7.3 GUIDE TO FINDING FORMULA MASS/MOLAR MASS OF A COMPOUND, % COMPOSITION, & EMPIRICAL FORMULAS

To find the FORMULA MASS (& MOLAR MASS) OF A COMPOUND:

1. Determine what types of atoms (which elements) and how many of each atom that you have in your compound. Make a list
    a. *Example: H_2O*
    2 x Hydrogen
    1 x Oxygen
2. Then determine the atomic mass for each atom and multiply that mass by the number of atoms of each element you have.
    a. Example
    2 x (mass of hydrogen atom = 1.0079 amu) = 2.0158 amu
    1 x (mass of oxygen atom = 15.9994 amu) = 15.9994 amu

3. Then add up the masses to find the mass of the chemical formula.
    a. Example
    2.0158 + 15.9994 = 18.0152 amu

To find the MOLAR MASS OF A COMPOUND:

Use the same process as you did for the formula mass, but report your masses in units of grams per mole instead of amu!!!!!

EXAMPLES (show all your work so you can use it as a guide later!):

- Find the formula mass for $KClO_3$

- Find the formula mass for $Ca(NO_3)_2$

- Find the molar mass for Al_2S_3

- Find the molar mass for $Ba(OH)_2$

To convert between mass, moles, and atoms

To convert moles to grams:

 # moles given x g/mol (or molar mass) = grams

To convert mass to moles:

Grams given x 1/(molar mass) = moles

To convert moles to number of atoms/molecules:

Moles given x 6.022 x 10^{23} = number of atoms/molecules

EXAMPLES (show all your work so you can use it as a guide later!):

- What is the mass in grams of 2.50 mol of oxygen gas (O_2)?

- How many moles of compound are there in 6.60g $(NH_4)_2SO_4$

- How many molecules are there in 2.89 mol of H_2SO_4?

To find the PERCENT COMPOSITION of the elements in a compound:

1. To find percent composition by mass: take the mass of each element (taking into account how many atoms of each you have) and divide that by the formula mass of your sample. Multiple that by 100. **The percentage will be the same regardless of the sample size!**
    a. *Example: H_2O. Formula weight is 18.0152 amu*

        2 x (mass of hydrogen atom = 1.0079 amu) = 2.0158 amu
        1 x (mass of oxygen atom = 15.9994 amu) = 15.9994 amu

        % composition of H in H_2O: (2.0158/18.0152) x 100 = 11%
        % composition of O in H_2O: (15.9994/18.0152) x 100 = 89%
        To check your answer, make sure the percentages add up to 100%.

2. To find percent composition by moles:
    a. Molar mass of each element divided by molar mass of the compound x 100

EXAMPLES (show all your work so you can use it as a guide later!):

- Find the percentage compositions of: $Ba(NO_3)_2$

- Magnesium Hydroxide is 54.87% oxygen by mass. How many grams of oxygen are in 175 g of the compound?

Background Info for Empirical Formulas

Empirical formulas: **show the smallest whole-number mole ratio of atoms** in the compound.
Molecular formulas: show **exactly how many of each type of atom** are in one molecule of the compound.

Example: Glucose

Empirical formula of glucose: CH_2O
- this formula shows that the ratio of C:H:O in glucose is 1:2:1

Molecular formula: $C_6H_{12}O_6$
- This formula shows that is 1:2:1 a glucose molecule contains 6 carbons, 12 hydrogens, & 6 oxygens

To Calculate Empirical Formulas

There are two ways to calculate this:

1. Calculating empirical formulas **from experimentally determined masses**
    a. Convert the given masses to moles of each element (by dividing by the molar mass)
    b. Compare ratio of moles of each element and divide all the moles by the smallest number
    c. If result from step "b" gives a ratio with a decimal, convert it to a fraction and multiply all the ratios by the denominator of the fraction to get whole numbers
    d. Use the resulting values as the subscripts for each element

Example: Analysis of a 10.150 g sample of a compound known to contain phosphorus and oxygen indicates 4.433 g of the sample is made of phosphorus. What is the empirical formula of the compound?

2. Calculating empirical formulas **from percentage composition**
    a. Convert percentage of each element to grams, assuming you have a 100 g sample (note: so if you have 33% Na in a compound, you will assume you have 33 grams of Na for this step).
    b. Multiply the grams of each element by 1/molar mass of that element.
    c. Compare ratio of moles of each element and divide all the moles by the smallest number
    d. If result from step "b" gives a ratio with a decimal, convert it to a fraction and multiply all the ratios by the denominator of the fraction to get whole numbers
    e. Use the resulting values as the subscripts for each element

Example: Quantitative analysis shows that a compound contains 32.38% sodium, 22.65% sulfur, and 44.99% oxygen. Find the empirical formula.

Finding a Molecular Formula from an Empirical Formula

The relationship between empirical and molecular formulas is:

$$\frac{\text{Empirical formula}}{X^*} = \text{molar mass (this will be given to you in the problem)}$$

So… $\frac{\text{empirical formula}}{\text{Molar mass}} = X^*$

* "X" is the factor you multiply the subscripts of your empirical formula by to get your molecular formula

Example: In a compound with empirical formula P_2O_5, experimentation showed that the molar mass of this compound is 283.89 g/mol. What is the compound's molecular formula?