

# Empirical & Molecular Formulas

## Chapter 3

Slide Set G

# Percent Composition

$$\% \text{ Element in compound} = \frac{\text{atomic mass of element} \times \# \text{ atoms}}{\text{molar mass of the compound}} \times 100\%$$

Calculate the percent phosphorus in

***calcium phosphate***

# Empirical and Molecular Formulas

- **Empirical Formula** - the smallest whole number ratio of atoms (or moles of atoms) in a compound.
- **Molecular Formula** - the actual number of atoms in a molecule (multiple of the empirical formula).
- **Example: Octane**
  - Molecular formula =  $C_8H_{18}$
  - Empirical formula =  $C_4H_9$

## Sample Problem: Empirical & Molecular Formulas

What is the molecular formula of the sugar ribose if it is 40.0% C, 6.7% H, and 53.3% O and it has a molecular mass of 150.1 g/mol?

# Sample Problem Solution

- *First, determine the empirical formula:*

**Step 1.** Assume 100.0 g of the compound.

If you have 100g of the material, you will have the following masses of C, H, & O:

40.0 g C

6.7 g H

53.3 g O

**Step 2.** Convert grams to moles:

$$\frac{40.0 \text{ g C}}{12.01 \text{ g C}} \times \frac{1 \text{ mol C}}{1 \text{ mol C}} = 3.33 \text{ mol C}$$

$$\frac{6.7 \text{ g H}}{1.01 \text{ g H}} \times \frac{1 \text{ mol H}}{1 \text{ mol H}} = 6.6 \text{ mol H}$$

$$\frac{53.3 \text{ g O}}{16.00 \text{ g O}} \times \frac{1 \text{ mol O}}{1 \text{ mol O}} = 3.33 \text{ mol O}$$

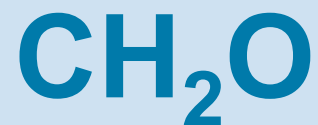
**Step 3.** Find the smallest ratio of atoms.

$$\text{C} \quad 3.33 / 3.33 = 1$$

$$\text{H} \quad 6.6 / 3.33 = 1.98 \approx 2$$

$$\text{O} \quad 3.33 / 3.33 = 1$$

Therefore, the *empirical formula* of ribose is



- *Next, determine the molecular formula.*

**Step 4.** Calculate the empirical formula mass.

$$\text{C} = 12.01 \times 1 = 12.01 \text{ g/mol}$$

$$\text{H} = 1.01 \times 2 = 2.02 \text{ g/mol}$$

$$\text{O} = 16.00 \times 1 = 16.00 \text{ g/mol}$$

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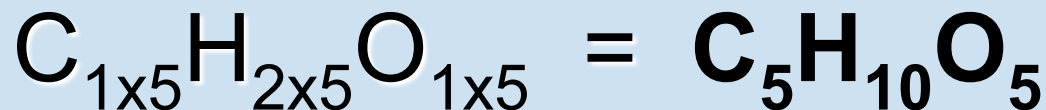
$$30.03 \text{ g/mol}$$



**Step 5.** Calculate the number of empirical formula units within the molecular formula.

Multiply the subscripts of the empirical formula by this number to get the ***molecular formula***.

$$\frac{150.1 \text{ g/mol}}{30.03 \text{ g/mol}} = 4.998 \approx 5$$



## Example: Empirical Formulas

An oxide of osmium is a pale yellow solid. If 2.89 g of the compound contains 2.16g of osmium, what is its formula?

## Example: Empirical & Molecular Formulas

A 30.5-g sample of acrylic acid, used in the manufacture of acrylic plastics, is found to contain 15.25 g C, 1.71 g H, and 13.54 g O.

In a separate experiment, the acrylic acid is found to have a molar mass of approximately 72 g/mol.

What are the empirical and molecular formulas of acrylic acid?

# Calculating Waters of Hydration

- A 10.00-g sample of  $\text{CoCl}_2 \cdot x \text{H}_2\text{O}$  is heated. The mass of the resulting solid was found to be 5.46 g.
  - How many waters of hydration are in the formula unit?
  - What is the formula & name of the hydrate?