

The Mole & Chemical Formulas

Moles, molar mass, Avogadro's number, percent composition, and empirical/molecular formulas.

01 What you're counting

CORE RULE

Molecular compounds: count molecules (H_2O , CO_2). Ionic compounds: count formula units (NaCl). Elements: atoms (Na , Fe) or molecules (H_2 , O_2 , P_4 , S_8).

02 Moles of each element

CORE RULE

Each subscript = moles of that element per mole of compound. 1 mol $\text{Al}_2(\text{SO}_4)_3$ = 2 mol Al, 3 mol S, 12 mol O. Hydrate waters add to the count.

03 Molar mass

CORE RULE

Sum the atomic masses of every atom in one formula unit (expand parentheses, include hydrate water), in g/mol. $\text{Al}_2(\text{SO}_4)_3$ = $2(26.98) + 3(32.06) + 12(16.00)$ = 342.14 g/mol.

04 Mass $\leftrightarrow$ moles

CORE RULE

Mass $\rightarrow$ moles: $\times$ (1 mol / molar mass). Moles $\rightarrow$ mass: $\times$ (molar mass / 1 mol). g/mol cancels; carry units to self-check.

05 Avogadro's number

CORE RULE

$N_A = 6.022 \times 10^{23}$ entities/mol. Moles $\rightarrow$ particles: $\times N_A$. Particles $\rightarrow$ moles: $\div N_A$. Atoms of an element = mol compound $\times$ subscript $\times N_A$.

06 Hydrates

CORE RULE

Use the full hydrate molar mass (including water). 1 mol $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ = 1 mol anhydrous CuSO_4 + 5 mol H_2O .

Atom count includes the waters: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ has 9 O ($4 + 5$) and 10 H (2×5).

Dissociation uses the anhydrous ions only: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightarrow \text{Cu}^{2+} + \text{SO}_4^{2-} + 5\text{H}_2\text{O}$ (2 ions, not 7).

07 Percent composition

CORE RULE

Mass % of X = (atomic mass of X $\times$ subscript) / molar mass $\times$ 100%. All element percents sum to 100.00% ($\pm 0.05\%$ rounding).

08 Empirical vs molecular formula

CORE RULE

Empirical formula = smallest whole-number atom ratio. Molecular formula = actual atoms = (empirical)_n, where n is a positive integer (n = 1 if they match).

09 Empirical formula from % or mass

METHOD

Assume 100 g (so % = g); convert each element to moles; divide all by the smallest; if a ratio isn't near an integer, multiply all by 2 (for .5), 3 (.33/.67), or 4 (.25/.75).

10 Combustion analysis

METHOD

All C $\rightarrow$ CO_2 (mass C = mol $\text{CO}_2 \times 12.01$), all H $\rightarrow$ H_2O (mass H = $2 \times$ mol $\text{H}_2\text{O} \times 1.008$). For C-H-O, mass O = sample - C - H (by difference).