TOPIC: 1.3 ELEMENTAL COMPOSITION OF PURE SUBSTANCES

ENDURING UNDERSTANDING:	
SPQ-2	Chemical Formulas identify substances by their unique combination of atoms
LEARNING OBJECTIVE:	
SPQ-2.A	Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance
ESSENTIAL KNOWLEDGE:	
SPQ-2.A.1	Some pure substances are composed of individual molecules, while others consist of atoms or ions held together in fixed proportions as described by a formula unit.
SPQ-2.A.2	According to the law of definite proportions, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.
SPQ-2.A.3	The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.
EQUATION(S):	
	N/A

NOTES:

A pure substance is one with constant composition; a pure substance can either be an element or a compound

When dealing with compounds you can assume it follows the law of definite proportion, which states compounds with the same elements in the same proportion are the SAME compound.

Following the law of definite proportion, you can find the percent composition which is the percent by mass of each element that makes up a compound.
To calculate the percent composition, you divide the mass of each element in a compound by the total molar mass of the substance.

In compounds, the **empirical formula** represents the simplest ratio of one element to another in a compound. The **molecular formula** represents the actual formula for the substance.

An example is glucose which has the molecular formula $C_6H_{12}O_6$ but the empirical formula is CH_2O.

To determine the empirical and molecular formula.

1. Determine the *empirical formula* for the compound when given percent of each element
    a. Assume you are given a 100g sample so you can change percent to grams
    b. For each element take grams / molar mass to get moles of each element
    c. Divide each mole value by the lowest of the values
    d. If you are within 0.1 of a whole number round to the whole number, if you are not you must multiply by a factor that gives you whole numbers for all.
    e. The values you found are the subscripts for each element
2. Determine *molecular formula* (can only determine if given molar mass of substance)
    a. Find mass of empirical formula
    b. Molar mass/ empirical formula mass to find factor
    c. Multiply all subscripts in the empirical formula by the value

I DO:

A certain sugar used in treating patients with low blood sugar has the following chemical composition: 40.0 % carbon, 6.70 % hydrogen, and 53.3 percent oxygen. What is the empirical formula?

40 % C → $40\,g\,C \times \frac{1\,mol\,C}{12.011\,g\,C} = 3.33\,mol\,C$

6.7 %H → $6.7\,g\,H \times \frac{1\,mol\,H}{1.01\,g\,H} = 6.63\,mol\,H$

53.3% O → $53.3\,g\,O \times \frac{1\,mol\,O}{16.0\,g\,O} = 3.33\,mol\,O$

$\frac{3.33\,mol\,C}{3.33\,mol} = 1$ $\frac{6.63\,mol\,H}{3.33\,mol} = 2$ $\frac{3.33\,mol\,O}{3.33\,mol} = 1$

∴ CH_2O

The molar mass of the compound is 180 grams/mole. What is the molecular formula of this compound?

C = 1 x 12.01 = 12.01

H = 2 x 1.01 = 2.02

O = 1 x 16.0 = 16.00

30.03 g/mol

$(30.03\,g/mol)x = 180\,g/mol$

$x = 6$ ∴ $C_6H_{12}O_6$

WE DO:

a. A compound is found to contain 56.5% carbon, 7.11% hydrogen, and 36.4% phosphorus. Find the empirical formula.

b. If the compound has a molar mass of 170.14 g/mol, what is its molecular formula?

SCAN ME

YOU DO:

1. The most abundant molecule found in the human body is 88.810% oxygen and 11.190% hydrogen. Calculate the empirical formula for this substance.

2. Arginine is one of the amino acids; it is used in the biosynthesis of proteins. Analysis revealed that a sample of arginine was 41.368 % carbon, 8.101% hydrogen, 32.162 % nitrogen and 18.369% oxygen.
   a. What is the empirical formula of arginine?

   b. The molecular weight of arginine is 174.204 grams/mole. What is the molecular formula?

3. The empirical and molecular formulas of urea are the same. 90 % of the world's urea is used for fertilizer. If the percentage composition of the elements in urea are 19.999% carbon, 6.713% hydrogen, 46.646% nitrogen and 26.641% oxygen.

4. A compound containing phosphorus and oxygen is a powerful desiccant. The compound is 43.642% phosphorus and 56.358% oxygen.
    a. Calculate the empirical formula for this compound.

    b. The molar mass of this compound is 283.889044 g/mol, determine the molecular formula.

5. Emeralds are composed of 4 different elements in a fixed proportion. They are composed of 5.030 % beryllium, 10.040 % Aluminum, 31.351% Silicon and 53.579% oxygen. The empirical and molecular formula are the same.
    a. Calculate the empirical formula.

    b. Calculate the molar mass.

6. Iron can form three different oxides, FeO, Fe_2O_3 and Fe_3O_4. A sample of iron oxide was analyzed and was found to contain 69.943% iron with the rest of the mass from oxygen. Determine the empirical formula to determine the identity of the iron oxide.

7. Serotonin is a chemical that nerve cells produce from an essential amino acid called tryptophan. Tryptophan must enter our body through a balanced diet, and is commonly found in nuts, cheese and red meat. Serotonin is considered to be a natural mood stabilizer as it helps with sleeping, eating and digestion. A sample of serotonin was found to be 6.864% hydrogen, 68.159% carbon, 15.897% nitrogen and 9.079% oxygen. Calculate the empirical formula for serotonin.