Mass transfer

Lecture 12: *Film theory*

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Learning objectives

- **Understand the assumptions underlying film theory and be able to apply it when analyzing mass transfer across the interface.**

- **Become motivated in executing the team project that requires design of a separation process.**

Today's outline

- **Film theory**
  - ✓ Basic concepts
  - ✓ Film theory and assumptions
  - ✓ Two-film theory

- **Team project**
  - ✓ Overview
  - ✓ Team formation
  - ✓ Schedule
  - ✓ Grading

17.2 Basic concepts

- **In a common mass transfer operation, turbulent flow dominates to increase the rate of transfer.**
  - ✓ Mass transfer film thickness B_T is not known.

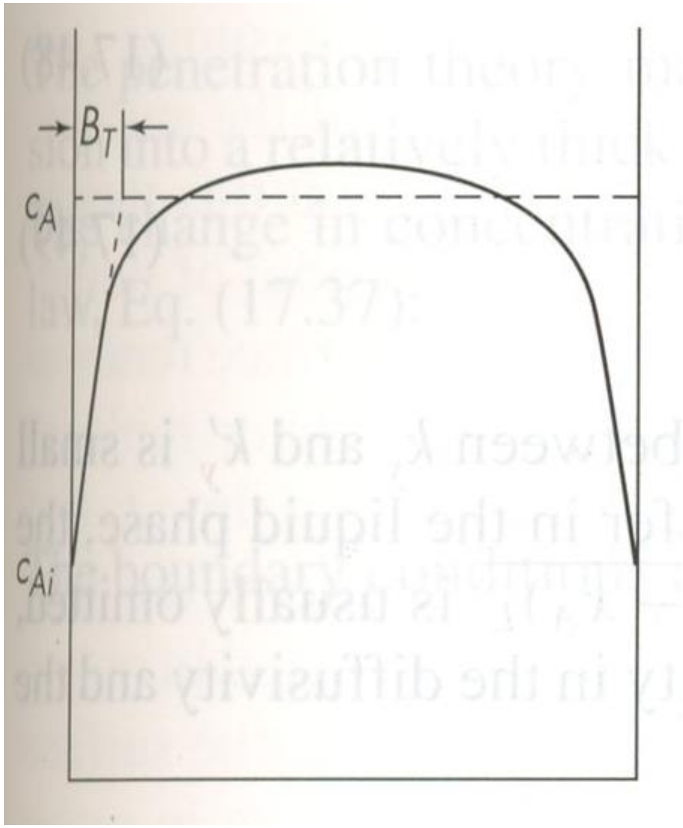
- **Mass transfer to the fluid interface is also unsteady.**
  - ✓ Both ΔC and N_A vary continuously throughout the process.

- **Mass transfer coefficient *k* is used instead for estimating transfer rates:**
  - ✓ For concentration gradients, $k_c = \frac{J_A}{C_{Ai} - C_A}$ [$\frac{mol}{s\ cm^2\ mol/cm^3}$ = cm/s]
  - ✓ For a steady-state, equimolal diffusion in a stagnant film,

$$k_c = \frac{J_A}{C_{Ai} - C_A} = \frac{D_v (C_{Ai} - C_A)}{B_T} \frac{1}{(C_{Ai} - C_A)} = \frac{D_v}{B_T}$$

17.2 Film theory

- **It assumes that there is a stagnant, thin film of a certain thickness at the interface.**
  - ✓ This film mostly belongs to the laminar layer, if not all.
  - ✓ Mass transfer is mainly by diffusion.
  - ✓ ΔC is almost linear.
  - ✓ C_A is not the maximum value but instead the *flow-weighted average* assuming a thorough mixing.



17.2 Two-film theory

- **In many separation processes, molecules diffuse from one phase into another.**
  - ✓ The overall mass transfer is affected by diffusion in both phases.
  - ✓ Assuming equilibrium at the interface, there is usually discontinuity of concentration between the two phases.

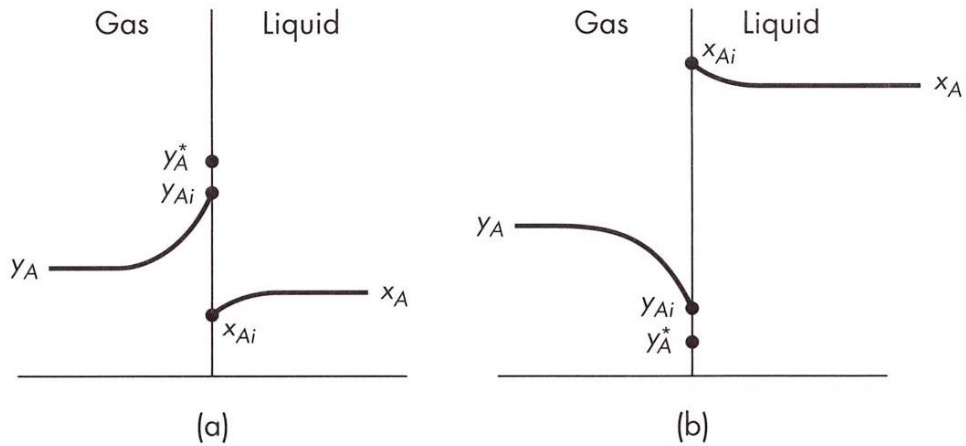


FIGURE 17.3
Concentration gradients near a gas-liquid interface: (*a*) distillation; (*b*) absorption of a very soluble gas.

17.2 Two-film theory

- **The rate of transfer to the interface is set equal to the rate of transfer from the interface.**

$$r = k_x(x_A - x_{Ai}) = k_y(y_{Ai} - y_A) = K_y(y_A^* - y_A)$$

where y_A^* is the vapor composition in equilibrium with ?

✓ K_y can be calculated as follows:

$$\frac{1}{K_y} = \frac{y_A^* - y_A}{r} = \frac{y_A^* - y_{Ai}}{r} + \frac{y_{Ai} - y_A}{r} = \frac{y_A^* - y_{Ai}}{k_x(x_A - x_{Ai})} + \frac{y_{Ai} - y_A}{k_y(y_{Ai} - y_A)}$$

$$\frac{1}{K_y} = \frac{m}{k_x} + \frac{1}{k_y}$$

✓ The term $\frac{1}{K_y}$ denotes *overall resistance to* mass transfer while the latter two terms are ?