Name: ____________________ **Chemistry** ___/___/___

Empirical Formula & Molecular Formula

Today we will study empirical and molecular formulas. An **empirical formula** for a compound is the formula written in its most reduced form. A **molecular formula** is the formula for the compound as it exists in nature. For example: the **molecular formula** for hydrogen peroxide is $\mathbf{H_2O_2}$. The **empirical formula** for hydrogen peroxide is **HO**. Basically, all we are doing is reducing the **ratio** between the elements to its lowest common factor.

On many occasions, the empirical formula and the molecular formula will be the same. For example: the molecular formula for water is H_2O. Since the 2 : 1 ratio between hydrogen and oxygen cannot reduce, the empirical formula for water is also H_2O.

Part I: Calculating Empirical Formulas

When determining empirical formula, you will be given either a percent composition of the elements in the compound or the mass of the elements in the compound. In either case, the steps are exactly the same.

Example #1: A compound consists of 72.2% magnesium and 27.8% nitrogen by mass. What is the **empirical formula**?

Description of Action	Action
1. Divide each element's percent composition or mass composition by its atomic weight. Remember to use significant figures.	**1.** Mg: 72.2 ÷ 24.3 = **2.97** N: 27.8 ÷ 14.0 = **1.98**
2. **Divide** each result by the **smallest result**. Remember to use significant figures.	**2.** Mg: 2.97 ÷ 1.98 = **1.50** N: 1.98 ÷ 1.98 = **1.00**
3. Multiply each result by the **same** whole number until both equal a whole number (or at least within a couple hundredths). Hint: start at 2 and work your way up.	**3.** Mg: 1.50 x 2 = **3** N: 1.00 x 2 = **2**
4. Write the formula with the each element's result as its subscript.	**4.** $\mathbf{Mg_3N_2}$
5. Name the compound. Note: If you see a compound that we have not yet learned how to name, you will not have to name it.	**5.** **magnesium nitride**

Try this one. Determine the **empirical formula** of a compound that is composed of 36.5% Na, 25.4% S, and 38.1% O.

Description of Action	Action
1.	
2.	
3.	
4.	
5.	

Practice Problem:

1. Calculate the empirical formula and name the compound that contains 1.67 grams of cerium and 4.54 grams of iodine.

Part II: Calculating Molecular Formulas From Empirical Formulas

Example #1: From above, we see that the empirical formula is Na_2SO_3. If the molecular formula mass is 378.3 g/mol, what is the molecular formula?

Description of Action	Action
1. Determine the gram formula mass of the empirical formula.	**1.** Na: 2 x 23.0 = 46.0 S: 1 x 32.1 = 32.1 0: 3 x 16.0 = <u>48.0</u> **126.1 g/mol**
2. Divide the molecular formula mass by the empirical formula mass.	**2.** 378.3 ÷ 126.1 = **3.000**
3. Multiply each subscript in your empirical formula by your result.	**3.** Na_2SO_3 becomes $\mathbf{Na_6S_3O_9}$ because we must multiply each of the formula's subsripts by 3.

You try this one: For a compound with an empirical formula CH_2O, determine its molecular formula if its molecular formula mass is 180 g/mol.

Description of Action	Action
1.	
2.	
3.	

Practice Problem

1. For a compound with an empirical formula C_4H_9, determine its molecular formula if its molecular formula mass is 114 g/mol.

Part III: Putting it Together: Empirical Formula & Molecular Formula

Example #1: A compound is analyzed and found to contain 32.5% manganese, 24.9% silicon, and 42.6% oxygen. The molecular weight of this compound is known to be approximately 676.2 g/mol. What is the **empirical formula**? What is the **molecular formula**?

Description of Action	Action
1. Divide each element's percent composition by its atomic weight. Remember to use significant figures.	**1.** Mn: 32.5 ÷ 54.9 = 0.592 Si: 24.9 ÷ 28.1 = 0.886 O: 42.6 ÷ 16.0 = 2.66
2. Divide each of the results by the smallest result. In our example, 0.592 is our smallest result.	**2.** Mn: 0.592 ÷ 0.592 = 1.00 Si: 0.886 ÷ 0.592 = 1.50 O: 2.66 ÷ 0.592 = 4.49
3. Multiply each of your new results by the same whole number until each of their result is a whole number. The best way to do this is to start with two and increase until you find a number that produces all whole number results.	**3.** Mn: 1.00 x 2 = 2 Si: 1.50 x 2 = 3 O: 4.49 x 2 = 9 (Rounded from 8.98)
4. Using your new results as the subscripts for the specific elements, write the formula of the compound.	**4.** $\mathbf{Mn_2Si_3O_9}$
5. Determine the gram formula mass of the empirical formula.	**5.** Mn: 2 x 54.9 = 109.8 Si: 3 x 28.1 = 84.3 O: 9 x 16.0 = <u>144.0</u> **338.1 g/mol**
6. Divide the given molecular formula mass by the calculated gram formula mass. **(given ÷ calculated)**	**6.** 676.2 ÷ 338.1 = **2.000**
7. Multiply each subscript in your empirical formula by your result.	**7.** $Mn_2Si_3O_9$ becomes $\mathbf{Mn_4Si_6O_{18}}$

Summary for solving Empirical & Molecular Formula Problems

Empirical Formula

Given: Percentage or mass of each element or compound.

1. Divide each percentage or mass by either the element's atomic weight or, if it's a compound, its gram formula mass.
2. Divide each result by the smallest result.
3. Multiply each result by the SAME whole number to get a whole number result. (This step is not necessary for hydrates).
   a. x.25 --- multiply by 4
   b. x.33 --- multiply by 3
   c. x.50 --- multiply by 2
   d. x.66 --- multiply by 3
   e. x.75 --- multiply by 4

Molecular Formula

4. Find the gram formula mass of the empirical formula.
5. Divide the molecular formula mass (given) by the empirical formula mass (calculated).
6. Multiply each subscript by the result. (The result MUST be a whole number.)

Homework:

Part I: Calculate the empirical formula for each of the following.

1. What is the empirical formula of a compound that is 25.9% nitrogen and 74.1% oxygen?

2. Determine the empirical formula of a compound that is composed of 88.8% O, 11.1% H.

3. Magnetite is an iron ore with natural magnetic properties. It contains 72.5% Fe & 27.5% O. What is the empirical formula for magnetite?

4. An inorganic chemical used to treat burn patients is made up of silver, nitrogen, and oxygen in corresponding percentages of 78, 10, and 12. Calculate the empirical formula of this substance.

5. Propane is a hydrocarbon composed of 81.8% carbon and 18.2% hydrogen. What is its empirical formula?

6. What is the empirical formula of a compound that is sixty six percent calcium and the rest phosphorus?

7. Gigi is given 14.0 grams of an oxide of iron and asked to determine the empirical formula of the oxide. She finds that the sample contains 9.8 grams of iron and 4.2 grams of oxygen. What answer did she get?

8. 2-Methylpropene is a compound used to make synthetic rubber. A sample contains 0.556 g of carbon and 0.0933 g of hydrogen. Determine its empirical formula. Determine the molecular formula if the molecular formula mass is 56 g/mol.

Part II: Calculate the molecular formula for each of the following. (These are like the problems in part III above.)

9. What is the empirical formula of a compound that contains 46.2% carbon & 53.8% nitrogen? What is its molecular formula if it has a molecular mass of 52 g/mol.

10. A compound has a percentage composition of 40.0% carbon, 6.71% hydrogen and 53.3% oxygen. What is the empirical formula? What is the molecular formula if the compound has a molecular mass of 180.0 g/mol.

11. Ascorbic acid, also known as vitamin C, has a percentage composition of 40.9% carbon, 4.58% hydrogen, and 54.5% oxygen. Its molecular mass is 176.1 g/mol. What is its molecular formula?

12. Aspirin contains 60.0% carbon, 4.48% hydrogen, and 35.5% oxygen. It has a molecular mass of 180.0 g/mol. What are its empirical and molecular formulas?

13. Find the molecular formula of a compound with percentage composition 26.7% P, 12.1% N, and 61.2% Cl and a molecular mass 695 g/mol.