Empirical Formulas

The empirical formula is the simplest ratio of atoms in a compound. Formulas for ionic compounds are always empirical formulas, but for covalent compounds, the empirical formula is not always the actual formula for the molecule. Molecules such as glucose, C₆H₁₂O₆, would have an empirical formula of CH₂O.

Empirical formulas can be determined from experimental data or from percent composition. Example:

A 2.5 gram sample is analyzed and found to contain 0.9 grams of calcium and 1.6 grams of chlorine.

**Step 1:** Find the moles of each element present in the compound.

\[
\text{moles of Ca} = \frac{0.9 \text{ g Ca}}{40 \text{ g}} \times 1 \text{ mole Ca} = 0.0224 \text{ mol Ca} \\
\text{moles of Cl} = \frac{1.6 \text{ g Cl}}{35.5} \times 1 \text{ mole Cl} = 0.0451 \text{ mol Cl}
\]

**Step 2:** We need to find the simplest whole number ratio. To do this, divide each of them by the smaller number.

\[
\text{Ca} = \frac{0.0224 \text{ mol}}{0.0224 \text{ mol}} = 1 \text{ mole Calcium} \\
\text{Cl} = \frac{0.0451 \text{ mol}}{0.0224 \text{ mol}} = 2 \text{ moles of Chlorine}
\]

The correct empirical formula for this compound is CaCl₂.

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1. Calculate the % composition for potassium sulfate.

   K₂SO₄

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Mass</th>
<th>Coefficient</th>
<th>% Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>39.09831</td>
<td>2</td>
<td>44.8736 %</td>
</tr>
<tr>
<td>S</td>
<td>32.0655</td>
<td>1</td>
<td>18.4010 %</td>
</tr>
<tr>
<td>O</td>
<td>15.99943</td>
<td>4</td>
<td>36.7255 %</td>
</tr>
</tbody>
</table>

2. A compound is 85.7 % carbon and 14.3 % hydrogen. Calculate the empirical formula.

   **Step 1: Find the moles**

   \[
   \frac{85.7 \text{ g carbon}}{12 \text{ g carbon}} \times 1 \text{ mole carbon} = 7.14 \text{ moles carbon}
   \]

   \[
   \frac{14.3 \text{ g hydrogen}}{1 \text{ g hydrogen}} = 14.3 \text{ moles hydrogen}
   \]

   **Step 2: Find the simplest whole number ratio**

   \[
   \text{C} - \frac{7.14}{7.14} = 1 \quad \text{H} - \frac{14.3}{7.14} = 2 \quad \text{CH}_2
   \]
3. Ethylene Glycol (Antifreeze) is 38.7% Carbon, 51.6% Oxygen and 9.7% Hydrogen. What is the empirical formula?

\[
\begin{align*}
38.7 \text{ g carbon} \times \frac{1 \text{ mole carbon}}{12 \text{ g carbon}} &= 3.23 \text{ moles carbon} \\
51.6 \text{ g oxygen} \times \frac{1 \text{ mole oxygen}}{16 \text{ g carbon}} &= 3.23 \text{ moles oxygen} \\
9.7 \text{ g hydrogen} \times \frac{1 \text{ mole hydrogen}}{1 \text{ g hydrogen}} &= 9.7 \text{ moles hydrogen}
\end{align*}
\]

C - 3.23/3.23 = 1  \quad O - 3.23/3.23 = 1  \quad H - 9.7/3.23 = 3  \quad \text{COH}_3

4. The percentage composition of acetic acid is found to be 39.9% C, 6.7% H, and 53.4% O. Determine the empirical formula of acetic acid.

\[
\begin{align*}
39.9 \text{ g carbon} \times \frac{1 \text{ mole carbon}}{12 \text{ g carbon}} &= 3.33 \text{ moles carbon} \\
6.7 \text{ g hydrogen} \times \frac{1 \text{ mole hydrogen}}{1 \text{ g hydrogen}} &= 6.7 \text{ moles hydrogen} \\
53.4 \text{ g oxygen} \times \frac{1 \text{ mole oxygen}}{16 \text{ g carbon}} &= 3.34 \text{ moles oxygen}
\end{align*}
\]

C - 3.33/3.33 = 1  \quad H - 6.7/3.33 = 2  \quad O - 3.34/3.33 = 1  \quad \text{CH}_3\text{O}

5. What's the empirical formula of a molecule containing 18.7% lithium, 16.3% carbon, and 65.0% oxygen?

\[
\text{Li}_2\text{CO}_3
\]

6. The compound benzamide has the following percent composition. What is the empirical formula?  C = 69.40 %  H= 5.825 %  O = 13.21 %  N= 11.57 %

\[
\text{C}_7\text{H}_7\text{NO}
\]