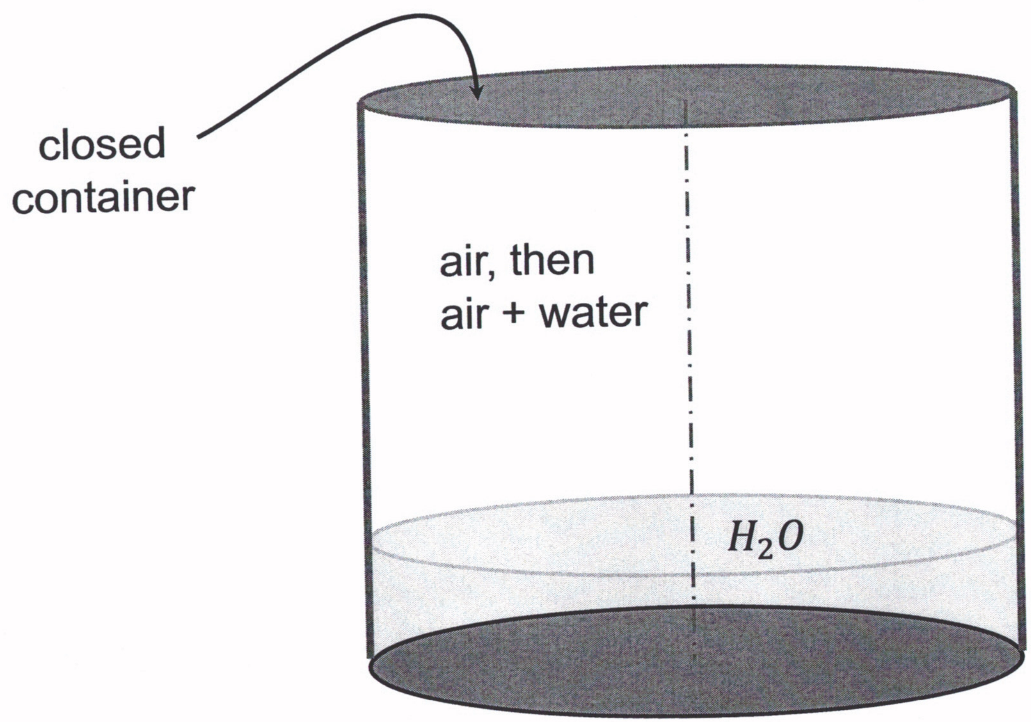
5 APRIL 2021 CM3120 MOD 4 Lect IV (part one) 1

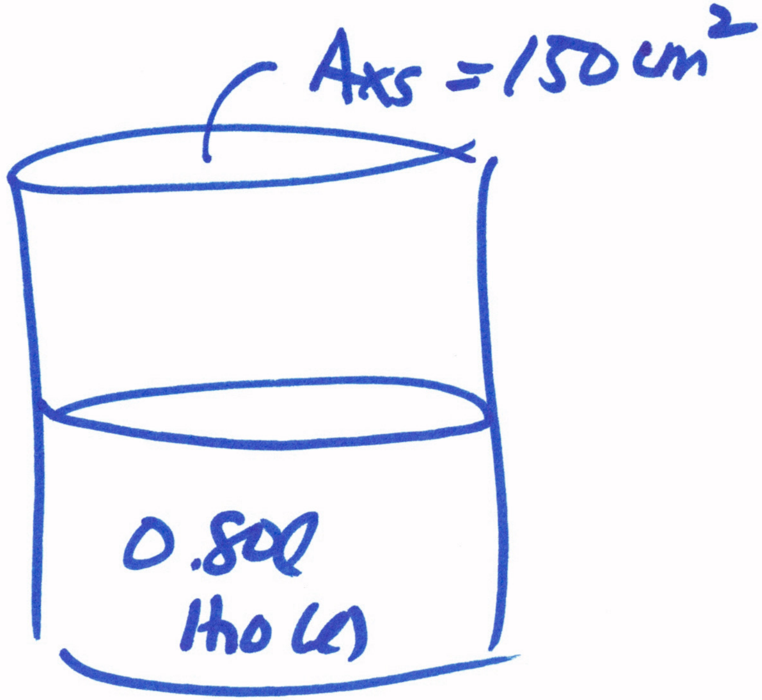
Example 7: Bone dry air and liquid water (water volume $= 0.80\ liters$) are introduced into a closed container (cross sectional area $= 150\ cm^2$; total volume $= 19.2\ liters$). Both air and water are at 25^oC, $\sim 1.0\ atm$ throughout this scenario. Three minutes after the air and water are placed in the closed container, the vapor is found to be 5.0% saturated with water vapor. What is the mass transfer coefficient for the water transferring from the liquid to the gas? How long will it take for the gas to become 90% saturated with water?

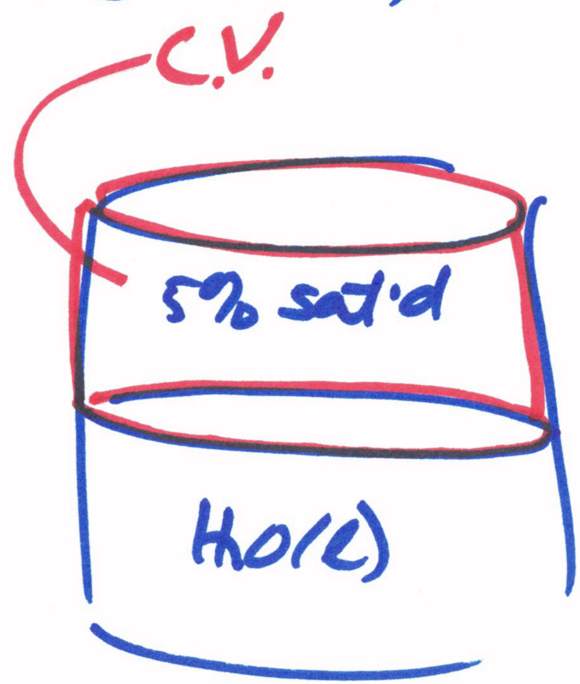


Cussler, p239, FAM v64 p59

EXAMPLE 7 (unsteady state)

25°C
1.0 atm





$V_{tot} = 19.2\ l$

$V_{H_2O} = 0.80\ l$
(initially)

assume cnst. $\left\{ \overline{19.2 - 0.8} = \text{volume } \Omega \text{ C.V.} \right.$

What is the mass xfer coef for H_2O transferring from liquid to gas?

Choose: C.V. is the gas in the headspace.

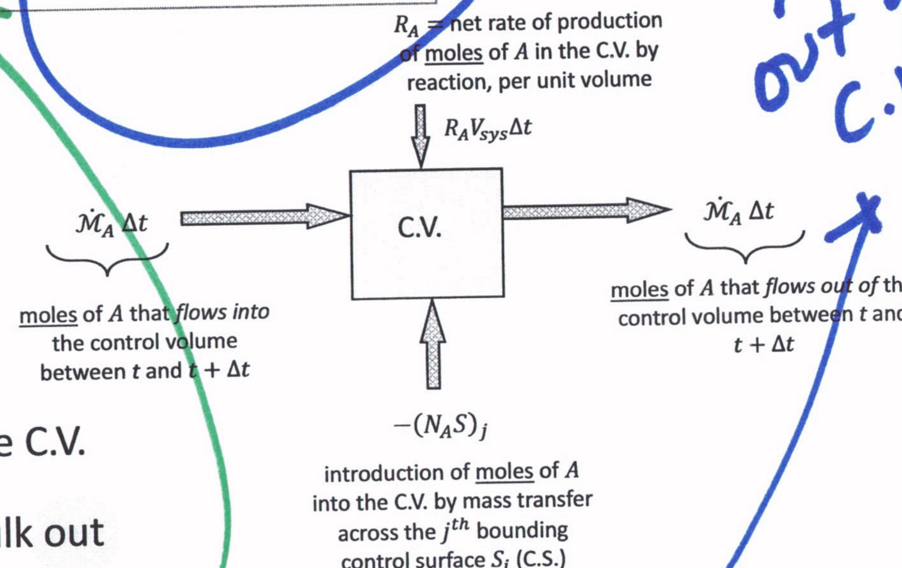
Unsteady Macroscopic Species A Mass Balance

MOLES

accumulation = net flow in + production + introduction

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

mass xfer of A out of C.V.



flow of gas out − in

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

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

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

homo-geneous rxn

V_{sys} = system volume

$N_{A_j} = K\Delta c_{df}$ = molar flux of A out through the j^{th} C.S.

$S_{sys} = \sum_j S_j$

Δ is "out" - "in"

C.S. = control surface

C.V. = control volume

Unsteady Macroscopic Species A mass bal:

$$\frac{d}{dt}\Big(\underbrace{M_{A,sys}}_{c_A V_{sys}}\Big) = -\cancel{\Delta \dot{M}_A} + \cancel{R_A} V_{sys} - N_A S$$

no bulk flow across c.v. boundaries

no rxn

c_A = water conc in C.V. (gas) $= c_{A_b}$

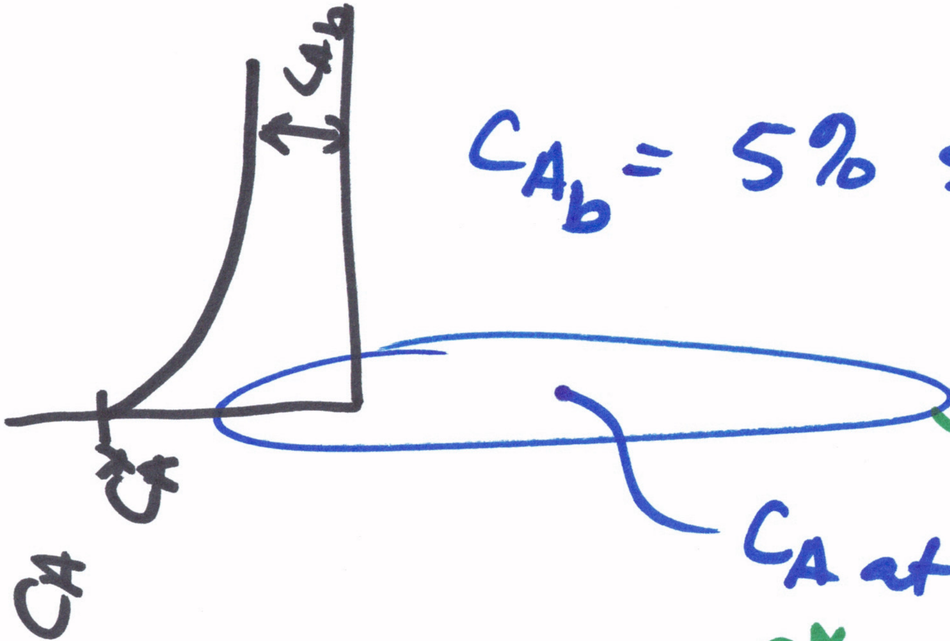
$$V_{sys}\frac{dc_A}{dt} = -N_A S = -N_A A_{xs}$$

$$N_A = k_c\Big(\underbrace{\ ?\ }_{c_A^* - c_A}\Big) \rightarrow$$

$$\frac{dc_A}{dt} = -\underline{k_c}\,(c_A^* - c_A)\,\frac{A_{xs}}{V_{sys}}$$

SOLVE

HOW TO WRITE N_A in complex c.v.? 8



C_{A_b} = 5% saturation

boundary between water + air

C_A at surface

C_A^* assume saturated

$$\boxed{N_A = k_c\big(\overbrace{C_A^* - C_{A_b}}^{\Delta C_{df}}\big)}$$

ΔC_{df} — driving force

back to balance

Linear driving force model for complex mass xfr

interface conditions

(includes internal bulk flow) + diffusion

$$\frac{dC_A}{dt} = \underbrace{\left(-\frac{k_c A_{xs}}{V_{sys}}\right)}\left(C_A^* - C_A\right)$$

Variable

constant

$$\frac{dC_A}{C_A - C_A^*} = \left(\frac{k_c A_{xs}}{V_{sys}}\right) dt$$

- integrate
- initial condition: $t = 0$

$C_A = 0 \leftarrow$ Bone dry AIR

⋮

$$\boxed{\frac{C_A}{C_A^*} = 1 - e^{\left(-\frac{k_c A_{xs}}{V_{sup}}\right)t}}$$

- Evaluate k_c from 3 minute data

$C_A = 0.05 C_A^*$

- How long to 90% saturation?

$0.95 C_A^* = C_A(t)$

$$\boxed{t = 2.3\,h}$$