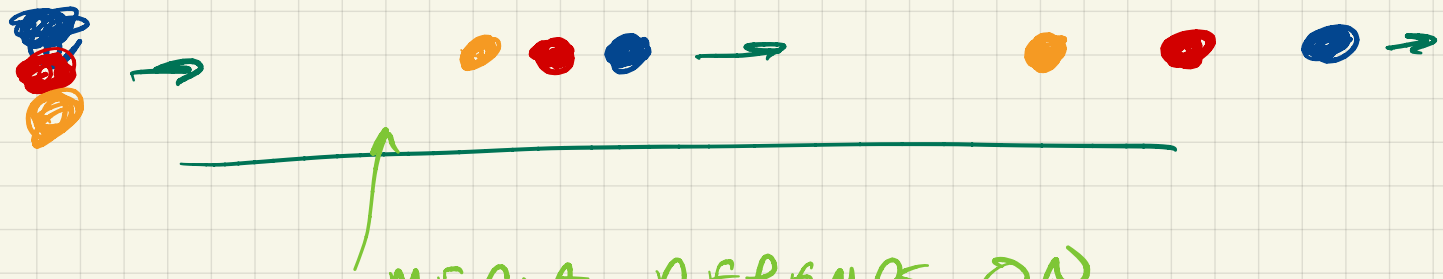
CBE 40448

3/17/21 – St. PATRICK'S DAY

A REALLY SHORT INTRODUCTION TO

CHROMATOGRHAPHY

GENERALLY CAUSES A SEPARATION



MEDIA DEPENDS ON APPLICATION

OFTEN A PACKED BED OF PARTICLES

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A new general method for designing affinity chromatography processes

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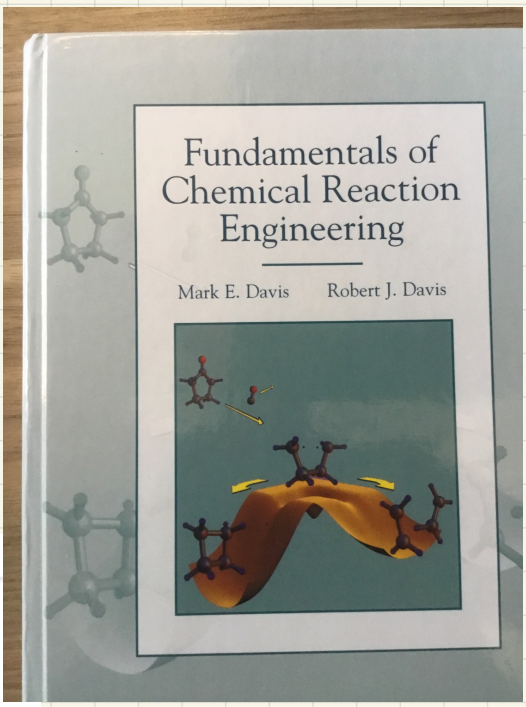
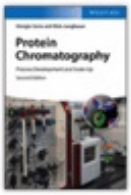
ARTICLE INFO

ABSTRACT





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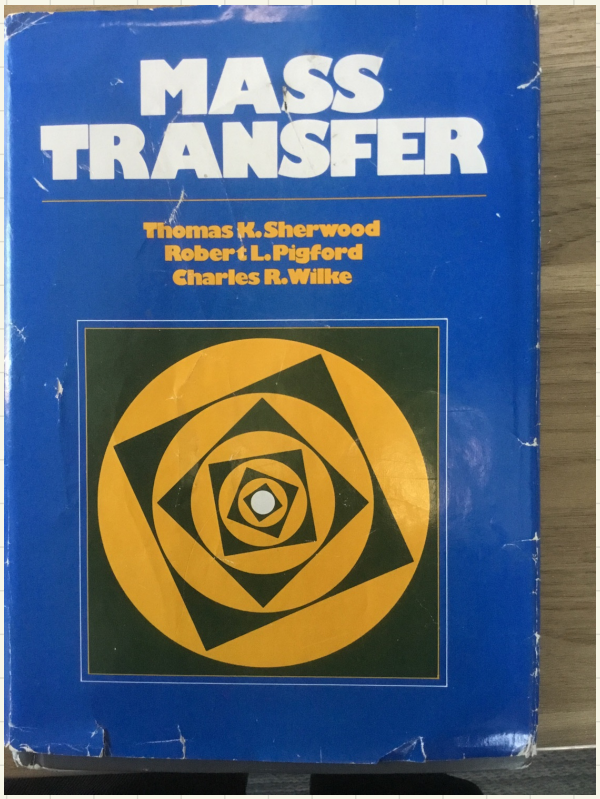


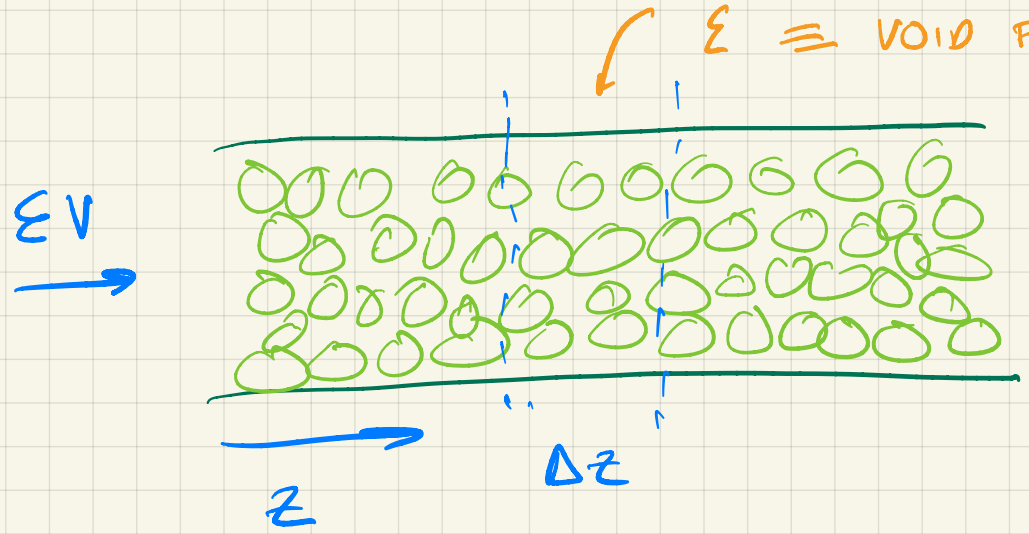
NORMALLY A LIQUID OR GAS

CARRIER PHASE

MIXTURE OF COMPONENTS INTERACTS WITH "PACKING"

- PHYSICAL ADSORPTION
- CHEMICAL ADSORPTION
- PHYSICAL HINDERENCE

THIS CREATES A DIFFERENCE IN RATE OF TRAVEL THROUGH COLUMN FOR VARIOUS COMPONENTS



C → CONCENTRATION OF COMPONENT IN FLUID PHASE

q → CONCENTRATION OF COMPONENT ON/IN SOLID PHASE

V → AVERAGE FLUID VELOCITY IN VOID SPACE OF BED

ρ_B → BULK DENSITY OF SOLID PARTICLES

MASS BALANCE:

DISPERSION IS NEGLECTED

$$\varepsilon \frac{\partial c}{\partial t} + \rho_B \frac{\partial q}{\partial t} + \varepsilon v \frac{\partial c}{\partial x} = 0$$

ACCUMULATION IN FLUID PHASE

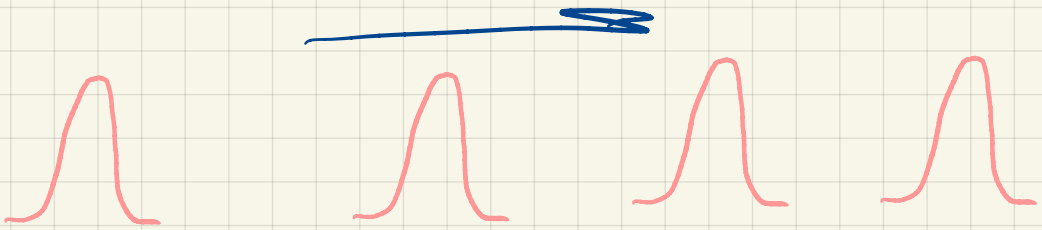
ACCUMULATION ON SOLID PHASE

CONCENTRATION CHANGE ACROSS DIFFERENTIAL SLICE

IF NO EFFECT OF SOLID PHASE!

$$\frac{\partial c}{\partial t} + v\frac{\partial c}{\partial x} = 0$$

SOLUTION IS A TRAVELING WAVE



TO CAUSE A SEPARATION,

SOME INTERACTION WITH SOLID IS NECESSARY

RATE OF ADSORPTION TO SOLID

$$g_B \frac{\partial q}{\partial t} = k\, a\, F(c, q)$$

CONTACT AREA – INCLUDES INSIDE PARTICLES

MASS TRANSFER COEFFICIENT

EQUILBRIUM RELATION BETWEEN SOLID & FLUID PHASE

GAS – SOLID EQUILIBRIUM

SIMPLEST MODEL IS LANGMUIR ADSORPTION

- PHYSICAL ADSORPTION
- SINGLE LAYER
- IDEAL GAS

θ → FRACTIONAL COVERAGE OF ADSORBENT

q^* = EQUILIBRIUM SOLID CONCENTRATION

p – PARTIAL PRESSURE OF COMPONENT

K → RATE CONSTANT FOR ADSORPTION

$$Kp(1-\theta) = K'\theta$$

RATE OF ADSORPTION

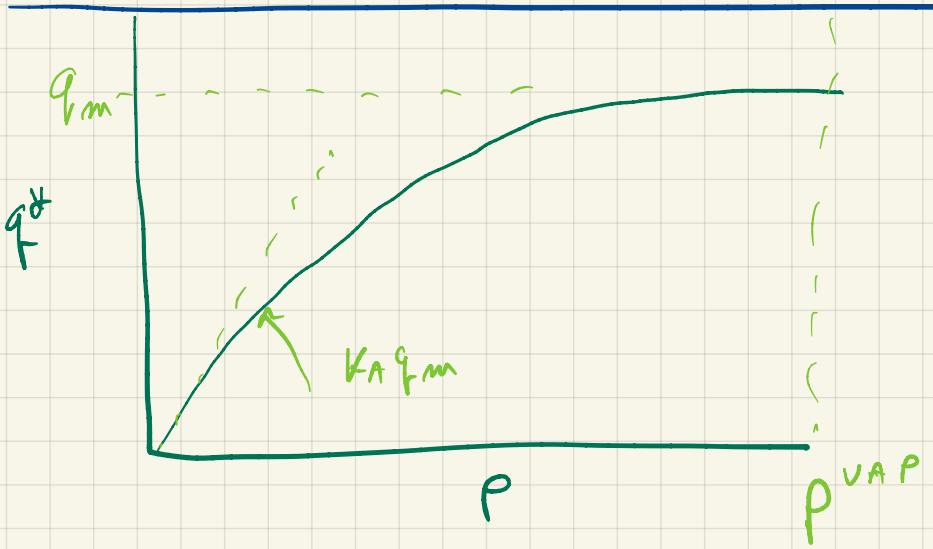
RATE OF DESORPTION

ADSORPTION CONSTANT

$$q^* = q_m \frac{K_A p}{1 + K_A p}$$

q_m ↑ MAX COVERAGE

TYPICAL LANGMUIR DIAGRAM



NO LIQUID PHASE SYSTEM OR MIXTURE WITH "LARGE" MOLECULES IS REALLY "LANGMUIR"

NEVERTHELESS — IT IS USUALLY USED ANY WAY!!

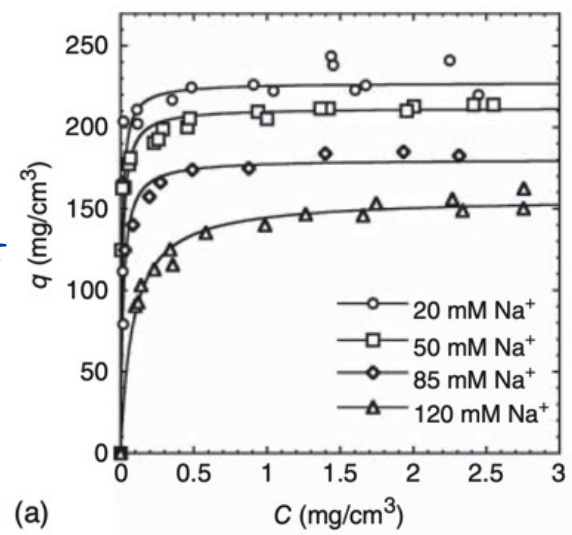
FOR A SPECIFIC PACKING, THERE IS A MAXIMUM CAPACITY OF THE ADSORBENT AT FEED CONCENTRATION

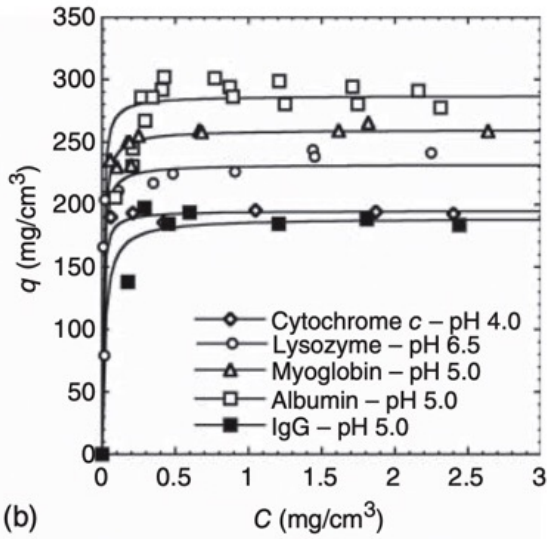
$$q_m^* = \frac{a C_F}{1 + b C_F} = a^* C_F$$

a^* ← PACKING CONSTANT

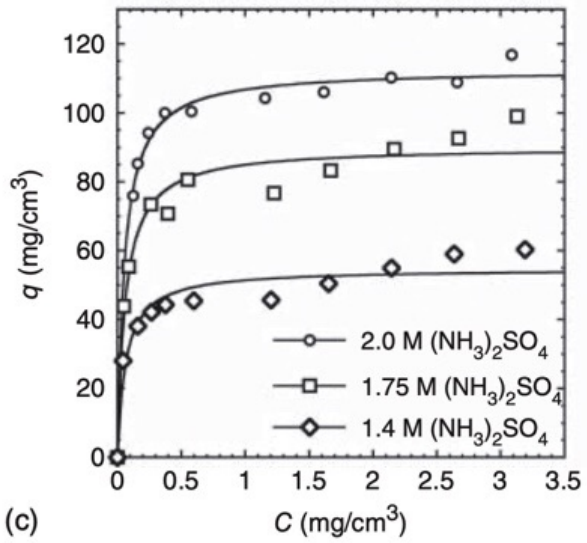
ADSORPTION EQ DATA

q^*





q^*



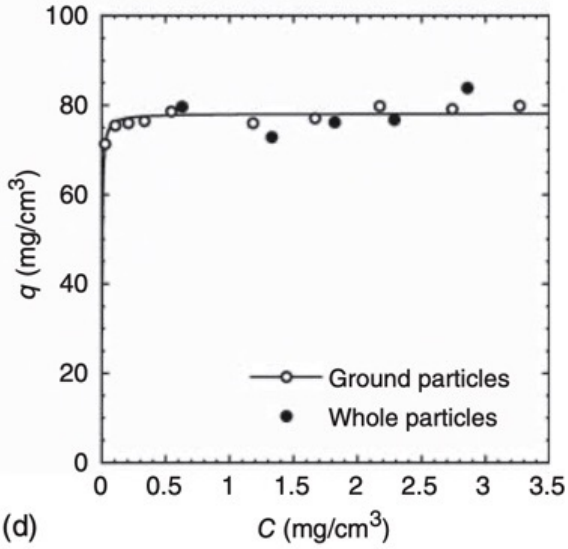


Figure 5.1 Examples of adsorption isotherms for ion exchange chromatography (a, b), hydrophobic interaction chromatography (c), and protein A affinity chromatography (d). The experimental data have been approximated by the Langmuir adsorption isotherm with parameters q_m and K_L fitted at each mobile-phase composition and for each protein. Source: Adapted from Bankston et al. 2008 [2].

IF YOU WANT COMPONENT TO "STICK", q^* IS NOT A STRONG FUNCTION OF C

NEXT IDEALIZATION

FAST MASS TRANSFER

$$q^* = f(c)$$

LOCAL EQUILBRIUM

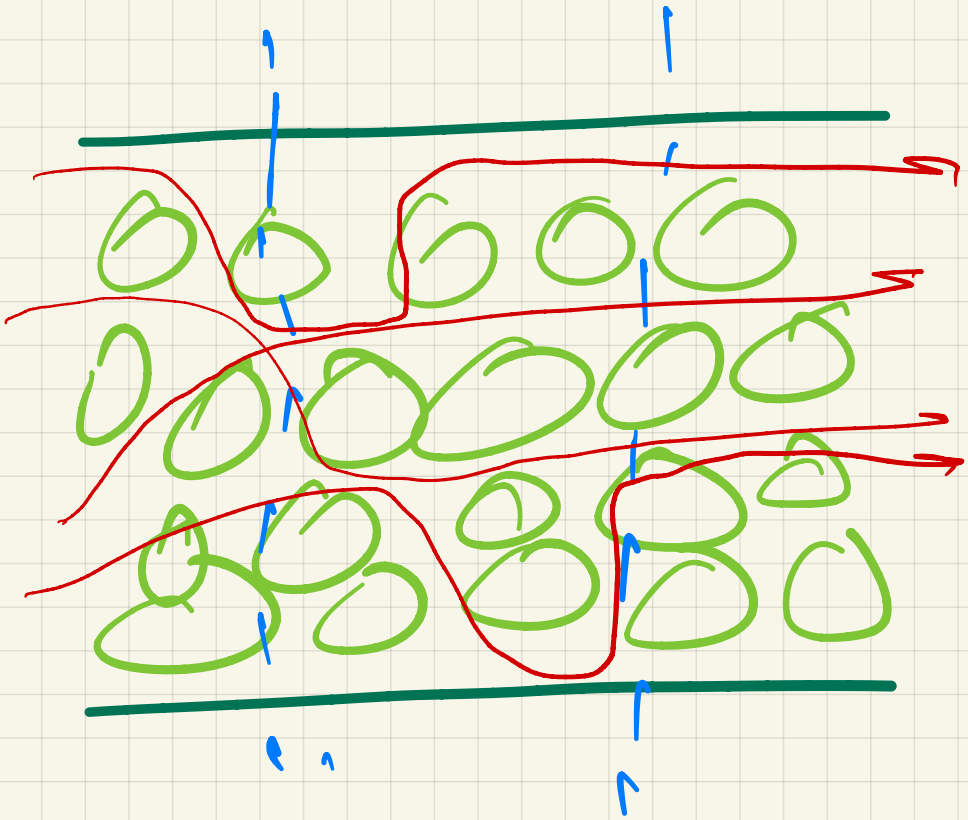
$$\frac{\partial q}{\partial t} = \frac{\partial q^*}{\partial t} = \frac{\partial f(c)}{\partial t} = f'(c)$$

MASS BALANCE

$$\frac{\partial c_i}{\partial t} + \left(\frac{v}{1 + \frac{\beta_0}{\varepsilon} f_i'(c)} \right) \frac{\partial c_i}{\partial x} = 0$$

RATE OF TRAVEL OF COMPONENT i THROUGH BED

LARGER $f_i'(c)$ STRONGER INTERACTION SLOWER TRANSPORT



MANY PATHS THROUGH BED.

FOR:

- ION EXCHANGE
- AFFINITY CHROMATOGRAPHY

YOU DON'T WANT THIS!

YOUTUBE VIDEO!!

https://www.youtube.com/watch?v=sKC--1kknTg

THUS NEED A RESIDENTIME

SUCH THAT DIFFUSION TO SURFACE OF PARTICLES AND WITHIN PARTICLES IS FAST COMPARED TO CONVECTION THROUGH

BED!!

YOU WOULD LIKE THIS TO BE SMALL

MAY NOT BE

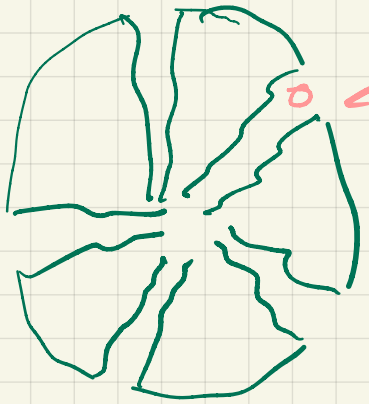
$$Pe = \frac{V L}{D}$$

V ← SUPERFICIAL VELOCITY

L ← DIAMETER OF PARTICLE

D ← DIFFUSIVITY OF COMPONENT

$\sim 10^{-7}\ cm^2/s$!!



MAY BE KNOWN → D_{KA}

IF YOU WANT TO USE FULL CAPACITY OF PARTICLES!

"THIELE" MODULUS

$$\phi \sim \frac{(L/2)^2 / D_{KA}}{\frac{V}{Z}} < 1$$

$L/2 = 25\ \mu m = 25 \times 10^{-4}\ cm$

$D_{KA} = 1 \times 10^{-7}\ cm^2/s$

$$\text{INTERNAL DIFFUSION TIME} \sim \frac{(25 \times 10^{-4}\ cm)^2}{1 \times 10^{-7}\ cm^2/s} = 60\ s$$

THE VALUE OF V COULD BE

10 cm/min

SO THE COLUMN NEEDS TO

BE 50 cm OR MORE

FOR INTERNAL CAPACITY

TO BE UTILIZED

WHAT IS PRESSURE DROP?

ERGUN EQ:

$$\frac{\Delta P}{Z} = \frac{150\,(1-\varepsilon)^2\,\mu\,V}{\varepsilon^3\,L^2}$$

$$= 150\,\frac{(1-.4)^2}{(.4)^3}\,\frac{2\times10^{-3}\,\frac{kg}{m\text{-}s}\,(.002\,m/s)}{(50\times10^{-6}\,m)^2}$$

$$= 50{,}000\ Pa/m$$

$$= 1/2\ ATM/m$$

SO YOU COULD HAVE A LONGER COLUMN OR SMALLER PARTICLES OR FASTER V.

SOME PACKING MATERIALS LIMIT MAX $\frac{\Delta P}{Z}$