CEN 3313

MASS TRANSFER

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Species Concentration in Binary Systems

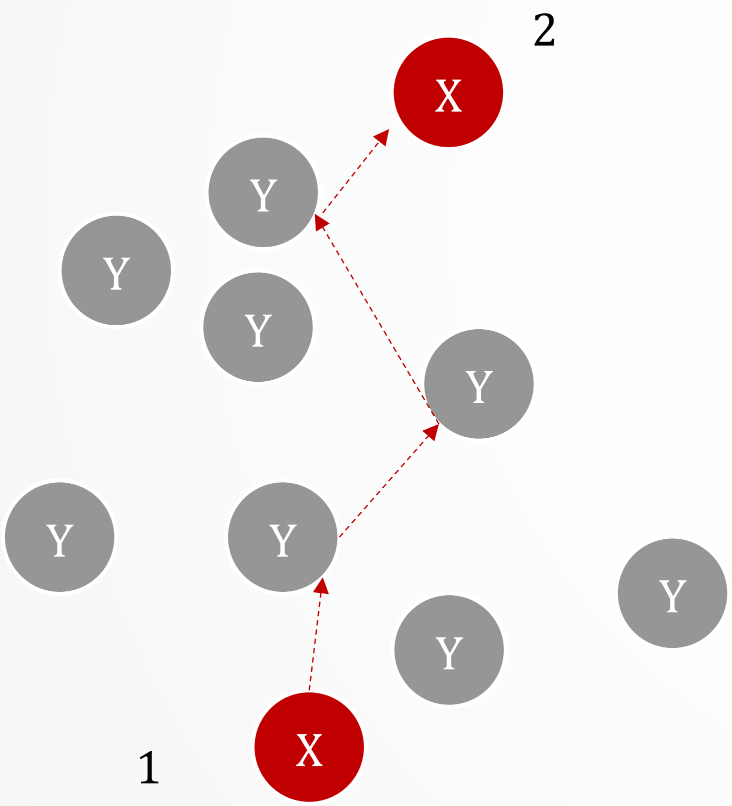
ρ_A = mass of A per unit volume	(A)[a]	c_A = moles of A per unit volume	(F)
$\rho = \rho_A + \rho_B$ = mass density of mixture	(B)	$c = c_A + c_B$ = molar density of mixture	(G)
$\omega_A = \rho_A/\rho$ = mass fraction of A	(C)	$x_A = c_A/c$ = mole fraction of A	(H)
$\omega_A + \omega_B = 1$	(D)	$x_A + x_B = 1$	(I)
$\nabla\omega_A = -\nabla\omega_B$	(E)	$\nabla x_A = -\nabla x_B$	(J)

$\rho_A = c_A M_A$	(A)	$c_A = \rho_A/M_A$	(F)
$M = x_A M_A + x_B M_B$	(B)	$1/M = \omega_A/M_A + \omega_B/M_B$	(G)
$\rho = cM$	(C)	$c = \rho/M$	(H)
$\omega_A = \dfrac{x_A M_A}{M}$	(D)	$x_A = \dfrac{\omega_A/M_A}{1/M}$	(I)
$\nabla\omega_A = \dfrac{M_A M_B \nabla x_A}{M^2}$	(E)	$\nabla x_A = \dfrac{M^2}{M_A M_B}\nabla\omega_A$	(J)
$= \dfrac{\omega_A\omega_B}{x_A x_B}\nabla x_A$	(E′)	$= \dfrac{x_A x_B}{\omega_A\omega_B}\nabla\omega_A$	(J′)

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

○ **Molecular Diffusion (*random-walk process*)**

Molecular diffusion can be explained as the transfer or movement of individual molecules through a fluid as a result of random, individual movements of molecules.



Point 1 to Point 2

Net diffusion of X is **from high to low concentration.**

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

- **Molecular Diffusion (*random-walk process*)**

Diffusion is caused by **random molecular motion** that results in complete mixing.

In gases, diffusion progresses at a rate of about 5 cm/min;

In liquids, its rate is about 0.05 cm/min;

In solids, its rate may be only about 0.00001 cm/min.

○ **Molecular Diffusion (*random-walk process*)**

Forms of Fick's Law in dilute solutions. No convection in the same direction.

Lack of convection often indicates a dilute solution.

For one-dimensional diffusion in Cartesian coordinates	$-j_1 = D\frac{dc_1}{dz}$
For radial diffusion in cylindrical coordinates	$-j_1 = D\frac{dc_1}{dr}$
For radial diffusion in spherical coordinates	$-j_1 = D\frac{dc_1}{dr}$

Your Turn

A gas of CH_4 and He is contained in a tube at 101.32 kPa pressure and 298K. At one point the partial pressure of methane is 60.79 kPa, and a point 0.02 m distance away the partial pressure of methane is 20.26 kPa. If the total pressure is constant throughout the tube, calculate the flux of methane at steady state.

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.

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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.