

Assignment MT1-2023-4
Section 1
(Based on Lecture Notes)

- 1.1)** Explain Two Resistance Theory or Two Film Theory. Why is it called so?
- 1.2)** Establish the graphical relationship between local mass transfer coefficients and interfacial concentration in case of inter phase mass transfers.
- 1.3)** What is Overall mass transfer coefficients? Why is it necessary to express the molar flux in terms of overall mass transfer coefficient rather than local mass transfer coefficients? How many ways can you define overall mass transfer coefficients?
- 1.4)** Establish the relationship between local and overall mass transfer coefficients.
- 1.5)** Derive and represent graphically operating line equations for
- a)** Co-current steady state continuous contact process.
 - b)** Counter-current steady state continuous contact process.
 - c)** Cross-current steady state contact process.
- 1.6)** Define stages. Derive and represent graphically operating line equations for stage wise countercurrent steady state process.
- 1.7)** What is the name of the equation used to determine the number of ideal stages in stage wise countercurrent steady state operation. Write down the equation.

Section-2
(Based on the work out problems in the text book)

From book: Principle of Mass Transfer by B.K.Dutta

2.1) Example 4.1 page no-133

EXAMPLE 4.1 (*Overall coefficient and driving force*) The equilibrium distribution of a solute A between air and water at low concentration at a particular temperature is given below.

$$y = 1.2x$$

At a certain point in a mass transfer device, the concentration of solute A in the bulk air is 0.04 mole fraction and that in the bulk aqueous phase is 0.025. In which direction does the transport of the solute A occur (i.e. from the gas to the liquid or from the liquid to the gas)? Calculate the overall gas-phase and the overall liquid-phase driving forces for mass transfer?

At the same point, the local individual mass transfer coefficients for the transport of A are, $k_y = 7.2 \text{ kmol/(h)(m}^2\text{)(}\Delta y\text{)}$ and $k_x = 4.6 \text{ kmol/(h)(m}^2\text{)(}\Delta x\text{)}$. Calculate (a) the interfacial concentrations in both the gas-phase and the liquid-phase; (b) the overall mass transfer coefficients, K_x and K_y ; and (c) the local mass flux, N_A .

Which resistance controls the role of mass transfer?

2.2) Example 4.2 page no-134

EXAMPLE 4.2 (*Interfacial resistance to mass transfer*) The individual mass transfer coefficients for absorption of A in a solvent are: $k_y = 60 \text{ kmol/(h)(m}^2\text{)(}\Delta y\text{)}$ and $k_x = 35 \text{ kmol/(h)(m}^2\text{)(}\Delta x\text{)}$. The equilibrium relation is $y = 0.8x$. At a particular section of the equipment, the bulk compositions are $x_b = 0.03$ and $y_b = 0.08$. The local mass transfer flux is $1.2 \text{ kmol/(h)(m}^2\text{)}$. Is there any interfacial resistance to mass transfer? If so, calculate its magnitude.

2.3) Example 4.3 page no-134

EXAMPLE 4.3 (*Application to a gas-liquid system*) In a laboratory experiment, the solute A is being absorbed from a mixture with an insoluble gas in a falling film of water at 30°C and a total pressure of 1.45 bar. The gas-phase mass transfer coefficient at the given gas velocity is estimated to be $k_c = 90.3 \text{ kmol/(h)(m}^2\text{)(kmol/m}^3\text{)}$. It is known that 13.6% of the total mass transfer resistance lies in the gas-phase. At a particular section of the apparatus, the mole fraction of the solute in the bulk gas is 0.065 and the interfacial concentration of the solute in the liquid is known to be $x_i = 0.00201$. The equilibrium solubility of the gas in water at the given temperature is

$$p = 3.318 \times 10^4 x^*$$

where p is the partial pressure of A in the gas in mm Hg and x^* is the solubility of A in water in mole fraction.

Calculate (a) the absorption flux of the gas at the given section of the apparatus, (b) the bulk liquid concentration at that section of the apparatus, (c) the overall liquid-phase mass transfer coefficient, and (d) the individual and overall gas-phase driving forces in terms of Δp and Δy .

2.4) Example 4.4 page no-136

EXAMPLE 4.4 (*Mass transfer in a continuous-stirred cell*) In an experimental study on absorption of SO_2 in a stirred cell, 100 ml of water is taken in the cell described in Problem 3.21 and a mixture of 14.2% SO_2 and 85.8% N_2 is passed through the cell at a rate of 1.5 litre per minute at 20°C and 1 atm pressure. Water is also passed through the cell at a rate of 27 ml per minute, the volume of solution being maintained at 100 ml. Both the gas and liquid phases are 'well stirred'. The outlet gas has 11% SO_2 in it at steady state. The gas-phase mass transfer coefficient has been measured separately (by absorbing NH_3 in a solution of H_2SO_4 under identical conditions of stirring in the cell and making the necessary diffusivity correction) and is found to be $3.8 \text{ kmol}/(\text{h})(\text{m}^2)(\Delta y)$.

- Calculate the concentration of SO_2 in the effluent solution, the liquid-phase mass transfer coefficient and the rate of surface renewal.
- What must be the flow rate of water through the cell (keeping the liquid volume constant at 100 ml) so that the rate of absorption increases and the outlet gas concentration drops to 10%?

Solubility data of SO_2 in water at 20°C is given by $y = 31.3x$ in the concentration range involved; diffusivity of SO_2 in water = $1.51 \times 10^{-5} \text{ cm}^2/\text{s}$.

2.5) Example 4.5 page no-137

EXAMPLE 4.5 (*Graphical determination of interfacial concentrations*) The equilibrium solubility of SO_2 in water at 30°C is given by Sherwood [*Ind. Eng. Chem.*, 17(1925) 745]

p_{SO_2} , mm Hg	0.6	1.7	4.7	8.1	11.8	19.7	36	52	79
g SO_2 per 100 g H_2O	0.02	0.05	0.10	0.15	2.0	0.3	0.5	0.7	1.0

At a point in an absorption column operating at a total pressure of 4.5 bar, the bulk concentrations in the gas and the liquid-phases are $x = 0.0014$ and $y = 0.02$. The individual gas-phase and liquid-phase mass transfer coefficients are $k_x = 80 \text{ kmol}/(\text{h})(\text{m}^2)(\Delta x)$ and $k_y = 15 \text{ kmol}/(\text{h})(\text{m}^2)(\Delta y)$.

Calculate (a) the interfacial concentrations at the particular location, (b) the overall mass transfer coefficients and the rate of absorption, (c) the mass transfer coefficients k'_x and k'_y , and (d) the individual and overall driving forces at the location in terms of Δx and ΔC .

What fraction of the total resistance is offered by the gas-film? What should have been the value of the coefficient k_y , if the gas-phase offered 60% of the total resistance to mass transfer (for the given liquid-phase coefficient)?

2.6) Example 4.6 page no-148

EXAMPLE 4.6 (*Number of trays for countercurrent contact*) It is required to remove 99% of the solute C from a solution of C in G by using a 'pure' solvent L in a counter-current cascade. The feed containing 12% C in the mixture enters the column at the bottom at the rate of 6000 kg/h. The solvent enters at the top at a rate of 7685 kg/h. Write down the equation of the operating line. Determine the number of trays required to perform the separation if the overall tray efficiency is 40%. The equilibrium relation is linear, $Y = 1.32X$, where $Y = \text{kg } C \text{ per kg } C\text{-free } G$, and $X = \text{kg } C \text{ per kg } C\text{-free } L$.

2.7) Example 4.7 page no-151

EXAMPLE 4.7 (*Batch adsorption from a solution*) An adsorbent, which is a modified clay, is used to separate an organic compound A from an aqueous solution. One kilogram of the solution containing 10% of the organic was treated with varying amounts of the clay in a number of laboratory tests. The following data were collected.

<i>Gram clay used</i>	15	40	60	100	135	210	325	450
<i>% A in the solution in equilibrium</i>	9.1	7.81	6.93	5.66	4.76	3.38	2.44	1.48

- Do the test data fit the Freundlich adsorption isotherm in the form $Y = aX^b$, where Y = gram solute per gram clay, and X = gram solute per gram solute-free solvent?
- How much of the adsorbent is required to recover 90% of the solute from 1000 kg of 10% solution?
- If 678 kg of the adsorbent is used per 1000 kg of the solution, how much of the solute is recovered if the treatment is done in two stages, using half of the clay in each stage?

Section 3
Unsolved Problems
(Assume atmospheric temperature and pressure, and required
constants if not mentioned.)

3.1. For a system in which component (A) is transferring from the liquid to the gas phase, the equilibrium is given by $y_A^* = 0.75x_A$. At one point in the apparatus the liquid contain 90 mol% of (A) and gas contain 45 mol% of (A). The individual gas film mass transfer coefficient at this point in the apparatus of $0.02716 \text{ kmol/m}^2\cdot\text{s}$, and 70% of the overall resistance to mass transfer is known to be encountered in the gas film. Determine:

- (a) The molar flux of (A).
- (b) The interfacial concentration of (A).
- (c) The overall mass transfer coefficient for liquid and gas phases.

3.2. In a liquid-liquid contacting device the equilibrium distribution of solute C in the solvents A and B can be represented as

$$y = 10.5x$$

where x and y are the concentrations of the solute C in phases A and B respectively. If the individual mass transfer resistances are

$$k_x = 10.21 \text{ lbmol/h}\cdot\text{ft}^2 \quad \text{and} \quad k_y = 4.35 \text{ lbmol/h}\cdot\text{ft}^2$$

which phase resistance controls the rate of mass transfer?

3.3. In an experimental study of the absorption of ammonia by water in a wetted-wall column, the value of overall mass transfer coefficient, K_G was found to be $2.75 \times 10^{-6} \text{ kmol/m}^2\cdot\text{s}\cdot\text{kPa}$. At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole% NH_3 , respectively. The temperature was 300K and the total pressure was 1 atm. 85% of the total resistance to mass transfer was found to be in the gas phase. At 300 K, Ammonia –water solutions follow Henry's law up to 5 mole% ammonia in the liquid, with $m = 1.64$ when the total pressure is 1 atm. Calculate the individual film coefficients and the interfacial concentrations. Interfacial concentrations lie on the equilibrium line.