MASS TRANSFER

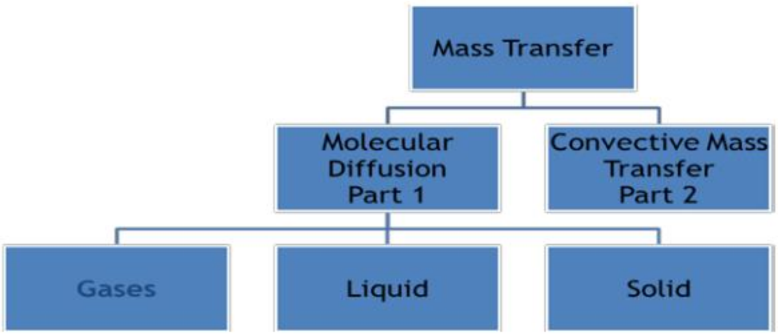
1. INTRODUCTION

When a system contains two or more components (**with concentrations of components vary from point to point**), there is a natural tendency for mass to be transferred (**to minimize the concentration differences within a system**).

The transport of one constituent **from a region** of **higher concentration** **to** that of a **lower concentration** is called **mass transfer**.

Mass transfer is the net movement of a component in a mixture from one location to another location where the component exists at a different concentration.

2. TYPES OF MASS TRANSFER



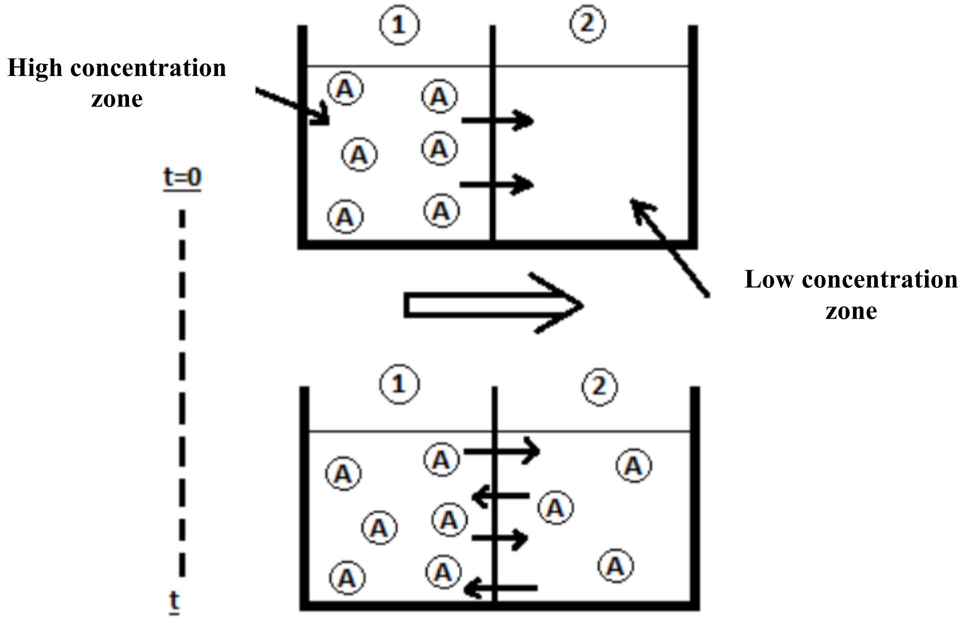
Example 1: A drop of blue liquid dye is added to a cup of water – the dye molecules will diffuse slowly by molecular diffusion to all parts of the water.

a) **Molecular Diffusion:** Transfer of individual molecules through a fluid by random movement from high concentration to low concentration.

Example 2: To increase this rate of mixing of the dye, the liquid can be mechanically agitated by a spoon and convective mass transfer will occur.

Example 3: stirred the water to dissolve coffee during coffee making.

b) **Convective Mass Transfer:** Using mechanical force or action to increase the rate of molecular diffusion.



3. VELOCITY AND DIFFUSION FLUX:

The flux (flow rate): the quantity of matter that crosses a surface perpendicularly during a unit of time (1s).

Unit:

- (**kg/s**) for: **mass flow rate**.
- (**mol/s**) for: **molar flow rate**.

Flux density (**flow rate density**): the flux per unit area ($1m^2$).

$$flux\ density = \frac{Flux}{Area}$$

Unit:

- (**$kg/m^2.s$**) for : **mass flow rate density**
- (**$mol/m^2.s$**) for : **molar flow rate density**.

When it comes to mass transport, three types of flow rates are defined:

- The volumetric flow rate is the volume per unit of time; [$L.s^{-1}$].
- The molar flow rate is the number of moles per unit of time; [$mol.s^{-1}$].
- The mass flow rate is the number of grams per unit of time; [$kg.s^{-1}$].

Mass transfer flux ≈ flux related to molecular diffusion + flux related to convection mass transfer

3.1. <u>Mass Transfer Flux</u>

$$n_A = J_A + C_A . V$$

Mass Transfer Flux (n_A)

Flux linked to molecular diffusion (by mass) (J_A)

Flux linked to convection. ($C_A . V$)

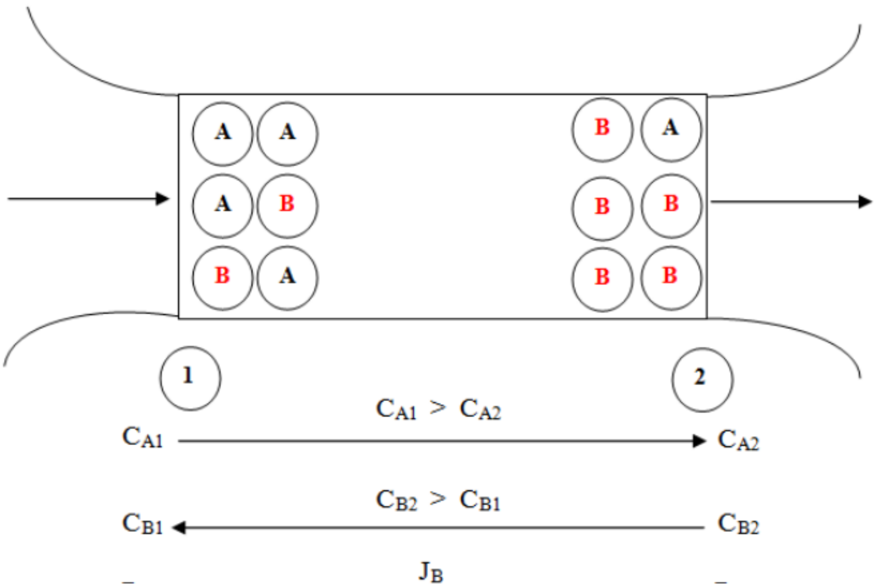
4. MOLECULAR DEFFUSION:

Diffusion depends on:

1. Driving force (ΔC), moles per unit volume (kmol/m^3).

2. The distance in the direction of transfer (Δz), meter (m).

3. Diffusivity coefficient, unit area per unit time (m^2/s).



Fick's Law of diffusion:

$$J_A = -D_{AB} \frac{dC_A}{d_z}$$

Where:

J_A: is the molecular diffusion flux of A , (moles per unit area per unit time) kmol/m^2.s

C_A: is the concentration of A (moles of A per unit volume) kmol/m^3 .

D_{AB}: is known as the diffusivity or diffusion coefficient for A in B (unit area per unit time) m^2/s

z: is distance in the direction of transfer (m).

Diffusion with bulk of mass in motion:

Total diffusion = Molecular diffusion + Convection term

Convection term = Eddy diffusion = Molar flux due to convection

Convection term = Concentration . mass transfer velocity = $C_A . V$

$$\text{Mass transfer velocity (V)} = \frac{\text{Mass flux}}{\text{Concentration}} = \frac{N_A + N_B}{C_T} = \frac{\frac{\text{kmol}}{\text{m}^2.\text{s}}}{\frac{\text{kmol}}{\text{m}^3}} = \frac{\text{m}}{\text{s}}$$

Total diffusion = $N_A = J_A + C_A . V$ ....(2)

Total diffusion equation in the form of concentration (normally used for liquids):

$$N_A = -D_{AB}\frac{dC_A}{d_z} + \frac{C_A}{C_T}(N_A + N_B) \qquad (3)$$

Total diffusion equation in the form of partial pressure (normally used for gases):

$$N_A = -\frac{D_{AB}}{RT}\frac{dP_A}{d_z} + \frac{P_A}{P_T}(N_A + N_B) \qquad (4)$$

Total diffusion equation in the form of mole fraction (used for gases and liquids):

$$N_A = -\frac{D_{AB}P_T}{RT}\frac{dX_A}{d_z} + x_A(N_A + N_B) \qquad (4)$$

If stagnant diffusion layer, then $N_B = 0$

$$N_A = \frac{D_{AB}}{RT}\frac{P_T}{d_z}\text{Ln}\left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right] \qquad (5)$$