Empirical and Molecular Formula
Outline

- This is a small section that is the continuation from the Chemical reactions unit.
- There will be a small quiz at the end of this section – NO unit test

- Calculating Percent % Composition
- Empirical formula
- Figuring out molecular formula
Percent composition

- **Purpose**: Calculates the amount (in %) of an element in a compound.

- **Example**: If a 100g sample contains 55g of element X and 45g of element Y, what is the % composition of each element?

  - Element X: \( \frac{55}{100} \times 100 = 55\% \) of Element X
  - Element Y: \( \frac{45}{100} \times 100 = 45\% \) of Element Y

This calculation was for a 100g sample. What if we were given the chemical formula?
Percent composition from chemical formula

To calculate for the % composition from a chemical formula, you have to:

1. Assume you have exactly 1 mol of the compound and Calculate the molar mass of the whole compound

2. Use the formula below to determine the percent by mass:

Formula:

\[
\text{Percent by mass} = \frac{\text{mass of element in 1 mol of compound}}{\text{molar mass of compound}} \times 100
\]
Example: Determine the percent composition of NaHCO\textsubscript{3} for each element

1. Assume you have 1 mol of NaHCO\textsubscript{3}, this means you can calculate the molar mass of NaHCO\textsubscript{3}

Molar mass:

\[(22.99g + 1.008g + 12.01g + 48.00g)\]

\[= 84.01g/mol\]
Example: Determine the percent composition of NaHCO$_3$ for each element

2. Then use the formula below:

**Formula:**

\[
\text{Percent by mass} = \frac{\text{mass of element in 1 mol of compound}}{\text{molar mass of compound}} \times 100
\]

- **Percent Na** = \( \frac{22.99\text{g/mol}}{84.01\text{g/mol}} \times 100 = 27.37\% \) of Na
- **Percent H** = \( \frac{1.008\text{g/mol}}{84.01\text{g/mol}} \times 100 = 1.200\% \) of H
- **Percent C** = \( \frac{12.01\text{g/mol}}{84.01\text{g/mol}} \times 100 = 14.30\% \) of C
- **Percent O** = \( \frac{48.00\text{g/mol}}{84.01\text{g/mol}} \times 100 = 57.37\% \) of O

Do all the Percentages add up to 100? If yes, you are RIGHT!
Practice work for homework:

- What is the percent composition of Phosphoric acid (H$_3$PO$_4$)?
- And CaCl$_2$?
- And H$_2$S$_2$O$_8$?
Empirical Formula

- Once the compound’s percent composition is known, its formula can be calculated.
- The **empirical formula** is the smallest whole-number mol ratio of the elements.
- It may or may not be the actual formula, but the **molecular formula** is the actual formula.
Empirical Formula question type: When % composition is given.

1. Assume the total mass of compound is 100g (This step allows you to change the % into mass)

2. Calculate moles for each (This keeps all the units consistent for the mass)

3. Divide by the smallest mole to get the subscripts for the formula (to get the subscript)

4. Multiply by the smallest mole ratio, IF NECESSARY. (This step gets you whole numbers instead of partial ratios)
Determine the empirical formula for methyl acetate that has the following chemical analysis:

**Carbon:** 48.64%, **Hydrogen:** 8.16%, **Oxygen:** 43.20%

1. Assume the total sample is in 100g, so you can change the % into masses:
   - C: 48.64g
   - H: 8.16g
   - O: 43.20g

2. Moles of each: (Work on board)
   - 4.050mol of C
   - 8.10mol of H
   - 2.700mol of O

3. Divide by smallest number of moles: (Work on board)

4. Multiply by smallest mole ratio
Practice:

1. Empirical formula of 35.85% of aluminum and 64.02% of sulfur

2. Propane is a hydrocarbon, a compound composed only of carbon and hydrogen. It is 81.82% of carbon, and 18.18% of hydrogen. What is the empirical formula.
Molecular Formula

- Determining the molecular formula requires the **empirical formula** but also the **molar mass** of the total compound.

- The molar mass in this case is determined experimentally.

- **Why is this useful?**
  - If you are a chemist analyzing an unknown sample, this method allows you to determine the molecular formula!
Determining Molecular Formula

- Succinic acid has composition of 40.68% Carbon, 5.08% of Hydrogen, 54.24% of oxygen. It has a molar mass of 118.1g/mol.

1st. Determine the empirical formula

2nd. Determine the molecular formula (you will need the molar mass provided).

To determine the molecular formula, use the formula below to multiply the subscripts to the ratio (n)

\[ N = \frac{\text{molar mass provided}}{\text{molar mass of from empirical formula}} \]
1. Determine the empirical formula for ilmenite (a mineral) that contains 5.41g of iron, 4.64g of titanium and 4.65g of oxygen.

2. Determine the molecular formula of a colorless liquid of 46.68% of nitrogen, and 53.32% of oxygen that has a molar mass of 60.01g/mol.

3. A compound was found to contain 49.98g of carbon and 10.47g of hydrogen. The molar mass of the compound is 58.12g/mol. Determine the molecular formula.