Percentage Composition and Empirical Formulas

- The formula for a compound indicates the **number** and **kind** of each atom in a representative particle of the compound.

- How many atoms of each element are found in the following formula?

$$Al_2(CrO_4)_3$$

Percentage Composition

- The percentage composition of a compound gives the **percent** of the total mass made up by each element in the compound.

- The percent composition can be determined either by calculating percentage composition from a **given** chemical **formula** or by experimental decomposition and **analysis** of a compound.

Example

- Ammonia has the formula NH_3. Use the formula to determine the percentage composition of ammonia.

Step 1

- Find the mass of one mole of chemical formula.

Step 1

- Mass of nitrogen

$$\frac{1 \text{ mole N}}{} \quad \frac{14 \text{ g}}{\text{mole}} = 14 \text{ g}$$

Step 1

- Mass of hydrogen

$$\frac{1 \text{ mole H}}{} \quad \frac{1 \text{ g}}{\text{mole}} = 1 \text{ g} \times 3$$

3 g

Step 1

- Total Mass of NH_3

14 g + 3 g = 17 g

Step 2

- Find the percent of each element

Step 2

- % element =

$$\frac{\text{Mass of element in compound}}{\text{Total Mass of compound}} \times 100\%$$

Step 2

- % nitrogen =

$$\frac{14\ g}{17\ g} \times 100\% = 82\ \%$$

Step 2

- % hydrogen =

$$\frac{3\ g}{17\ g} \times 100\% = 18\ \%$$

Determining an Empirical Formula given Percentage Composition

- A formula which gives the **simplest** whole number **ratio** of atoms (elements) of a compound.

Example

- Determine the formula for the compound that when analyzed showed 70.9% potassium and 29.1% sulfur by weight.

Step 1

- Percentage by mass may be assumed to be grams of element per 100 grams of compound

Step 1

- Thus, in every 100 grams of the compound there is

  70.9 g of potassium

  29.1 g of sulfur

Step 2

- Because potassium and sulfur do not the same atomic mass the ratio of the masses does not indicate their mole relationships.

Step 2

- Divide the percent (now considered grams) of each element by its molar mass.

Step 2

$$K = \frac{70.9\ g}{39\ g} \cdot \frac{mole}{} = 1.82\ mole$$

Step 2

$$S = \frac{29.1\ g}{32\ g} \times \frac{mole}{} =$$

.91 mole

Step 3

- Atoms combine in small whole number ratios, however, so these fractional values must be converted to whole numbers.

Step 3

- Divide each number by the smallest one.

Step 3

$$K = \frac{1.82 \text{ mole}}{.91 \text{ mole}} = 2$$

$$S = \frac{.91 \text{ mole}}{.91 \text{ mole}} = 1$$

Step 3

- The simplest formula must then be

$$K_2S$$

Note:

- A general rule to follow in these problems is to place the elements in the formula in the same sequence given in the problems.

Determining the Molecular Formula from the Empirical Formula

- The empirical formula of a compound indicates the simplest ratio of the atoms in the compound.

- It does not indicate to actual numbers of atoms in each molecule of the compound.

- The molecular formula gives the **actual** number of atoms of each element in a molecule. It is always a whole number **multiple** of the empirical formula.

Example:

- Analysis of a compound showed it to consist of 80% carbon and 20% hydrogen by mass. The molecular mass was found to be 30g. What is the molecular formula?

Step 1

- Find the empirical formula first.

Using the procedures above.

The empirical formula is CH_3.

Step 2

- Determine the molecular formula from the molecular mass and the formula mass.

Step 2

- Empirical formula mass

  12 + (1 X 3) = 15 g

  (calculated from CH_3)

Molecular mass = 30 g

(given in the problem)

Step 2

Number of multiples = $\frac{\text{molecular mass}}{\text{empirical formula mass}}$

$\frac{30\ g}{15\ g} = 2$

Step 2

molecular formula is

$(CH_3)_2$ or C_2H_6