g} = 2.04\ mol$; 1 mol

CH_2Cl

$MM = 49.5\ g/mol$

b) If the molecular mass of this compound is 99.5 g/mol, what is the molecular formula?

$\frac{\text{molecular mass}}{\text{empirical mass}} = \frac{99.5\ g/mol}{49.5\ g/mol} = 2$; $C_2H_4Cl_2$

5. The molar mass of a compound is 58g/mol. What is the molecular formula of the compound if the empirical formula is C_2H_5?

$MM = 29.0\ g/mol$

half of molar mass

C_4H_{10}

Molarity Calculations:

1. If a 4.50g sample of solid NaOH is dissolved to make 0.500L of solution, what is the molarity of the solution?

MM NaOH = 40.0 g/mol

? mols NaOH = $4.50\text{g} \times \frac{1\text{mol}}{40.0\text{g}} = 0.1125\text{mol}$

$C = \frac{n}{V} = \frac{0.1125\text{mol}}{0.500\text{L}} = 0.225\text{M}$

2. How many grams of Na_2CO_3 would be required to produce 400.0mL of 0.600M Na_2CO_3?

MM = 106.0 g/mol

$?\text{g } Na_2CO_3 = 0.4000\text{L} \times \frac{0.600\text{mol}}{1\text{L}} \times \frac{106.0\text{g}}{\text{mol}} = 25.4\text{g } Na_2CO_3$

3. If 75.7g of Magnesium chloride are mixed with sufficient water to make a 0.885M solution, what is the volume of the solution?

MM = 94.31 g/mol $MgCl_2$

$?\text{V } MgCl_2 = 75.7\text{g} \times \frac{1\text{mol}}{94.31\text{g}} \times \frac{1\text{L}}{0.885\text{mol}} = 0.907\text{ L } MgCl_2$

4. How many mL of 16.4 M H_2SO_4 are needed to prepare 755mL of 0.25M H_2SO_4?

$C_1V_1 = C_2V_2$

$C_1 = 16.4\text{M}$ $V_2 = 755\text{mL}$

$V_1 = ?$ $C_2 = 0.25\text{M}$

$V_1 = V_2 \cdot \frac{C_2}{C_1} = 755\text{mL} \cdot \frac{0.25\text{M}}{16.4\text{M}} = 12\text{mL}$

Chemical Reactions and Equations:

1. Balance and classify the following chemical reactions.

	Type of Reaction
a) 2 $KNO_3 \rightarrow$ 2 KNO_2 + O_2	decomposition
b) CaC_2 + 2 $O_2 \rightarrow$ Ca + 2 CO_2	single replacement
c) C_5H_{12} + 8 $O_2 \rightarrow$ 5 CO_2 + 6 H_2O	combustion
d) K_2SO_4 + $BaCl_2 \rightarrow$ 2 KCl + $BaSO_4$	double replacement
e) 2 KOH + $H_2SO_4 \rightarrow$ K_2SO_4 + 2 H_2O	double replacement (acid/base)
f) $Ca(OH)_2$ + 2 $NH_4Cl \rightarrow$ 2 NH_4OH + $CaCl_2$	double replacement

g) $4\,C_4H_9S + 29\,O_2 \rightarrow 16\,CO_2 + 4\,SO_2 + 18\,H_2O$ — combustion

h) $2\,C_{15}H_{30} + 45\,O_2 \rightarrow 30\,CO_2 + 30\,H_2O$ — combustion

i) $2\,BN + 3\,F_2 \rightarrow 2\,BF_3 + \_\_N_2$ — single replacement

j) $2\,Na + \_\_ZnI_2 \rightarrow 2\,NaI + \_\_Zn$ — single replacement

2. Classify, complete AND balance the following chemical equations. Type of Reaction

Ni

a) $\_\_Ni(s) + \_\_Cu(NO_3)_2(aq) \rightarrow Ni(NO_3)_2 + Cu$ — single replacement

need to know what type of Fe → b) $\_\_Fe(s) + \_\_O_2(g) \rightarrow FeO$ OR Fe_2O_3 — synthesis

c) $2\,NaCl(s) \rightarrow Na + Cl_2$ — decomposition

d) $\_\_H_2SO_4(aq) + \_\_NaOH(aq) \rightarrow Na_2SO_4 + H_2O$ — double replacement/neutralization

e) $\_\_C_4H10(l) + \_\_O_2(g) \rightarrow 4CO_2 + H_2O$ — combustion

f) $2\,Ag(s) + \_\_Cl_2(g) \rightarrow 2AgCl$ — synthesis

g) $\_\_Cl_2(g) + 2\,KI(s) \rightarrow 2KCl + I_2$ — single replacement

need to know what type of Fe → h) $\_\_Fe(s) + 2\,AgCl(aq) \rightarrow FeCl_2 + 2Ag$ — single replacement

i) $2\,AgNO_3(aq) + \_\_BaCl_2(aq) \rightarrow Ba(NO_3)_2 + 2AgCl$ — double replacement

j) $\_\_BaCO_3(aq) + \_\_Sr(OH)_2(aq) \rightarrow Ba(OH)_2 + SrCO_3$ — double replacement

k) $\_\_C_2H_5OH(l) + 2\,O_2(g) \rightarrow 2CO_2 + 3H_2O$ — combustion

l) $\_\_HNO_3(aq) + \_\_KOH(aq) \rightarrow KNO_3 + H_2O$ — double replacement/neutralization

3. Write a balanced chemical equation for each of the following, and classify each as synthesis, decomposition, single replacement, double replacement, neutralization or combustion.

a) potassium sulphate is mixed with cobalt (III) nitrate

$3\,K_2SO_4 + 2Co(NO_3)_3 \longrightarrow 6KNO_3 + Co_2(SO_4)_3$ double replacement

b) liquid propanol (C_3H_7OH) is burned in air

$2\,C_3H_7OH + 7O_2 \longrightarrow 6CO_2 + 8H_2O$ combustion

c) ammonium nitrate is decomposed into it's elements

omit

$NH_4NO_3 \longrightarrow$

d) a piece of zinc is placed in a test-tube containing a solution of silver nitrate

$Zn + 2AgNO_3 \longrightarrow Zn(NO_3)_2 + 2Ag$ single replacement

e) bromine reacts with sodium iodide

$Br_2 + 2NaI \longrightarrow 2NaBr + I_2$ single replacement

f) bromine reacts with aluminum

$3\,Br_2 + Al \longrightarrow 2AlBr_3$ synthesis

g) rubidium reacts with chlorine gas

$2Rb + Cl_2 \longrightarrow 2RbCl$ synthesis

h) hydrochloric acid reacts with strontium hydroxide

$HCl + Sr(OH)_2 \longrightarrow H_2O + SrCl_2$ double replacement + neutralization

Energy of Reactions:

1. Define ENDOTHERMIC and EXOTHERMIC reactions.

Endothermic: A chemical reaction that consumes/absorbs heat $\Delta H = +$

Exothermic: A chemical reaction that release heat $\Delta H = -$

2. Classify the following reactions as either endothermic or exothermic.

a) $2C + O_2 \rightarrow 2CO_2$ + energy — Exo

b) N_2O_4 + energy $\rightarrow N_2 + 2O_2$ — Endo

c) $AB + C \rightarrow CB + A + 56.9kJ$ — Exo

d) $AB + CD \rightarrow AD + BC$ $\quad \Delta H = -256.4kJ$ — Exo

Stoichiometry:

1. Ammonia combines with oxygen gas in the following reaction:

$$4\ NH_3 + 5O_2 \rightarrow 6H_2O + 4NO$$

b) How many moles of NH_3 are needed to combine with 3.57 moles of O_2 gas?

$$? mol\ NH_3 = 3.57 mol\ O_2 \times \frac{4\ NH_3}{5\ O_2} = 2.86 mol\ NH_3$$

c) If 1.5 grams of NO is produced in the above reaction, how many grams of NH_3 were reacted?

$$? g\ NH_3 = 1.5g\ NO \times \frac{1 mol}{30.0g} \times \frac{4\ NH_3}{4\ NO} \times \frac{17.0g}{1 mol} = 0.85g\ NH_3$$

2. $3Na_2CO_3 + 2FeCl_3 \rightarrow 6NaCl + Fe_2(CO)_3$

$MM = 106.0$

a) How many grams of NaCl will be produced from the reaction of 0.080moles of Na_2CO_3 with excess $FeCl_3$?

$$? g\ NaCl = 0.080 mol\ Na_2CO_3 \times \frac{1 mol}{106.0g} \times \frac{6\ NaCl}{3\ Na_2CO_3} \times \frac{58.5g}{1 mol} = 0.088g\ NaCl$$

b) How many grams of FeCl3 would be needed to react with 4.2g of Na2CO3?

$MM = 162.3g/mol$

$$? g\ FeCl_3 = 4.2g \times \frac{1 mol}{106.0g} \times \frac{2\ FeCl_3}{3\ Na_2CO_3} \times \frac{162.3g}{1 mol} = 4.3g\ FeCl_3$$

3. $3Mg + 2AlCl_3 \rightarrow 3MgCl_2 + 2Al$

a) How many grams of $MgCl_2$ would be formed if 50.0mL of 0.200M $AlCl_3$ is reacted with excess Mg?

$$?g\ MgCl_2 = 50.0mL\ AlCl_3 \times \frac{1L}{1000mL} \times \frac{0.200mol}{1L} \times \frac{3\ MgCl_2}{2\ AlCl_3} \times \frac{94.3g}{1mol} = 1.41g$$

b) How many mL of 0.150M $AlCl_3$ would be needed to react completely with 2.00g of Mg?

$$?V\ AlCl_3 = 2.00g\ Mg \times \frac{1mol}{24.3g} \times \frac{2\ AlCl_3}{3\ Mg} \times \frac{1L}{0.150mol} \times \frac{1000mL}{1L} = 366mL$$

Excess and Limiting Reagents/Percent Yield:

1. $2Fe_2S_3 + 9O_2 \rightarrow 2Fe_2O_3 + 6\ SO_2$

In a chemical reaction 6.92g of Fe_2S_3 is combined with 4.54g of oxygen gas.

a) Which reactant is the **LIMITING** reagent?

$$?g\ Fe_2O_3 = 6.92g\ Fe_2S_3 \times \frac{1mol}{207.9g} \times \frac{2\ Fe_2O_3}{2\ Fe_2S_3} \times \frac{159.6g}{1mol} = 5.31g\ Fe_2O_3$$

Excess

$$?g\ Fe_2O_3 = 4.54g\ O_2 \times \frac{1mol}{32.0g} \times \frac{2\ Fe_2O_3}{9\ O_2} \times \frac{159.6g}{1mol} = \boxed{5.03g\ Fe_2O_3}$$

Limit

b) How many grams of the **EXCESS** reactant will be **left over** after the reaction is complete?

$$?g\ Fe_2S_3 = 4.54g\ O_2 \times \frac{1mol}{32.0g} \times \frac{2\ Fe_2S_3}{9\ O_2} \times \frac{207.9g}{1mol} = 6.55g\ Fe_2S_3$$

$$Excess = 6.92g - 6.55g = \boxed{0.37g}$$

c) How many grams of Fe_2O_3 can be formed in this reaction?

2. What mass of P_4 will be produced when 41.5g of $Ca_3(PO_4)_2$, 26.3g of SiO_2, and 7.80g of C are reacted according to the following balanced equation?

$$2\ Ca_3(PO_4)_2 + 6\ SiO_2 + 10C \rightarrow P_4 + 6CaSiO_3 + 10CO$$

$?\ g\ P_4 = 41.5\ g\ Ca_3(PO_4)_2 \times \frac{1\ mol}{310.2\ g} \times \frac{1\ P_4}{2\ Ca_3(PO_4)_2} \times \frac{124.0\ g}{1\ mol} = 8.29\ g$

$?\ g\ P_4 = 26.3\ g\ SiO_2 \times \frac{1\ mol}{60.1\ g} \times \frac{1\ P_4}{6\ SiO_4} \times \frac{124.0\ g}{1\ mol} = 9.04\ g$

$?\ g\ P_4 = 7.80\ g\ C \times \frac{1\ mol}{12.0\ g} \times \frac{1\ P_4}{10C} \times \frac{124.0\ g}{1\ mol} = \boxed{8.06\ g}$

3. $4Al + 3O_2 \rightarrow 2Al_2O_3$

a) How many grams of aluminum oxide, Al_2O_3, would be expected to form in the reaction of 15.0g Al with 18.43g of oxygen gas?

$?\ g\ Al_2O_3 = 15.0\ g\ Al \times \frac{1\ mol}{27.0\ g} \times \frac{2\ Al_2O_3}{4\ Al} \times \frac{102.0\ g}{1\ mol} = \boxed{28.3\ g}$

$?\ g\ Al_2O_3 = 18.43\ g\ O_2 \times \frac{1\ mol}{32.0\ g} \times \frac{2\ Al_2O_3}{3\ O_2} \times \frac{102.0\ g}{1\ mol} = 39.2\ g$

b) If the actual yield of Al_2O_3 produced in the reaction was only 22.4g Al_2O_3, what would the PERCENT YIELD of the reaction be?

$\%\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100\% = \frac{22.4\ g}{28.3\ g} \times 100\% = \boxed{79.2\%}$

Extra Stoich Problems:

1. Given the following balanced equation, answer the questions following it:

$2NF_{3(g)} + 3H_{2(g)} \rightarrow N_{2(g)} + 6HF_{(g)}$

a) If 5.5 moles of H_2 are reacted, how many moles of NF_3 will be consumed?

$$P_{mol}\ NF_3 = 5.5 mol\ H_2 \times \frac{2NF_3}{3H_2} = 3.7 mol\ NF_3$$

Answer 3.7 mol NF_3

b) In order to produce 0.47 moles of HF, how many moles of NF_3 would be consumed?

$$P_{mol}\ NF_3 = 0.47 mol\ HF \times \frac{2NF}{6HF} = 0.16 mol\ NF$$

Answer 0.16 mol NF

c) If you needed to produce 180.6 g of N_2, how many moles of H_2 would you need to start with?

$$P_{mol}\ H_2 = 180.6 g\ N_2 \times \frac{1 mol}{28.0 g} \times \frac{3H_2}{1N_2} = 19.35 mol$$

Answer 19.4 mol H_2

d) If you completely react 17.04 g of NF_3, what mass of HF will be produced?

$$P_g HF = 17.04 g\ NF_3 \times \frac{1 mol}{71.0 g} \times \frac{6HF}{2NF} \times \frac{20.0 g}{1 mol} =$$

Answer 14.4 g HF

2. Given the following balanced equation, answer the questions following it:

$HBrO_3 + 5\,HBr \rightarrow 3\,H_2O_{(l)} + 3\,Br_{2(g)}$

a) If 3.56 moles of HBr are reacted, how many Litres of Br_2 will be formed at STP?

$$?L\,Br_2 = 3.56\,mol\,HBr \times \frac{3\,Br}{5\,HBr} \times \frac{22.4\,L}{1\,mol} = 47.8\,L$$

Answer 47.8 L Br_2

b) In order to produce 3.311×10^{24} molecules of Br_2, what mass of HBr is needed?

$$?g\,HBr = 3.311\times10^{24}\,molec \times \frac{1\,mol}{6.02\times10^{23}\,molec} \times \frac{5\,HBr}{3\,Br} \times \frac{80.9\,g}{1\,mol} = 742\,g$$

Answer 742 g HBr

3. Given the following balanced chemical equation, answer the question below it.

$MgCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CO_{2\,(g)} + H_2O_{(l)} + MgCl_{2(aq)}$

a) What mass of $MgCO_3$ will react completely with 15.0 mL of 1.5 M HCl?

$$?g\,MgCO_3 = 15.0\,mL\,HCl \times \frac{1\,L}{1000\,mL} \times \frac{1.5\,mol}{1\,L} \times \frac{1\,MgCO_3}{2\,HCl} \times \frac{84.3\,g}{1\,mol} = 0.948\,g$$

Answer 0.948 g $MgCO_3$

b) Calculate the volume of 2.0 M HCl which would be needed to react completely with
37.935 grams of magnesium carbonate.

$$?L\,HCl = 37.935\,g\,MgCO_3 \times \frac{1\,mol}{84.3\,g} \times \frac{2\,HCl}{1\,MgCO_3} \times \frac{1\,L}{2.0\,mol} = 0.45\,L$$

Answer 0.45 L HCl

4. Given the following balanced equation, answer the questions below it.

$$Ba(OH)_{2(aq)} + 2\,HNO_{3(aq)} \rightarrow 2\,H_2O_{(l)} + Ba(NO_3)_2$$

a) In a titration, 18.20 mL of 0.300 M $Ba(OH)_2$ is required to react completely with a 25.0 mL sample of a solution of HNO_3. Find the $[HNO_3]$.

$$?\,mol\,HNO_3 = 18.20\,mL \times \frac{1\,L}{1000\,mL} \times \frac{0.300\,mol}{L} \times \frac{2\,HNO_3}{1\,Ba(OH)_2} = 0.01092\,mol\,HNO_3$$

$$C = \frac{n}{V} = \frac{0.01902\,mol\,HNO_3}{0.0250\,L} = 0.439\,M$$

Answer 0.439 M HNO_3

b) In a titration, 11.06 mL of 0.200 M HNO_3 is required to react completely with a sample of 0.250M $Ba(OH)_2$. Find the volume of the $Ba(OH)_2$ sample.

$$?\,V\,Ba(OH)_2 = 11.06\,mL \times \frac{1\,L}{1000\,mL} \times \frac{0.200\,mol}{L} \times \frac{1\,Ba(OH)_2}{2\,HNO_3} \times \frac{1\,L}{0.250\,mol} = 0.00884\,L$$

$$= 8.84\,mL$$

Answer 8.84 mL

5. Given the following balanced equation, answer the questions below it.

$$3\,Cu_{(s)} + 8HNO_{3(l)} \rightarrow 3\,Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4\,H_2O_{(l)}$$

a) If 317.5 grams of Cu are placed into 756.0 grams of HNO_3, determine which reactant is in excess.

$$?_g NO = 317.5\,g\,Cu \times \frac{1\,mol}{63.6\,g} \times \frac{2\,NO}{3\,Cu} \times \frac{30.0\,g\,NO}{1\,mol} = 99.8\,g \leftarrow \text{Excess!}$$

$$?_g NO = 756.0\,g\,HNO_3 \times \frac{1\,mol}{63.0\,g} \times \frac{2\,NO}{8\,HNO_3} \times \frac{30.0\,g\,NO}{1\,mol} = 90.0\,g$$

Answer ~~90.0 g~~

b) If the reaction in (a) is carried out, what mass of NO will be formed?

Answer 90.0 g

6. Given the balanced equation: $2BN + 3F_2 \rightarrow 2BF_3 + N_2$,

When 161.2 grams of BN are added to an excess of F_2, a reaction occurs in which 326.118 grams of BF_3 are formed.

a) Calculate the *theoretical* yield of BF_3 in grams.

$$?\,g\,BF_3 = 161.2\,g\,BN \times \frac{1\,mol}{24\,g} \times \frac{2\,BF_3}{2\,BN} \times \frac{67.8\,g}{1\,mol} = 440.7\,g$$

Answer 441 g BF_3

b) Calculate the *percentage* yield of BF_3.

$$\%\,yield = \frac{Actual\,yield}{theo\,yield} \times 100\%$$

$$= \frac{326.118\,g}{440.7\,g} \times 100\% = 74.0\%$$

Answer 74.0%

7. When reacting NH_3 with O_2 according to the reaction:

$$4\,NH_3 + 5\,O_2 \rightarrow 4\,NO + 6\,H_2O$$

Using 163.2 grams of NH_3 with an excess of O_2 produces a 67% yield of NO.

a) Calculate the *theoretical yield* of NO in grams.

$$?\,g\,NO = 163.2\,g \times \frac{1\,mol}{17.0\,g} \times \frac{4\,NO}{4\,NH_3} \times \frac{30.0\,g}{1\,mol} = 288\,g\,NO$$

Answer 288 g NO

b) Calculate the *actual yield* of NO in grams.

$$actual\,yield = \frac{\%\,yield}{100\%} \times theo\,yield$$

Answer 193 g NO

$$= \frac{67\%}{100\%} \times 288\,g$$

$$= 192.96\,g$$