The **mole**, whose symbol is **mol**, is the unit of measure of a fundamental quantity, the **amount of substance (*n*)** or *chemical amount*.

The fundamental aspect of this quantity is that each mole of any substance is formed by the same number of particles (atoms or molecules). This number is called **Avogadro's Number** *(***N***)* and has the value $6.022 \cdot 10^{23}$ particles/mol.

One can easily derive the mass of each mole in that the mass in grams of one mole of any substance corresponds numerically to the atomic weight or molecular weight of the substance. This value is called the **molar mass (*M*).**

One mole of any gas, at the same pressure and temperature, occupies the same volume, this volume is called the **molar volume (V_m)**. If this volume is measured at STP (Standard Temperature and Pressure), i.e. $T = 273.15$ K e $p = 101.325$ kPa, it equals **22.4 L/mol**.

The chemical amount of a substance is the ratio between the mass in grams of the substance and its molar mass, expressed in grams per mole.

$$n = \frac{m}{M}$$

In the case of a gaseous substance of known volume, the chemical amount is the ratio between the volume and the molar volume, measured under the same conditions of temperature and pressure.

$$n = \frac{V}{V_m}$$

All the quantities that characterize the state of a gas appear in one equation, called the **general gas equation** for ideal gases: the product of the pressure (p) and volume (V) of a gas is equal to the product of the chemical amount (n) for the gaseous substance, its absolute temperature (T) and the gas constant (R).

$$p \cdot V = n \cdot \mathrm{R} \cdot T$$

The **concentration** is a fundamental characteristic of solutions indicating the relationship between the amount of solute and the amount of solution (or solvent).

There are several ways to express the concentration of a solution.

Mass per volume ($C_{m/V}$) is the mass of solute in a unit volume of solution and is calculated from the ratio of the mass of the solute in grams and the volume of the solution in litres.

$$C_{\mathrm{g/L}} = \frac{\text{mass of solute (in grams)}}{\text{volume of solution (in litres)}}$$

Percentage by mass ($C_{\%m/m}$) corresponds to the parts in mass of solute present in 100 parts by mass of solution. It is necessary that the mass of the solute and the solution are expressed in the same units.

$$C_{\%\,m/m} = \frac{\text{mass of solute}}{\text{mass of solution}} \cdot 100$$

The percentage by volume ($C_{\%V/V}$) corresponds to the parts in volume of the solute present in 100 parts in volume of the solution.

$$C_{\%\,V/V} = \frac{\text{volume of solute}}{\text{volume of solution}} \cdot 100$$

Parts per million (C_{ppm}) corresponds to the parts of solute present in one million parts of solution.

$$C_{ppm} = \frac{\text{parts of solute}}{\text{parts of solution}} \cdot 1\,000\,000$$

The concentration of a solution can also be defined with reference to moles.

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The **molar concentration** or **molarity (C_M)** is the ratio between the chemical amount of solute (in moles) and the volume of solution (expressed in litres). We can also say that the molarity indicates "the moles of solute present in a litre of solution".

$$C_M = \frac{\text{amount of solute (in moles)}}{\text{mass of solvent (in litres)}}$$

For example, the expression 0.1 M NaOH reads as: 0.1 molar aqueous solution of sodium hydroxide.

The **molal concentration** or **molality (C_m)** is the ratio between the chemical amount of solute (in moles) and the mass of solvent (in kilograms).

$$C_m = \frac{\text{amount of solute (in moles)}}{\text{volume of solution (in kilograms)}}$$

The dissolution of a substance in a solvent can result in a change in some of the properties of the solvent itself: for example, in solutions in which a solid is dissolved, the melting temperature undergoes a **cryoscopic decrease** and the boiling point an **ebullioscopic increase**. In addition, between solutions of different concentrations there is the phenomenon of **osmosis**.

The stoichiometric coefficients of chemical equations also indicate the ratio of moles of all species present in the equation. Consider the reaction in which one mole of magnesium reacts with one mole of sulfur to give a mass of one mole of magnesium sulfide.

$$\mathrm{Mg + S \rightarrow MgS}$$

These relationships between the stoichiometric coefficients allow us to assert that the reaction is carried out completely when equal amounts of the two chemical reagents (multiples or fractions of a mole) react with each other.

These relationships between moles also allow one to say that 24.31g of magnesium (mass of one mole) reacts with 32.07 g of sulfur (mass of a mole) to give 56.38 g of magnesium sulfide; of course, proportional masses of the two reagents can react.

If with one mole of magnesium reacts with more than one mole of sulfur, the excess quantity of sulfur does not react. That is, when the reagents are not in an exact stoichiometric ratio there is always an *excess reagent* (in this case sulfur). The amount of magnesium sulfide obtained is limited by the *reagent in deficit* (in this case, magnesium), which is therefore also termed the **limiting reagent**.

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