① Fick's law

$$J_A \propto \frac{dC_A}{dx}$$

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

$J_A \rightarrow$ Diffusional flux w.r.t an observer moving with molar avg. velocity.

$D_{AB} \rightarrow$ Diffusivity of A in a mixture A, B.

The -ve sign is incorporated as diffusion occurs spontaneously in the direction of decreasing conc.

WKT, $U = \frac{1}{c}(N_A + N_B)$

$N_A = C_A u_A \qquad N_B = C_B u_B$

$J_A = -D_{AB} \frac{dC_A}{dx}$; $\quad J_A = C_A(u_A - U)$

$= C_A u_A - C_A U$

$J_A = N_A - \frac{C_A}{c}(C_A u_A + C_B u_B)$

$$\therefore J_A = N_A - \frac{C_A}{c}(N_A + N_B)$$

$$\therefore N_A = -D_{AB}\frac{dC_A}{dx} + \frac{C_A}{c}(N_A + N_B)$$

$N_A \rightarrow$ Total flux of comp. A

$$N_B = -D_{BA}\frac{dC_B}{dx} + \frac{C_B}{c}(N_A + N_B)$$

② From Fick's law, $D_{AB} = -\frac{J_A}{(dC_A/dx)}$

$J_A = [N][L]^{-2}[s]^{-1}$

$C_A = [N][L]^{-3}$

$x = [L]$

$$[D_{AB}] = \frac{[N][L]^{-2}[s]^{-1}}{\frac{[N][L]^{-3}}{[L]}}$$

$$\therefore [D_{AB}] = [L]^2[s]^{-1}$$

Dimensions of D_{AB} $\rightarrow$ $[L]^2 [\theta]^{-1}$

S. I unit of D_{AB} (diffusivity) is m^2/s

③ From q1,

$$N_A = -D_{AB}\frac{dC_A}{dx} + \frac{C_A}{C}(N_A + N_B) \quad -①$$

$$N_B = -D_{BA}\frac{dC_B}{dx} + \frac{C_B}{C}(N_A + N_B) \quad -②$$

Adding ①, ②,

$$(N_A + N_B) = -\left(D_{AB}\frac{dC_A}{dx} + D_{BA}\frac{dC_B}{dx}\right) + \cancel{\left(\frac{C_A + C_B}{C}\right)}^{1} (N_A + N_B)$$

Considering a closed binary system,
(conc. is constant)

$$\Rightarrow -\left(D_{AB}\frac{dC_A}{dx} + D_{BA}\frac{dC_B}{dx}\right) = 0$$

$$\therefore D_{AB} = D_{BA}$$