Mass Transfer: Diffusion

Fundamental quantities in mass transfer

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HEATQUIZ

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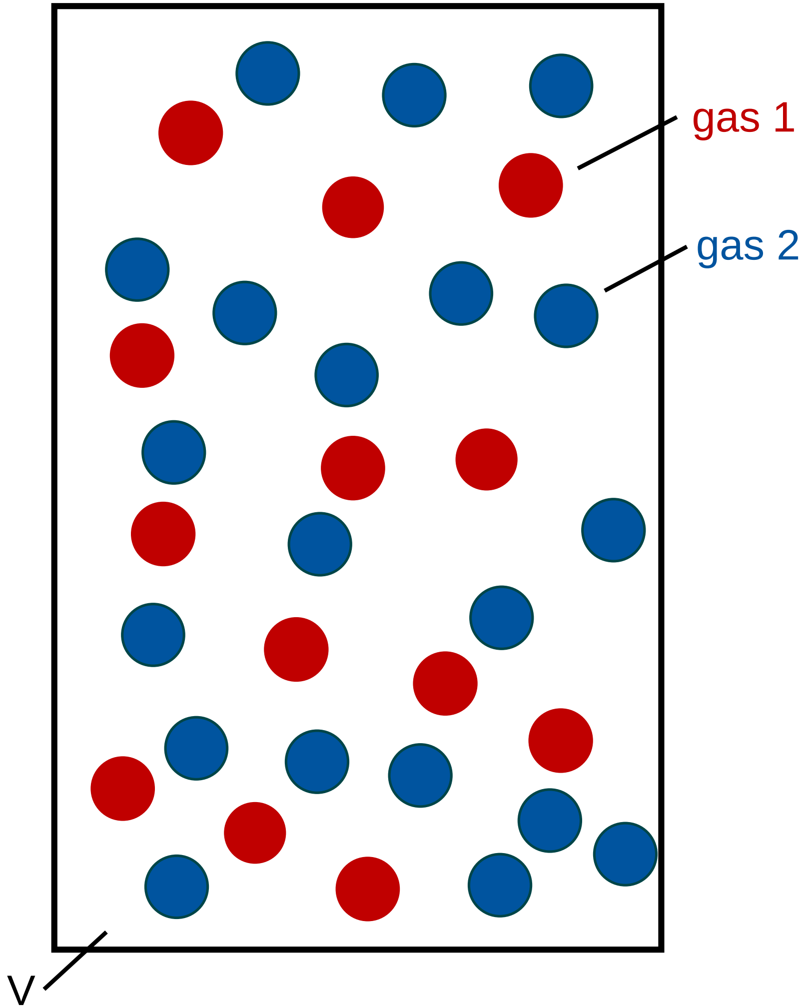
Mass transfer – fundamentals of binary mixtures



Introduction:

- Enclosed volume
- Two different gases
- Constant pressure at temperature

Quantity definitions in binary mixtures

Fundamental terms:

(filling) Mass		$m_1; m_2$	[kg]
Molar masses of the gases	Specific mass of one mol of substance	$M_1; M_2$	[kg/kmol]
Partial density	Density of one component	$\rho_1 = \frac{m_1}{V}; \rho_2 = \frac{m_2}{V}$	$[\mathrm{kg/m^3}]$
Mixture density	Total density of all components	$\rho = \frac{m_1 + m_2}{V}$	$[\mathrm{kg/m^3}]$
Molar quantity	Quantity of substance in moles	$n_1 = \frac{m_1}{M_1}; n_2 = \frac{m_2}{M_2}$	[kmol]
Molar concentration	Number of molecules in moles per volume	$C_1 = \frac{n_1}{V}; C_2 = \frac{n_2}{V}$	$[\mathrm{kmol/m^3}]$
Molar concentration of the mixture	Number of all molecules in moles per volume	$C = \frac{n_1 + n_2}{V}$	$[\mathrm{kmol/m^3}]$
Mole fraction	Proportion of a substance in the total number of all molecules	$\psi_1 = \frac{n_1}{n_1 + n_2} = \frac{C_1}{C}; \psi_2 = \frac{n_2}{n_1 + n_2} = \frac{C_2}{C}$	[−]
Mass fraction	Proportion of a substance in the total mass	$\xi_1 = \frac{\rho_1}{\rho} = \frac{m_1}{m_{\mathrm{tot}}}; \xi_2 = \frac{\rho_2}{\rho} = \frac{m_2}{m_{\mathrm{tot}}}$	[−]
Partial pressure	Pressure applied by a component	$p_1 = \frac{R_{\mathrm{m}}}{M_1}\rho_1 T = R_{\mathrm{m}} C_1 T; p_2 = \frac{R_{\mathrm{m}}}{M_2}\rho_2 T = R_{\mathrm{m}} C_2 T$	$[\mathrm{N/m^2}]$

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Quantity definitions in binary mixtures

Relationship between quantity/mass fractions and mean molar mass:

- Definition mole fraction ψ_1 : $$\psi_1 = \frac{n_1}{n_1+n_2} = \frac{n_1}{n} = \frac{C_1}{C}$$
- With definitions of molar quantity n_1 and mass m_1 : $$n_1 = \frac{m_1}{M_1};\ m_1 = \rho_1 \cdot V$$
- Molar concentration C_1 and mass fraction ξ_1 : $$C_1 = \frac{n_1}{V};\quad \xi_1 = \frac{m_1}{m} = \frac{\rho_1}{\rho}$$
- It follows for C_1 : $$C_1 = \frac{1}{V} \cdot \frac{m_1}{M_1} = \frac{\rho_1}{M_1}$$
- Finally, the mole fraction ψ_1 and the mean molar mass $\bar{M}$ result in:

$$\boxed{\psi_1 = \frac{\left(\frac{\rho_1}{M_1}\right) \cdot \frac{1}{\rho}}{\left(\frac{\rho_1}{M_1} + \frac{\rho_2}{M_2}\right) \cdot \frac{1}{\rho}} = \frac{\frac{\xi_1}{M_1}}{\frac{\xi_1}{M_1} + \frac{\xi_2}{M_2}}}$$

$$\boxed{\bar{M} = \frac{m_1 + m_2}{n_1 + n_2} = \frac{\frac{1}{V}(m_1 + m_2)}{\frac{1}{V}(n_1 + n_2)} = \frac{\rho}{C}}$$

Ideal gas behavior of individual components and mixture

Dalton's law:

$$\boxed{p = p_1 + p_2}$$

- The total pressure corresponds to the sum of the partial pressures

The Daltons are only seen together

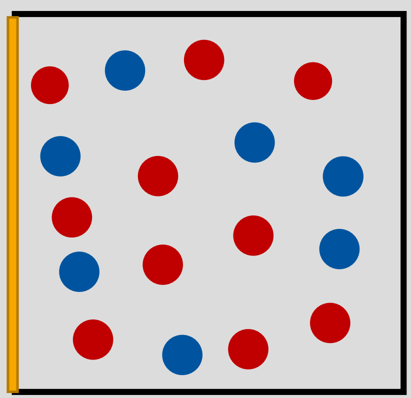
For air: N_2, O_2, CO_2, rare gases

- A transformation results in:

$$\frac{p_1}{p} + \frac{p_2}{p} = 1$$

$$= \frac{C_1}{C} + \frac{C_2}{C} = \psi_1 + \psi_2$$

$$p = p_1 + p_2$$



with: $\psi_1 = \frac{p_1}{p}; \quad \psi_2 = \frac{p_2}{p}$

ψ_1: Mole Fraction