Chem E-1a
Friday Review Problems
Chapter 3

1. A compound was found to contain 27.7% magnesium, 23.6% phosphorus, and 48.7% oxygen by mass. Calculate the empirical formula of this compound.

TO DETERMINE EMPIRICAL FORMULA: 1ST DETERMINE THE MASS OF EACH ELEMENT IN SOME TOTAL MASS OF COMPOUND.

FOR % BY MASS ⟹ ASSUME 100 g TOTAL
THEN 27.7 g Mg, 23.6 g P, 48.7 g O

	MASS	MOLES	MOLE RATIO	WHOLE # MOLE RATIO	
Mg	27.7 g	1.14	1.5	3	EMP. FORM
P	23.6 g	0.76	1	2	
O	48.7 g	3.04	4	8	
TOTAL:	100 g				

÷ BY 0.76 ; × 2

$$27.7\text{ g Mg} \times \frac{1\text{ mol Mg}}{24.31\text{ g Mg}} = 1.14\text{ mol Mg}$$

$$23.6\text{ g P} \times \frac{1\text{ mol P}}{30.97\text{ g P}} = 0.76\text{ mol P}$$

$$48.7\text{ g O} \times \frac{1\text{ mol O}}{16\text{ g O}} = 3.04\text{ mol O}$$

IF MOLE RATIO IS NEAR:

0.5 × 2

0.33 or 0.67 × 3

0.25 or 0.75 × 4

EMP. FORM:

$Mg_3P_2O_8$

OR: $Mg_3(PO_4)_2$

$$C_?H_?O_? + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$$

2. A certain compound containing only carbon, hydrogen, and oxygen is found to have a molar mass of approximately 145 g/mol. When 2.36 grams of this compound is subjected to combustion analysis, 5.76 g of CO_2 and 2.35 g of H_2O are produced. Determine this compound's empirical and molecular formula.

$$5.76\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44\text{ g } CO_2} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} \times \frac{12\text{ g C}}{1\text{ mol C}} = 1.57\text{ g C}$$

$$2.35\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18\text{ g } H_2O} \times \frac{2\text{ mol H}}{1\text{ mol } H_2O} \times \frac{1\text{ g H}}{1\text{ mol H}} = 0.263\text{ g H}$$

$$2.36\text{ g COMPOUND} - 1.57\text{ g C} - 0.263\text{ g H} = 0.527\text{ g O}$$

	MASS	MOLES	MOLE RATIO	WHOLE # MOLE RATIO
C	1.57 g	0.1308	3.98	4
H	0.263 g	0.2609	7.94	8
O	0.527 g	0.0329	1	1
TOTAL:	2.36 g			

÷ BY 0.0329

EMP. FORM. IS C_4H_8O

FIND MOLECULAR FORMULA: MUST KNOW MOLAR MASS

MOLAR MASS = 145 g/mol

EMP. FORM MASS = $4(12\text{ g/mol}) + 8(1\text{ g/mol}) + (16\text{ g/mol})$

$= 72\text{ g/mol}$

$$\frac{145\text{ g/mol}}{72\text{ g/mol}} \approx 2$$

SO MOLECULAR FORMULA IS TWICE EMP. FORM:

$C_8H_{16}O_2$

LIQUID

3. a) Solid dinitrogen pentoxide reacts with water to produce aqueous nitric acid. Write and balance the equation for this process.

$$N_2O_5\,(s) + H_2O\,(l) \longrightarrow 2\,HNO_3\,(aq)$$

b) A 5.734-gram sample of dinitrogen pentoxide is dissolved in excess water. What mass of nitric acid is produced?

STOICHIOMETRY

$$5.734\ g\ N_2O_5 \times \frac{1\ mol\ N_2O_5}{108\ g\ N_2O_5} \times \frac{2\ mol\ HNO_3}{1\ mol\ N_2O_5} \times \frac{63\ g\ HNO_3}{1\ mol\ HNO_3} =$$

$$= 6.69\ g\ HNO_3$$

4. Carbon tetrachloride, CCl_4, was once used as a dry-cleaning solvent, but its toxicity has put an end to that use.

   a) CCl_4 can be destroyed by reaction with Cr_2O_3:

   $$Cr_2O_3 + 2CCl_4 \rightarrow 2CrCl_3 + CO_2 + COCl_2$$

   Balance this chemical equation using the smallest whole-number coefficients. (Hint: Balance the Cr first.)

   b) What is the maximum mass of $CrCl_3$ that could be prepared from 100.0 g of Cr_2O_3 and 100.0 mL of liquid CCl_4? (Density of CCl_4 is 1.587 g/mL)

LIMITING REACTANT PROBLEM:

MEANINGLESS!

$$100\ g\ Cr_2O_3 \times \frac{1\ mol\ Cr_2O_3}{152\ g\ Cr_2O_3} \times \frac{2\ mol\ CrCl_3}{1\ mol\ Cr_2O_3} \times \frac{158.4\ g\ CrCl_3}{1\ mol\ CrCl_3} = 208.4\ g\ CrCl_3$$

$$100\ mL\ CCl_4 \times \frac{1.587\ g\ CCl_4}{1\ mL\ CCl_4} \times \frac{1\ mol\ CCl_4}{153.8\ g\ CCl_4} \times \frac{2\ mol\ CrCl_3}{2\ mol\ CCl_4} \times \frac{158.4\ g\ CrCl_3}{1\ mol\ CrCl_3}$$

$$= 163.4\ g\ CrCl_3$$

ACTUAL MASS OF PRODUCT FORMED

Cr_2O_3 IS EXCESS REAGENT

CCl_4 IS LIMITING REAGENT

4. (cont.)

c) What mass of Cr_2O_3 and CCl_4 will remain if this reaction proceeds to completion?

CCl_4 IS LIMITING REAGENT $\Rightarrow$ NONE REMAINS!

0 g CCl_4 REMAIN

WHAT ABOUT Cr_2O_3

$$163.4\ g\ CrCl_3\ \text{FORMED} \times \frac{1\ \text{mol}\ CrCl_3}{158.4\ g\ CrCl_3} \times \frac{1\ \text{mol}\ Cr_2O_3}{2\ \text{mol}\ CrCl_3} \times \frac{152\ g\ Cr_2O_3}{1\ \text{mol}\ Cr_2O_3}$$

$$= 78.4\ g\ Cr_2O_3\ \text{REACTED}$$

100 g Cr_2O_3 INITIALLY $-$ 78.4 g Cr_2O_3 REACT

$=$ **21.6 g Cr_2O_3 REMAIN UNREACTED**

5. A certain potent alcoholic beverage contains only ethanol (C_2H_6O) and water (H_2O). This mixture is flammable. When a sample of this beverage is completely combusted, the ethanol burns as expected, producing carbon dioxide and water, and the water present in the original mixture simply evaporates. A 10.00-gram sample of this beverage is completely combusted. The total mass of water collected (from combustion and evaporation) is 11.27 grams. Calculate the mass of ethanol and the mass of water in the original sample.

FOR THIS PROBLEM I WILL WRITE (g)

$C_2H_6O(\ell) + H_2O(\ell) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

MIXTURE

NO!

$C_2H_6O(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$

$H_2O(\ell) \longrightarrow H_2O(g)$

LET x = MASS OF $C_2H_6O(\ell)$
y = MASS OF $H_2O(\ell)$
} IN ORIG. MIXTURE

$$x + y = 10.00\ g$$ 1ST EQUATION

2ND EQUATION

(MASS OF H_2O FROM COMBUSTION) + (MASS OF H_2O FROM EVAP.) = $11.27\ g\ H_2O$

$$x\ g\ C_2H_6O(\ell) \times \frac{1\ mol\ C_2H_6O}{46.1\ g\ C_2H_6O} \times \frac{3\ mol\ H_2O}{1\ mol\ C_2H_6O} \times \frac{18\ g\ H_2O}{1\ mol\ H_2O} = 1.173x\ g\ H_2O$$ FROM COMB.

$$1.173x + y = 11.27\ g$$

SOLVE $x = 7.34\ g\ C_2H_6O$
$y = 2.66\ g\ H_2O$
IN ORIG. MIXTURE

How to Solve 2 Equations and 2 Unknowns:

5. (*continued – space for additional work)*

$$x + y = 10$$
$$1.173x + y = 11.27$$

1st: Solve one equation for one variable:

$$x + y = 10$$
$$-y \quad -y$$
$$x = 10 - y$$

2nd: Plug that variable into other equation

$$1.173x + y = 11.27$$
$$1.173(10 - y) + y = 11.27$$
$$11.73 - 1.173y + y = 11.27$$
$$11.73 - 0.173y = 11.27$$
$$-11.73 \qquad -11.73$$
$$\left(\frac{1}{-0.173}\right)\left(-0.173y = -0.46\right)$$

$$y = -0.46\left(\frac{-1}{0.173}\right) = 2.66$$

Plug back in:

$$x = 10 - y = 10 - 2.66 = 7.34$$

$$y = 2.66$$
$$x = 7.34$$