CHEMISTRY **E.F. AND M. F. Worksheet**

EMPIRICAL AND MOLECULAR FORMULAS

Example: EMPIRICAL FORMULA:

Suppose a compound is analyzed to contain 48.8 g of cadmium, 20.8 g of carbon, 2.62 g of hygrogen, and 27.8 g of oxygen. Determine the empirical formula of this compound.

To determine the empirical formula of a compound for which the amounts of each element are given you convert the amounts to moles using the elements atomic weights from the periodic table as follows:

48.8 g Cd | 1 mole Cd / 112.4 g Cd = 0.434 moles Cd

20.8 g C | 1 mole C / 12.01 g C = 1.67 moles C

2.62 g H | 1 mole H / 1.01 g H = 2.62 moles H

27.8 g O | 1 mole O / 16 g O = 1.74 moles O

This gives you the mole ratio of the elements in the formula and theoretically the formula for the compound could be written as:

$$Cd_{0.434}C_{1.67}H_{2.62}O_{1.74}$$

But we know that atoms are not fractional in nature so we must find the smallest whole number ratio for the elements making up the compound. To do this we divide each of the numbers by the smallest number in the set. In our case the smallest number is 0.434 moles. *

48.8 g Cd | 1 mole Cd / 112.4 g Cd = 0.434 moles Cd/0.434 moles = 1

20.8 g C | 1 mole C / 12.01 g C = 1.73 moles C/0.434 moles = 4

2.62 g H | 1 mole H / 1.01 g H = 2.62 moles H/0.434 moles = 6

27.8 g O | 1 mole O / 16 g O = 1.74 moles O/0.434 moles = 4

** After division if this step produces any number ending in .5 multiply all numbers by 2 to obtain small whole numbers*

** After division if this step produces any number ending in .33 multiply all numbers by 3 to obtain small whole numbers*

These whole numbers become the subscripts for the empirical formula: $CdC_4H_6O_4$. You don't write the (1) for Cd---the symbol already indicates (1). From experience it is probably safe to say the formula is: $Cd(C_2H_3O_2)_2$. Cadmium Acetate. This is the Empirical or Simple Formula for the compound. It is just the ratio of the amounts of each type of element in the compound.

EXAMPLE: MOLECULAR FORMULA

In order to determine the Actual or Molecular Formula, you need to know the molecular mass of the compound.

Suppose a compound whose molecular mass is 695 is analyzed to contain 26.7% phosphorus, 12.1% nitrogen, and 61.2% chlorine.

You first have to find the Empirical Formula the same way we did problem#1. We can state the % given to us for each element as grams if we base our calcualtions on 100 g of compound. Steps have been combined to give the following

26.7 g P	1 mole P / 30.97 g P	= 0.862 moles P/0.862moles = 1
12.1 g N	1 mole N / 14 g N	= 0.864 moles N/0.862 moles = 1
61.2 g Cl	1 mole Cl / 35.45 g Cl	= 1.726 mols Cl/0.862/moles = 2

Therefore the Empirical formual is $PNCl_2$

To determine the <u>molecular formula</u> you set the EF mass taken X times and set it equal to the Molecular Weight of the compound. Like this:

$(PNCl_2)\ X = 695$

Now substitute the atomic weight of the elements into the equation to get this:

$[30.97 + 14 + 2(35.45)]\ X = 695$

$[115.87]\ X = 695$

$X = 695/115.87$

$X = 6$

To get the Molecular Formula we must multiply each of the subscripts in the Empirical Formual by 6 to give us this:

$$P_6N_6Cl_{12}$$

As a check, you can find the formula mass as usual from the sum of the atomic weights:

P = 6 x 30.97	= 185.82
N = 6 x 14	= 84
Cl = 12 x 35.45	= 425.4
Total	= 695.22

You can see from this example that the MF is a multiple of the EF and represents the actual numbe of each type of atom that makes up the compound.

PRACTICE PROBLEMS:

1. What is the empirical formula of a substance composed 56.6% potassium, 8.68% carbon, and 34.7% oxygen.

2. What is the empirical formula of a compound composed of 3.26 gof arsenic and 1.04 g of oxygen?

3. An unknown compound is analyzed and found to consist of 24.3 % carbon, 4.1 % hydrogen, and 71.6 % chlorine. If the molecular mass of the compound is 98.8, what is the molecular formula of the compound?

4. What is the empirical formula of a substance composed 49.89% strontium, 13,67% carbon, and 36.44% oxygen?

5. What is the empirical formula of a compound composed of 10.12 g of aluminum and 17.93 g of sulfur?

6. An unknown compound is analyzed and found to consist of 49.0 % carbon, 2.7 % hydrogen, and 48.2 % chlorine. If the molecular mass of the compound is 150, what is the molecular formula of the compound?

7. Find the molecular formula for a compound with percentage composition 85.6 % C, 14.4 % H, and molecular mass 42.1.

8. What is the molecular formula of a substance with empirical formula $TlC_2H_2O_3$ and molecular mass 557?

9. Hydroquinone is an organic compound commonly used as a photographic developer. It has a molecular weight of 110 g/mole and a composition of 65.45% C, 5.45 % H, and 29.09 % O. Calculate the molecular formula of hydroquinone.