CEN 3313

MASS TRANSFER

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Molecular Diffusion in Gases-

Interface Fall for A Diffusing Through Stagnant Film of B

$$\overline{N_A} = N_A \times Area$$

$$= \frac{\rho_A}{M_A}\frac{dz}{dt} \times Area$$

$$\frac{D_{AB}}{z}\frac{P}{RT}\frac{p_{A1} - p_{A2}}{p_{BM}} = \frac{\rho_A}{M_A}\frac{dz}{dt}$$

$$D_{AB}\frac{P}{RT}\frac{p_{A1} - p_{A2}}{p_{BM}}\int_0^{t_F} dt = \frac{\rho_A}{M_A}\int_{z_0}^{z_F} z\,dz$$

$$(z_F^2 - z_0^2) = \left(\frac{P}{RT}\frac{p_{A1} - p_{A2}}{p_{BM}}\right)\left(\frac{M_A}{\rho_A}\right)(2D_{AB})t_F$$

$$t_F = \frac{\rho_A}{M_A}\frac{(z_F^2 - z_0^2)}{2D_{AB}}\left(\frac{P}{RT}\frac{p_{A1} - p_{A2}}{p_{BM}}\right)^{-1}$$

Diffusion through a Varying Cross-Sectional Area

a) Diffusion from a sphere

- Evaporation of a ball of naphthalene
- Evaporation of a drop of liquid
- Diffusion of nutrients from a spherical micro-organism

For spherical geometry,

$$N_A = \frac{\overline{N_A}}{4\pi r^2}$$

Diffusion through a Varying Cross-Sectional Area: 1. ***Diffusion from a sphere***

$$N_A = \frac{\overline{N_A}}{4\pi r^2} == -D_{AB}\frac{P}{RT}\frac{1}{(P - p_A)}\frac{dp_A}{dr}$$

A Diffusing Through Stagnant, Nondiffusing B

$$N_A\left(1 - \frac{p_A}{P}\right) = -\frac{D_{AB}}{RT}\frac{d(p_A)}{dz}$$

$$\frac{\overline{N_A}}{4\pi}\int_{r_1}^{r_2}\frac{dr}{r^2} = -D_{AB}\frac{P}{RT}\int_{p_{A1}}^{p_{A2}}\frac{1}{(P - p_A)}dp_A$$

$$\frac{\overline{N_A}}{4\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = D_{AB}\frac{P}{RT}\ln\frac{P - p_{A2}}{P - p_{A1}}$$

For $r_2 >> r_1$, $1/r_2 \rightarrow 0$

$$\frac{\overline{N_A}}{4\pi r_1} = D_{AB}\frac{P}{RT}\ln\frac{P - p_{A2}}{P - p_{A1}}$$

$$N_A = \frac{\overline{N_A}}{4\pi r_1^2} = \frac{D_{AB}}{r_1}\frac{P}{RT}\left[\ln\frac{P - p_{A2}}{P - p_{A1}}\right] = \frac{D_{AB}}{r_1}\frac{P}{RT}\left[\frac{p_{A1} - p_{A2}}{p_{BM}}\right]$$

Diffusion through a Varying Cross-Sectional Area

2) Diffusion through a conduit of non-uniform cross-sectional area

$$r = \left(\frac{r_2 - r_1}{z_2 - z_1}\right) z + r_1$$

$$A = \pi r^2 = \pi \left[\left(\frac{r_2 - r_1}{z_2 - z_1}\right) z + r_1\right]^2$$

$$N_A = \frac{\overline{N_A}}{\pi r^2} == -D_{AB} \frac{P}{RT} \frac{1}{(P - p_A)} \frac{dp_A}{dr}$$

$$N_A = \frac{\overline{N_A}}{\pi} \int_{r_1}^{r_2} \frac{dz}{\left[\left(\frac{r_2 - r_1}{z_2 - z_1}\right) z + r_1\right]^2} = -D_{AB} \frac{P}{RT} \int_{p_{A1}}^{p_{A2}} \frac{1}{(P - p_A)} dp_A$$

Your Turn

A sphere of naphthalene having a radius of 2 mm is suspended in a large volume of still air at 318K, and 1 atm. The surface temperature of naphthalene can be assumed to be 318K and its vapor pressure at 318K is 0.55 mm Hg. $D_{AB} = 6.92 \times 10^{-6} m^2/s$. Calculate the rate of evaporation of naphthalene from the surface.

References

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