CEN 3313

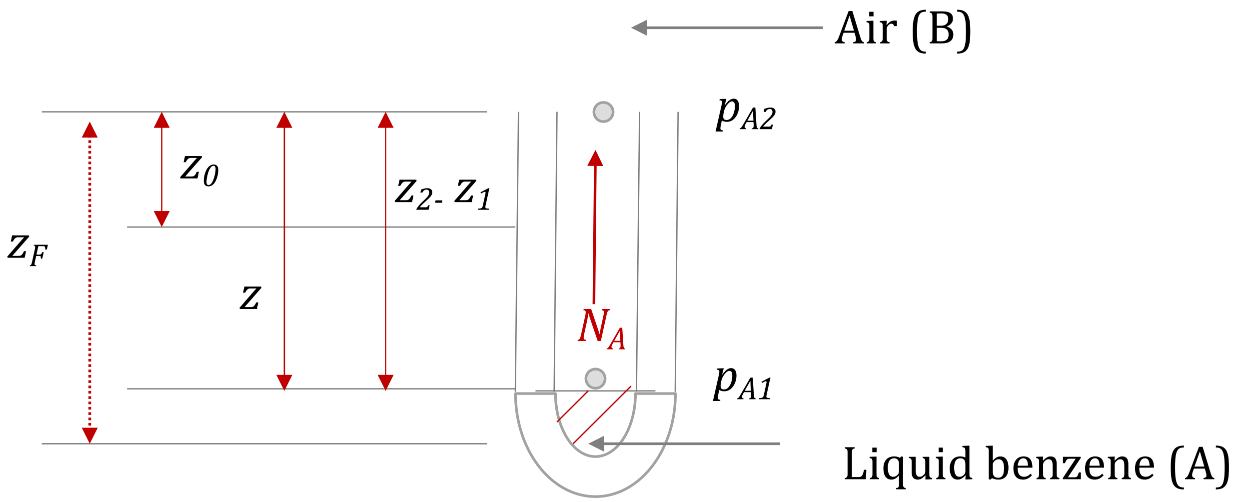
MASS TRANSFER

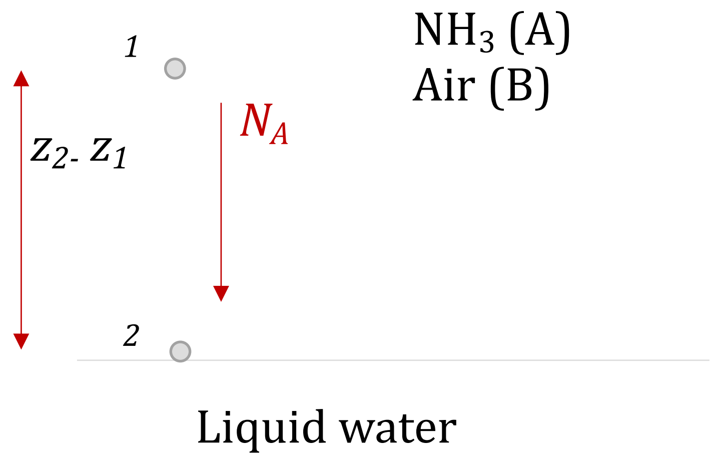
Assoc. Prof. Ayşe Karakeçili

Assoc. Prof. Berna Topuz

Molecular Diffusion in Gases-
Special Case for A Diffusing Through Stagnant, Nondiffusing B

Impermeable boundary to component B





Benzene evaporating into air

($N_B = 0$)

Ammonia in air being absorbed into water

(N_B=0)

Geankoplis, C.J., Transport Processes and Separation Process Principles, Prentice-Hall, Pearson Education, 2003

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$N_B = 0$

$$N_A = -cD_{AB}\frac{d(x_A)}{dz} + \frac{c_A}{c}(N_A + N_B)$$

$$N_A = -cD_{AB}\frac{d(x_A)}{dz} + \frac{c_A}{c}(N_A + 0)$$

$$c = \frac{P}{RT};\ p_A = x_A P;\ \frac{c_A}{c} = \frac{p_A}{P}$$

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

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

Constant Pressure

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

$$N_A\int_{Z_1}^{Z_2} dz = -D_{AB}\frac{P}{RT}\int_{p_{A1}}^{p_{A2}}\frac{dp_A}{(P - p_A)}$$

$$N_A = \frac{D_{AB}}{(z_2 - z_1)}\frac{P}{RT}\ln\frac{P - p_{A2}}{P - p_{A1}}$$

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$$N_A = \frac{D_{AB}}{(z_2 - z_1)} \frac{P}{RT} \ln \frac{P - p_{A2}}{P - p_{A1}}$$

$$N_A = \frac{D_{AB}}{(z_2 - z_1)} \frac{P}{RT} ln \frac{p_{B2}}{p_{B1}}$$

Total Pressure (P) = $p_{A1} + p_{B1} = p_{A2} + p_{B2}$

$p_{B1} = P - p_{A1}$

$p_{B2} = P - p_{A2}$

$$p_{BM} = \frac{p_{B2} - p_{B1}}{ln \frac{p_{B2}}{p_{B1}}} = \frac{p_{A1} - p_{A2}}{ln \frac{p_{B2}}{p_{B1}}}$$

Log mean value of the Inert B

$$N_A = \frac{D_{AB}}{(z_2 - z_1)} \frac{P}{RT} \frac{p_{A1} - p_{A2}}{p_{BM}}$$

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$$N_A = \frac{D_{AB}}{(z_2 - z_1)} \frac{1}{RT} \frac{P}{p_{BM}} (p_{A1} - p_{A2})$$

$$J^{\star}_{Az} = \frac{D_{AB}}{(z_2 - z_1)} \frac{1}{RT} (p_{A1} - p_{A2})$$

Your Turn

Diffusion of Water Through Stagnant, Non-diffusing Air

Water in the bottom of a narrow metal tube is held at a constant temperature of 293 K. The total pressure of air (assumed dry) is 1.01325×10^5 Pa (1.0 atm) and the temperature is 293 K (20°C). Water evaporates and diffuses through the air in the tube and the diffusion path ($z_2 - z_1$) is 0.1524 m long. Calculate the rate of evaporation at steady state. The diffusivity of water vapor at 293 K and 1 atm pressure is 0.250×10^{-4} m^2/s. Assume that the system is isothermal.

References

1. Geankoplis, C.J., Transport Processes and Separation Process Principles, Prentice-Hall, Pearson Education, 2003

2. Incropera F. P., Dewitt D. P. , Bergman T.L., Lavine A.S., Fundamentals of Heat and Mass Transfer, John Wiley & Sons Inc.

3. Middleman S., An Introduction to Mass and Heat Transfer: Principles of Analysis and Design, John Wiley, High Education, 1997.

4. Cussler E.L., Diffusion : Mass Transfer in Fluid Systems, Cambridge University Press, 3rd Edition, 2009.

5. Bird R.B., Stewart W.E., Lightfoot E.N., Transport Phenomena, John Wiley & Sons, 1960.