Assignment and Short type questions

Module 3: Mass Transfer Coefficients

Assignment problems:

Assignment problem 3.1: Ammonia is absorbed into water from an air-ammonia mixture at 300 K and 1 atm. The individual film coefficients are $k_L = 6.3$ cm/hr and $k_G = 1.17$ kmol/m$^2$-hr-atm. The equilibrium relationship for very dilute solutions of ammonia in water at 300 K and 1 atm is 1.64. Determine: a) $k_y$ and $k_x$ c) $K_y$. Ans: a) $3.25 \times 10^{-4}$ kmole/m$^2$s, b) $9.722 \times 10^{-4}$ kmole/m$^2$s, c) 0.21 kmole/m$^2$s.

Assignment problem 3.2: An ethanol (A)-water (B) solution in the form of a stagnant film 2.0 mm thick at 293 K is in contact at one surface with an organic solvent in which ethanol is soluble and water is insoluble. Hence $N_B = 0$. At point 1, the concentration of ethanol is 16.8 wt% and the solution density is 972.8 kg/m$^3$. At point 2, the concentration of ethanol is 6.8 wt% and density is 988.1 kg/m$^3$. The diffusivity of ethanol is $0.740 \times 10^{-9}$ m$^2$/s. Calculate the steady state flux $N_A$.

Assignment problem 3.3: In an experimentation, dry air flows upward through the core of a wetted column where water flows down the inside wall. The wetted column is a 25-mm ID and 1 m long. Dry air enters at the rate of 7 kg/m$^2$-s. The air is controlled everywhere at its average conditions of 309 K and 1 atm, the water at 294 K, and the mass-transfer coefficient constant. Estimate the average partial pressure of water in the air leaving. Ans: 1.578 kPa.

Assignment problem 3.3: For a system in which component A is transferring from the gas phase to the liquid phase, the equilibrium relation is given by $P_{A,i} = 0.8X_{Ai}$ where $P_{A,i}$ is the equilibrium partial pressure in atm. and $X_{Ai}$ is the
equilibrium liquid concentration in molar fraction. At one point in the apparatus, the liquid stream contains 4.5 mole % and the gas stream contains 9.0 mole % A. The total pressure is 1 atm. The individual gas-film coefficient at this point is $k_G = 3.0 \text{ mole/m}^2\text{-s-atm}$. Fifty per cent of the overall resistance to mass transfer is known to be encountered in the gas phase. Evaluate

a) The overall mass-transfer coefficient and individual liquid-film coefficient
b) The molar flux of A
c) The interfacial concentrations of A.

Ans: a) $k_y = 3.0 \text{ mole/m}^2\text{-s}$, $K_y = 1.5 \text{ mole/m}^2\text{-s}$, $k_x = 2.4 \text{ mole/m}^2\text{-s}$; b) 0.081 mole/m$^2$/s; c) $x_{AI} = 0.079$, $y_{AI} = 0.0632$

**Assignment problem 3.4:** Show that for equi-molar counter-diffusion from a sphere to a surrounding stationary infinite medium, the Sherwood number ($K_g d / D_{AB}$) based on the diameter of the sphere is equal to 2. $K_g$ is the mass transfer coefficient, $d$ is the diameter of sphere and $D_{AB}$ is the molecular diffusivity.

**Short type questions**

1. How mass transfer coefficient can be defined from the concept of molecular diffusion?
2. Why are $k$-type mass transfer coefficients for very dilute solutions more significant than $F$-type mass transfer coefficients?
3. How mass transfer coefficient related to film thickness of liquid?
4. How mass transfer coefficient is related to void fraction in a paced bed?
5. What is film theory? According to film theory, how mass transfer coefficient is related to molecular diffusivity?
6. What is penetration theory? How as per the penetration theory, the mass transfer coefficient is proportional to the square root of the diffusivity.
7. How the penetration theory is different from surface renewal theory?
8. How hydrodynamic flow characteristics affect the mass transfer phenomena?

9. Explain the two-film resistance theory.

10. Why overall mass transfer coefficient is considered in many practical mass transfer operations?

11. Give an example where total resistance equals the liquid film resistance during interphase mass transfer.

12. Derive the relationship between the overall mass transfer coefficient and individual mass transfer coefficients as \( \frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x} \). Assume the equilibrium-distribution represent a straight line. The notations imply their usual meanings.

13. The absorption of a very soluble gas is said to be gas–phase controlling mass transfer and the absorption of a gas of low solubility is said to be liquid–phase controlling mass transfer. Explain.