

Empirical Formulas

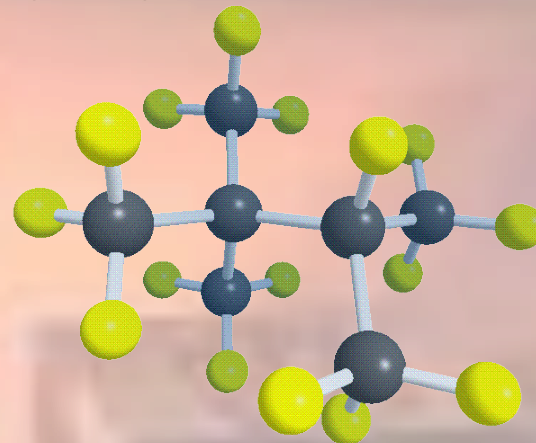
Chemical Formulas
in Lowest Terms

What is an Empirical Formula?

- An empirical formula is the simplest ratio of the atoms present in a molecule.
- The following are empirical formulas because they cannot be reduced to lower terms:
 - CO_2 , H_2O , NaCl , NaCO_2 , CH , and C_3H_5 .
- The following are NOT empirical formulas because they CAN be reduced to lower terms:
 - $\text{C}_6\text{H}_{12}\text{O}_6$, H_2O_2 , $\text{Na}_2\text{C}_2\text{O}_4$, C_6H_6 , and C_6H_{10} .

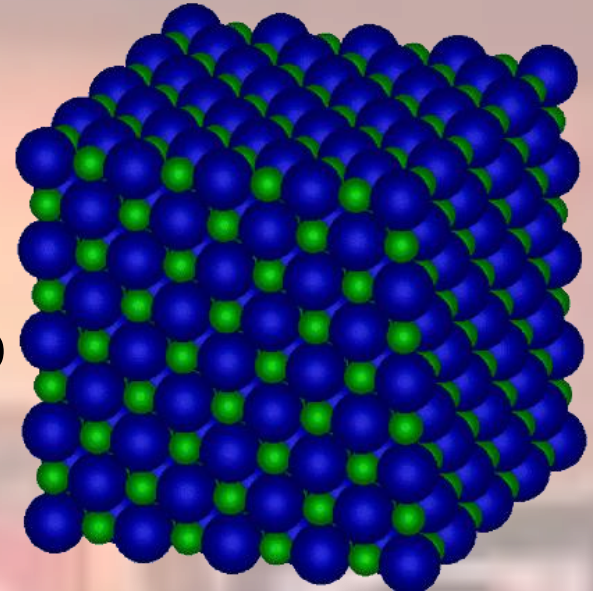
Why Empirical Formulas?

- When chemists analyze compounds to find out what they are made of, they find out what elements are present and in what proportions.
- The proportion of elements in a compound is not the same as the molecular formula.
- For example, the octane in gasoline can be burned to form carbon dioxide and water.
- Measuring the masses of the products will show that octane has 4 carbon atoms to every 9 hydrogen atoms (C_4H_9).
- C_4H_9 is an empirical formula. The molecular formula is C_8H_{18} .



Why Else?

- For many ionic substances, only an empirical formula exists.
- In a sodium chloride crystal, every sodium ion (shown in green) is ionically bonded to every adjacent chloride ion (shown in blue).
- There is no separate sodium chloride molecule. Instead, only the ratio of sodium to chloride ions is known. It is one to one.
- The formula is therefore NaCl.



Determining the Empirical Formula

- To determine the empirical formula from a molecular formula, simply reduce the subscripts to lowest terms.
- Examples:
 - Glucose:
 - ✓ Molecular formula = $\text{C}_6\text{H}_{12}\text{O}_6$; The subscripts are all divisible by 6
 - ✓ Empirical formula = CH_2O ;
 - Hydrogen peroxide:
 - ✓ Molecular formula = H_2O_2 ; The subscripts are all divisible by 2
 - ✓ Empirical formula = HO

Determining the Molecular Formula

- It is possible to determine molecular formulas from empirical formulas and formula mass
- Procedure : molecular formulas are always some multiple of empirical formulas
 - Find the empirical formula mass like any other formula mass.
 - Divide the empirical formula mass into the molecular mass. This gives you a multiple.
 - Multiply the empirical formula by the multiple

Sample Problem

A compound with an empirical formula of CH_2 has a molecular mass of 42 amu. What is its molecular formula?

- **Step 1:** Determine the empirical formula mass.



$$\text{C} = 12 \times 1 = 12$$

$$\text{H} = 1 \times 2 = \underline{2}$$
$$14$$

- **Step 2:** Divide the molecular mass by the empirical formula mass to determine the multiple.

$$\frac{42}{14} = 3$$

- **Step 3:** Multiply the formula by the by the multiple to find the molecular formula

