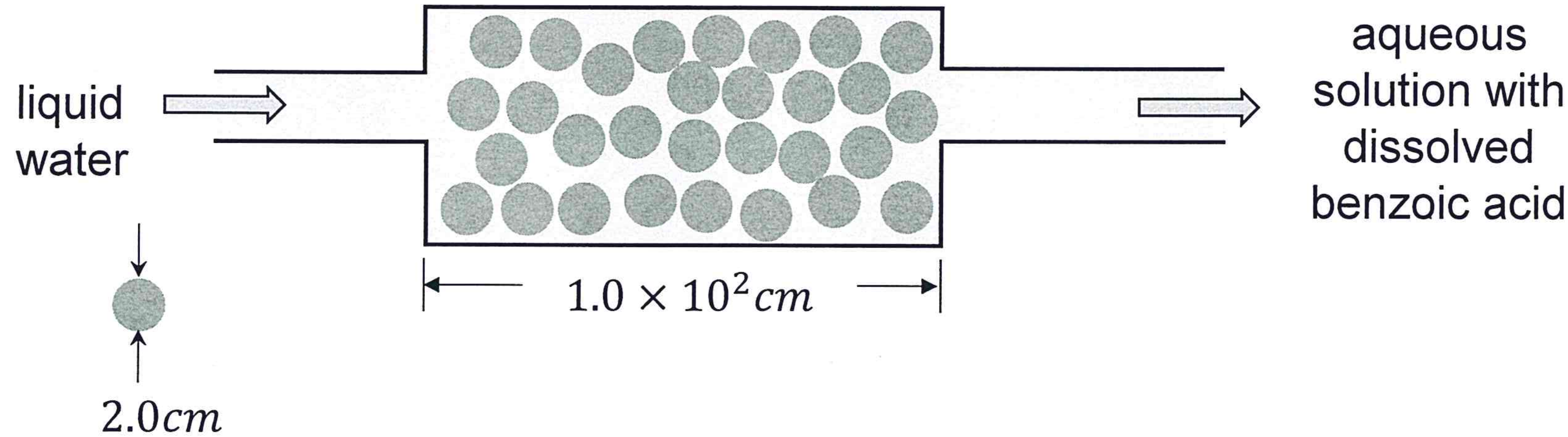
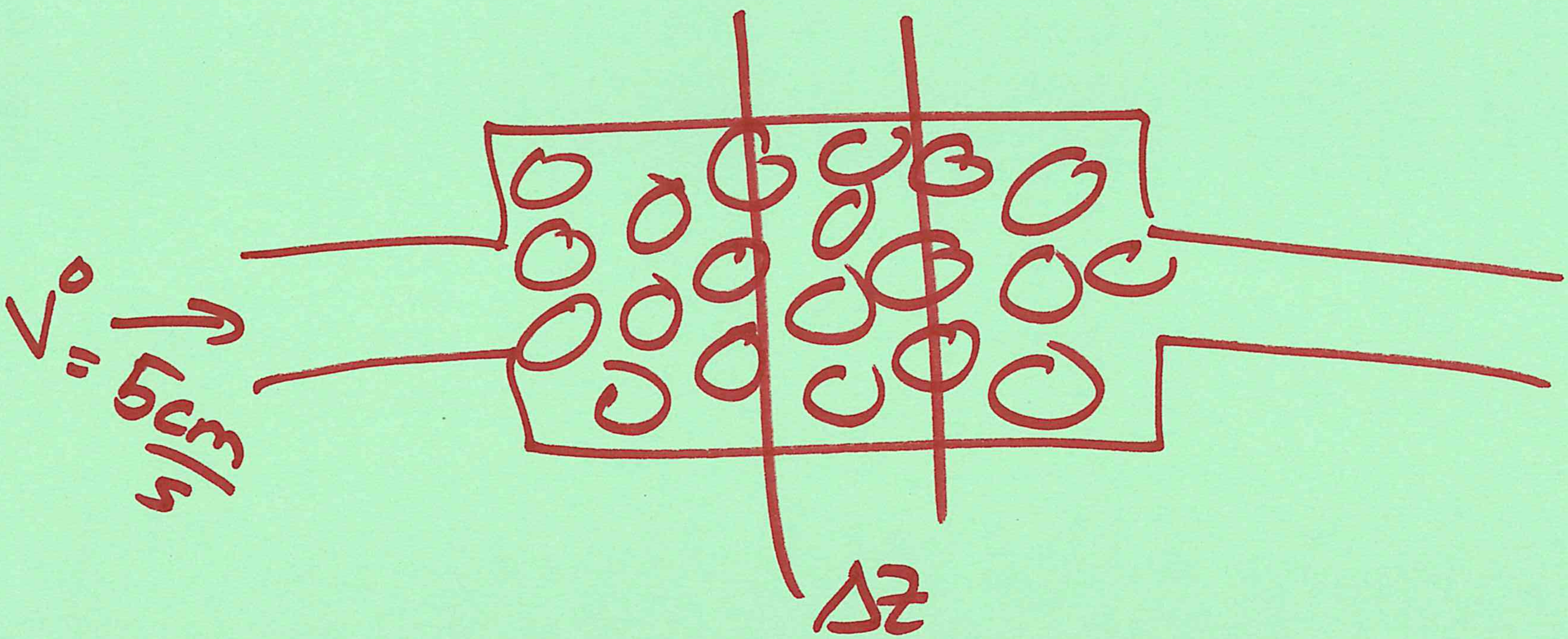
EXAMPLE 9 (in class) 12April 2019 FAM

1

Example: Flow through a packed bed of soluble spherical pellets.



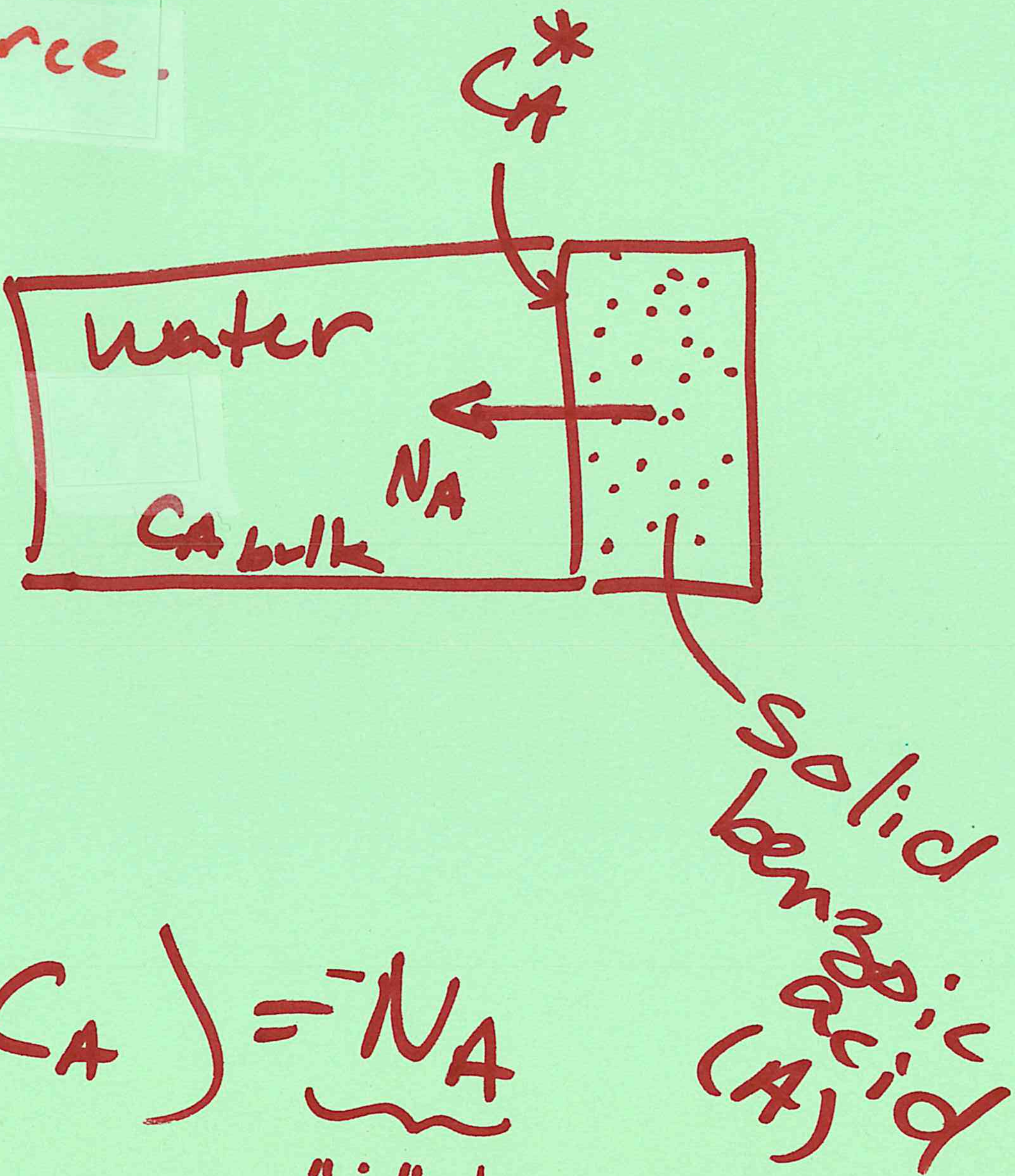
Two-centimeter diameter spheres of benzoic acid (soluble in water) are packed into a bed as shown. The spheres have $23\ cm^2$ of surface area per cm^3 volume of bed. What is the mass transfer coefficient when pure water flowing in ("superficial velocity"= $5.0\ cm/s$) exits 62% saturated with benzoic acid?



C.V. the liquid in this slice.

- Source = pellets of benzoic acid
- Sink = liquid (water becoming acid solution)
- to capture the variable driving force for mass xfer, choose a slice of the column

We can re-draw, separating the sink and the source.



$$S_i k_c (C_A^* - C_A) = \underbrace{-N_A}_{\text{"in" to C.V.}}$$

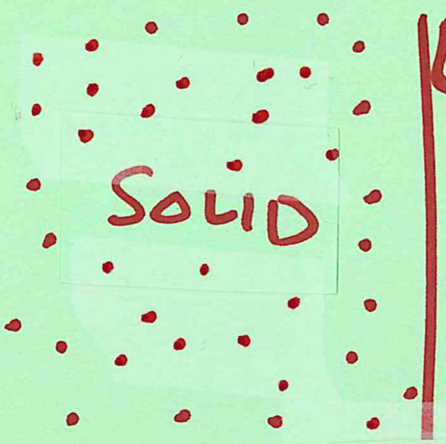
surface area for mass xfer

N_A = flux out to C.V.

$-N_A$ = flux in to C.V.

C_A^* ← interface conc = sat'd

S = x-section of bed



LIQUID

C_A ← bulk

$$-N_A = k_c\left(C_A^* - C_A\right)\underbrace{S_i}_{\underbrace{\Delta z S}_{\text{volume of bed}}\,a}$$

$\dfrac{\text{mols A}}{\text{area time}}$ into C.V. (the liquid)

a ← $\dfrac{\text{cm}^2 \text{ of transfer area}}{\text{vol of bed}}$

5

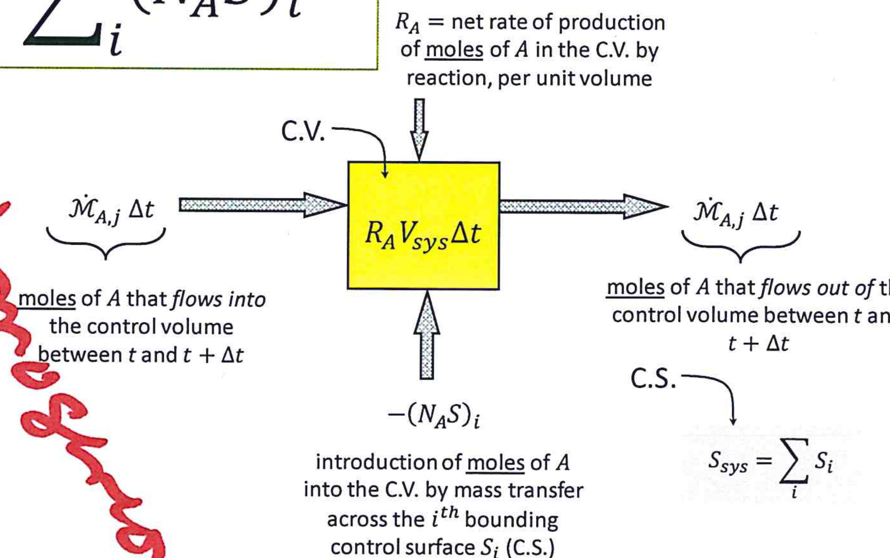
MOLES

accumulation = net flow in + production + introduction

$$\frac{d}{dt}\left(\cancel{\mathcal{M}_{A,sys}}\right) = -\Delta\dot{\mathcal{M}}_A + \cancel{R_A} V_{sys} - \sum_i (N_A S)_i$$

pseudo SS

no homogeneous rxn



$\mathcal{M}_{A,sys} = c_A V_{sys}$ = total moles of A in the C.V.

$\Delta\dot{\mathcal{M}}_A = \sum_{j,outs} \dot{\mathcal{M}}_{A,j} - \sum_{j,ins} \dot{\mathcal{M}}_{A,j}$

R_A = net rate of production of moles of A in the C.V. by reaction, per unit volume

V_{sys} = system volume

N_{A_i} = molar flux of A out through the i^{th} C.S.

$S_{sys} = \sum_i S_i$

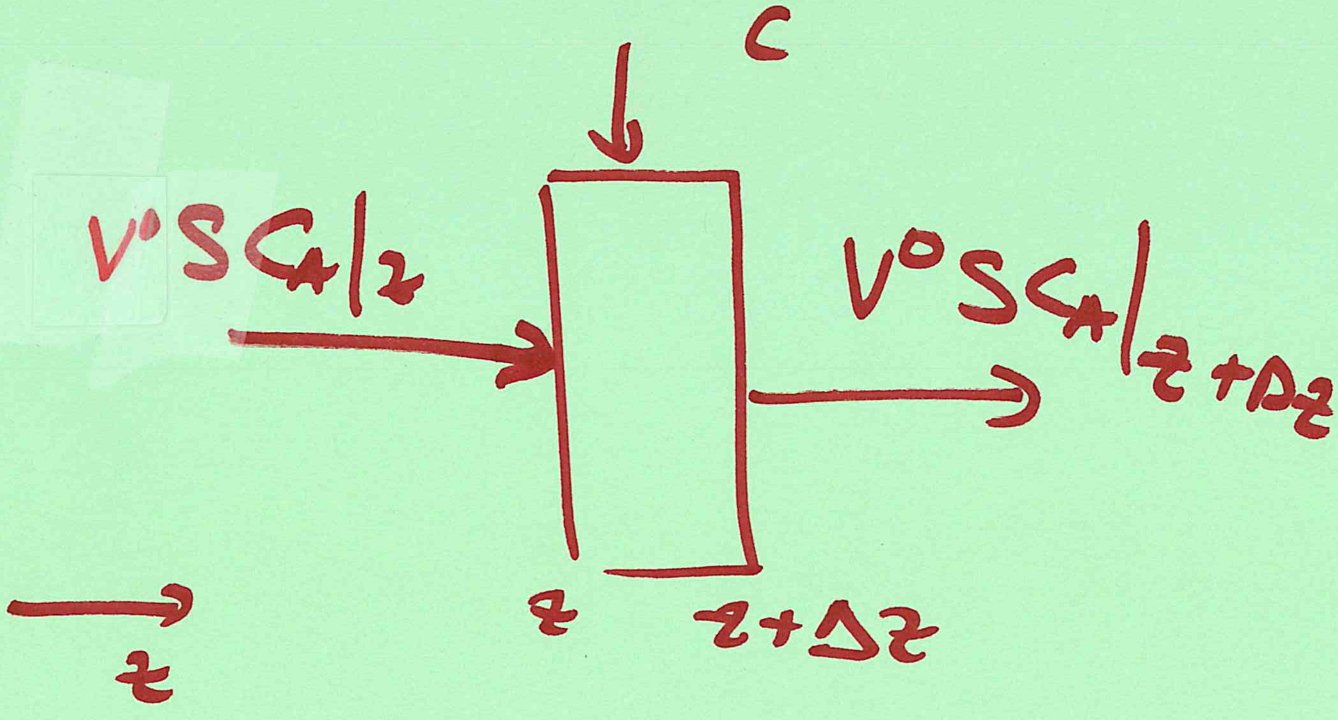
Δ is "out"- "in"

C.S. = control surface

C.V. = control volume

$$0 = -(M_{out} - M_{in}) - N_A S_i$$

$$0 = V^0 S C_A\Big|_z - V^0 S C_A\Big|_{z+\Delta z} + k_c(C_A^* - C_A)\underbrace{a S \Delta z}_{=S_i}$$



$$V^0 \cancel{S} \frac{\left(C_A\big|_{z+\Delta z} - C_A\big|_{z} \right)}{\Delta z} = k_c \left(C_A^* - C_A \right) a \cancel{S}$$

$$\boxed{\frac{dC_A}{dz} = \frac{(k_c a)}{V^0} \left(C_A^* - C_A \right)}$$

C_A^* is constant since bed is at const T, P. $\therefore$ we can integrate over the entire bed. //

$$\boxed{\text{Answer: } k_c = 2.1 \times 10^{-3} \ \frac{cm}{s}}$$