MOLE CONCEPT

Mole

The mole is the SI base unit for an amount of a chemical species. It is always associated with a chemical formula and refers to Avogadro's number (6.022×10^{23}) of particles represented by the formula. It is denoted as N_A.

$$1 \text{ mole of a substance} = 6.022 \times 10^{23} \text{ species}$$

$$\text{Number of moles } (n_A) = \frac{\text{Weight of substance in grams}}{\text{Molecular weight of substance}}$$

$$\text{Gram weight} \underset{\text{Multiply by molar mass}}{\overset{\text{Divide by molar mass}}{\rightleftarrows}} \text{Mole} \underset{\text{Divide by } N_A}{\overset{\text{Multiply by } N_A}{\rightleftarrows}} \text{Molecule}$$

Example 1: How many moles of sucrose ($C_{12}H_{22}O_{11}$) are there in a table spoon of sugar that contains 2.85g?

Solution

Given, $2.85\text{g of sucrose} = \frac{2.85}{342}$ mol (Divide by molar mass)

$= 0.00833$ mol

$= 8.33 \times 10^{-3}$ mol

Molar Volume

It is the volume occupied by one mole of an ideal gas at STP (standard temperature and pressure, 0°C and one atmosphere pressure). It is value is 22. 414 mol^{-1}.

Using PV = nRT, we can calculate the value for molar volume. V is the unknown and n=1 mol. We know that the value of pressure and temperature to their standard values and use R= 0.08206 (gas constant).

$$PV = nRT$$

$$1 \text{ atm} \times V = 1 \times 0.08206 \text{ L atm/mol K} \times 273\text{K}$$

$$V = 22.4\text{L}$$

$$\text{Mole} \underset{\text{Divide by 22.4L}}{\overset{\text{Multiply by 22.4L}}{\rightleftarrows}} \text{Molecule}$$

Example 2: How many moles are there in 10ml of Proline?

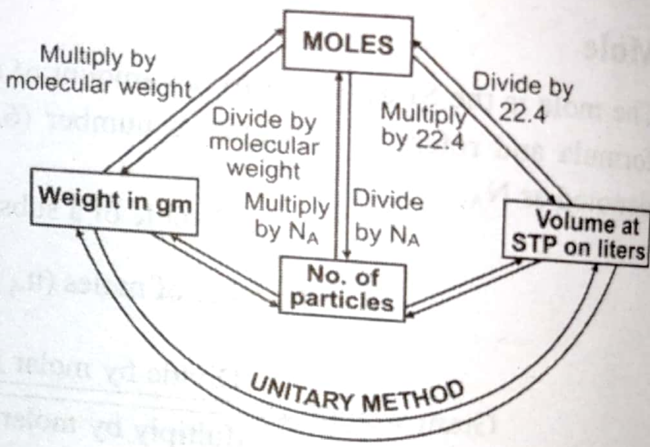
Solution

$$\text{Number of moles} = \frac{\text{Volume (ml)}}{22.4\text{ L}} = \frac{10\text{ ml}}{1000 \times 22.4\text{ ml}}$$

$$= \frac{10}{22400} = 4.4 \times 10^{-4}\text{ mol}$$

Atomic Mass Unit

Atoms are so tiny that even the smallest speck of dust visible to the naked eye contains about 10^{19} atoms. Thus, the mass of single atom in gram is too small a number for convenience, and chemists therefore use a unit called an atomic mass unit (amu), also known as dalton (Da). One amu is defined as exactly one twelth the mass of an atom of ${}^{12}_{6}C$ and is equal to 1.66054×10^{-24} g.



$$\text{Mass of one } {}^{12}_{6}C \text{ atom} = 12 \text{ amu}$$

$$1 \text{ amu} = \frac{\text{Mass of one } {}^{12}_{6}C \text{ atom}}{12} = 1.66054 \times 10^{-24} \text{ g}$$

To convert atomic mass into atomic mass unit, divide it by N_A or simply multiply atomic mass of element by 1 amu.

Thus,

$$\text{Mass of one H atom} = \frac{1}{N_A} = 1 \text{ amu}$$

$$\text{Mass of one O atom} = \frac{16}{N_A} = 16 \text{ amu}$$

Atomicity versus moles

The number of atoms in the molecules of an element is known as the atomicity.

- Number of atoms (n) = Number of moles × Atomicity × N_A
- Number of ions = Number of moles × N_A

Example 3: Calculate the number of atoms in 0.25 moles of P_4?

Solution

$$\text{Number of atoms (n)} = 0.25 \times 4 \times 6.023 \times 10^{23}$$

$$= 6.023 \times 10^{23} \times 1$$

$$= 6.023 \times 10^{23}$$

Example 4: Calculate the number of atoms in 48g Mg?

Solution

$$\text{Number of atoms (n)} = \frac{48}{24} \times 6.023 \times 10^{23}$$

$$= 12.04 \times 10^{23} \text{ atoms}$$

Mole Fraction

Fraction of the substance in the mixture expressed in terms of mole is called its mole fraction.

- n_A = mole of A in mixture of A and B
- n_B = mole of B in same mixture

$$\text{Mole fraction of A in the mixture} = X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B in the mixture} = X_B = \frac{n_B}{n_A + n_B}$$

Thus,

$$X_A + X_B = 1$$

Percent concentration

In a solution, let there be, w_1 g solute (molar mass = m_1) and w_2 g solvent (molar mass = m_2) and V mL solution of density dg/mL.

There are following types of expressions need to denote % concentration

1. **Mass per cent:** $\left(\frac{w}{W}\right) = \frac{\text{Mass solute}}{\text{Mass solution}} \times 100\% = \left(\frac{w_1}{w_1 + w_2}\right) \times 100$

2. **Volume per cent:** $\left(\frac{v}{V}\right) = \frac{\text{Volume solute}}{\text{Volume solution}} \times 100\% = \frac{v}{V} \times 100$

3. **Mass/ volume per cent:** $\left(\frac{w}{V}\right) = \frac{\text{Mass solute (g)}}{\text{Mass solution (mL)}} \times 100\% = \frac{w}{V} \times 100$

For every dilute solutions, parts per million, 10^6, (ppm) is a convenient way to express concentration

$$\text{Concentration (ppm)} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6 \text{ ppm}$$

For even more dilute solutions, parts 10^9 (ppb) per billion rather than 10^6 ppm is used

$$\text{Concentration (ppb)} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^9 \text{ppb}$$

Concentration in part per thousand (ppt) is also commonly used

$$\text{Concentration (ppt)} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^3 \text{ppt}$$

Example 5: Aqueous urea solution in 20% by mass of solution. Calculate percentage by mass of solvent.

Solution

If solute, $w_1 = 20g$

Then, Solution $w_1 + w_2 = 100g$

$\therefore$ $\text{Solvent} = 100 - 20 = 80g$

Hence,

$$\text{Percentage by mass of solvent} = \frac{20}{80} \times 100 = 25\%$$