

CE407 SEPARATIONS

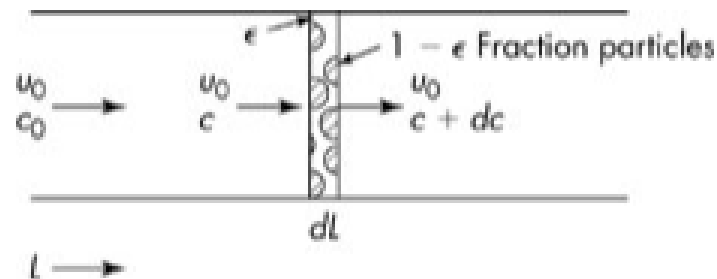
Lecture 25

Instructor: David Courtemanche

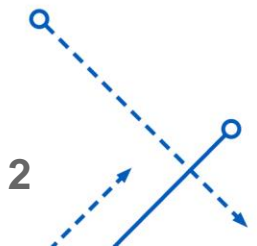


Adsorption Fundamentals

- The last lecture looked at Adsorption as an observation of typical results
- Today we will look at it from more of a viewpoint of fundamental principles
 - *Did someone say “Material Balances”?*



- The concentration of solute in the solution, c , is changing because the solute is being adsorbed onto the surface of the adsorbent solid
- The change in superficial velocity is small for a dilute solution and we will treat it as a constant, u_0
- ϵ is the external void fraction (i.e. How much open space exists around the particles)
- $(1 - \epsilon)$ is the fraction of space taken up by the adsorbent particles

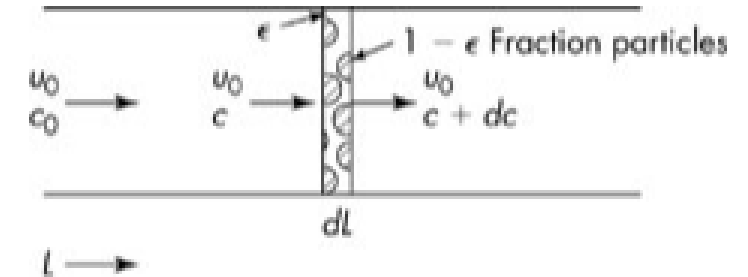


Adsorption Fundamentals

- The change in the amount of solute per unit cross-sectional area is:

$$u_0 c - u_0 (c + dc) = -u_0 dc$$

what goes in the control volume – what leaves the control volume = change in amount in control volume



- The change in the amount of solute results from two different causes:

1) The change in the fluid concentration

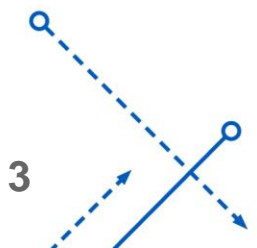
$$\epsilon dl \frac{\partial c}{\partial t}$$

ϵdl is the volume of fluid in the control volume per unit cross-sectional area

$\frac{\partial c}{\partial t}$ is the change in concentration (mass/volume) with respect to time

2) The change in surface adsorption

$$(1 - \epsilon) dl \rho_p \frac{\partial w}{\partial t}$$



Adsorption Fundamentals

- The change in surface adsorption

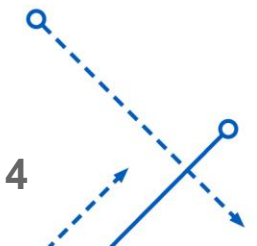
$$(1 - \epsilon) dl \rho_p \frac{\partial w}{\partial t}$$

- $(1 - \epsilon) dl$ is the volume occupied by particles in the control volume per unit cross-sectional area
 - ρ_p is the mass of particles per unit volume
 - $(1 - \epsilon) dl \rho_p$ is the mass of particles in the control volume per unit cross-sectional area
 - $\frac{\partial w}{\partial t}$ is the change with respect to time of the $\frac{\text{mass of solute adsorbed}}{\text{mass of adsorbent particles}}$
- The two causes added to one another must equal the change in the amount of solute in the control

volume per unit cross-sectional area, therefore we arrive at this partial differential equation:

$$\epsilon dl \frac{\partial c}{\partial t} + (1 - \epsilon) dl \rho_p \frac{\partial w}{\partial t} = -u_0 dc$$

$$\epsilon \frac{\partial c}{\partial t} + (1 - \epsilon) \rho_p \frac{\partial w}{\partial t} = -u_0 \frac{\partial c}{\partial l}$$



Mass Transfer to Adsorbent Particles

Three Steps:

- 1) Diffusion through film layer around the particle
- 2) Diffusion through pores into internal surfaces
- 3) Actual adsorption step
 - Practically instantaneous relative to steps 1) and 2)

This can be modeled as:

$$(1 - \epsilon) \rho_p \frac{\partial w}{\partial t} = K_c a (c - c^*)$$

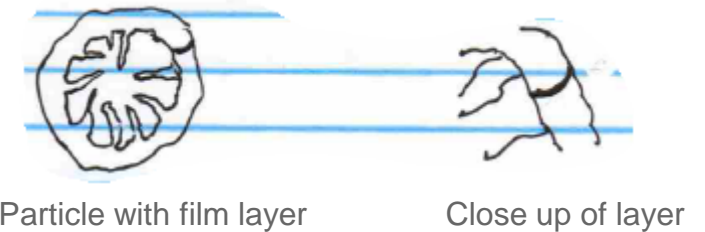
a is the external surface area of the particles

c^* is the concentration value in equilibrium with w

- Obtained via the isotherm

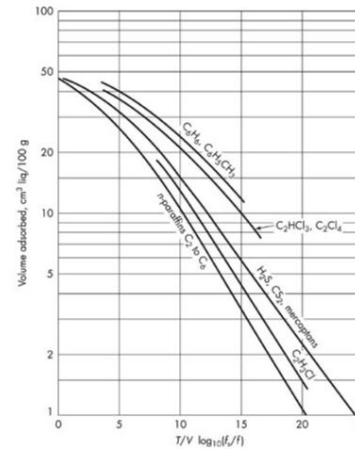
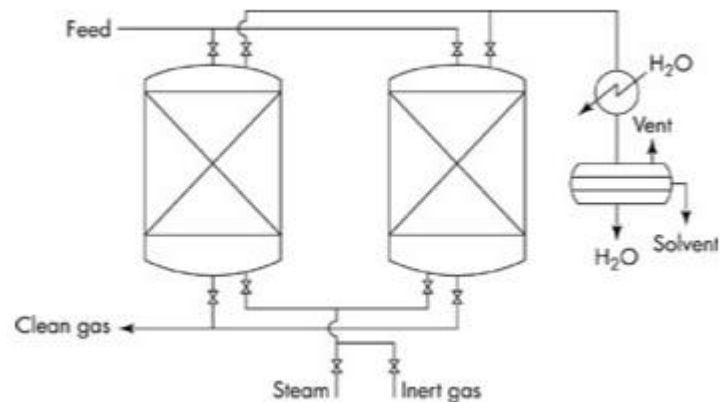
$$\frac{1}{K_c} = \frac{1}{k_{c_{ext}}} + \frac{1}{k_{c_{int}}} = \frac{1}{\text{Film Resistance}} + \frac{1}{\text{Pore Resistance}}$$

- These equations are not generally solvable, but there are special cases that can be worked out



Regeneration

- If the particles and the product can withstand high temperatures than you can use heat to release the product from the adsorbent



- At higher temperature the equilibrium shifts and the adsorbent releases the solute
- Use a back flow of steam or air (if the materials are all non-flammable) or N_2
- Regeneration is stopped soon after the temperature front reaches the feed entrance
 - A significant amount of adsorbed material remains which means breakthrough time is reduced
 - Exit end is almost fully regenerated so that high percentage removal of solute is still possible
 - Balance of energy cost per cycle versus length of cycle