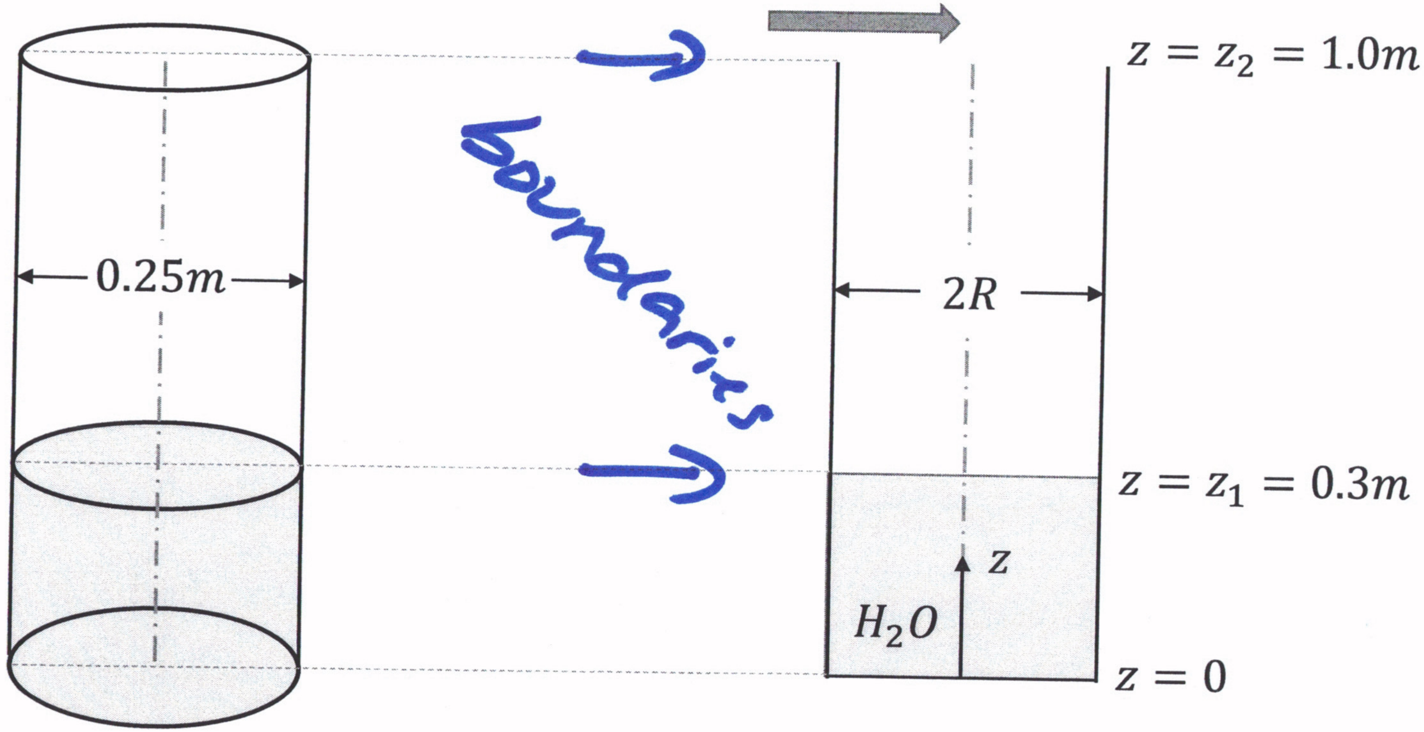
1D Evaporation from tank

QUICK START

Example 1 Redo: Water $(40^oC, 1.0\ atm)$ slowly and steadily evaporates into nitrogen $(40^oC, 1.0\ atm)$ from the bottom of a cylindrical tank as shown in the figure below. A stream of dry nitrogen flows slowly past the open tank. The mole fraction of water in the gas at the top opening of the tank is 0.02. The geometry is as shown in the figure. What is water mole fraction as a function of vertical position in the tank? You may assume ideal gas properties **and that the concentration is dilute in water.** What is the rate of water evaporation?

* Continued



BSL2, p547

See HW Plm 3.13

1.5

Diffusion and Mass Transfer QUICK START

Combined molar flux:

$$\underline{N}_A = \begin{pmatrix} N_{A,x} \\ N_{A,y} \\ N_{A,z} \end{pmatrix}_{xyz}$$

QUICK START

$$\underline{N}_A [=] \frac{moles\ A}{area \cdot time}$$

combined molar flux of A

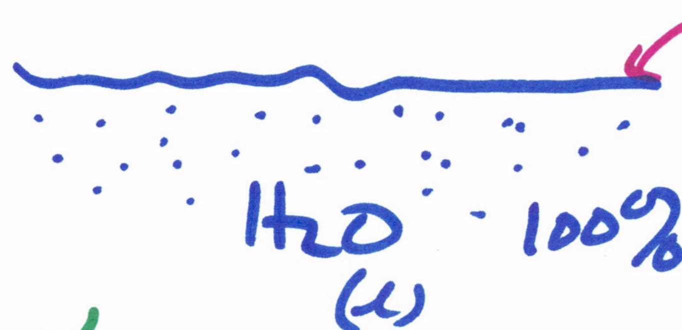
(due to both diffusion and convection)

Flux of moles of species A, both magnitude and direction, in the mixture

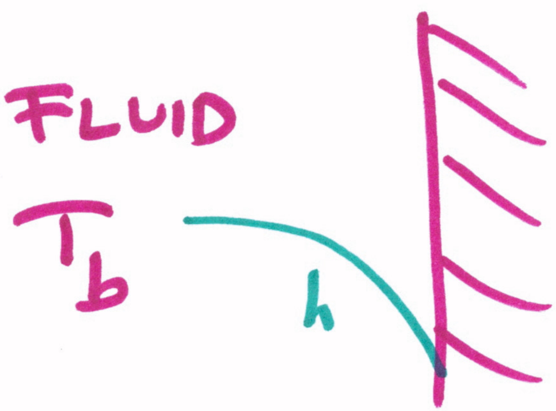
What are the BC?

$z = z_1$ — ~~pure $H_2O(l)$ → $x_A = 1$~~ — $x_A = x_A^*$ at 40°C

H_2O^{vap}, N_2

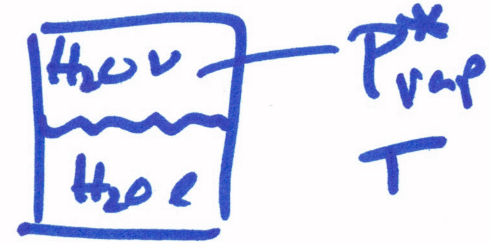


This does not work because our domain is the gas and mole frac = 1 is in liquid



$T(x) = ?$

Saturation



Raoult's Law:

$$yP = P^*$$

Boundaries between phases require some thought + observation

$$x_A P = P^*$$

BC:

$z = z_1 \quad x_A = \frac{P^*(40°C)}{P}$

$z = z_2 \quad x_A = 0.02$ (given)

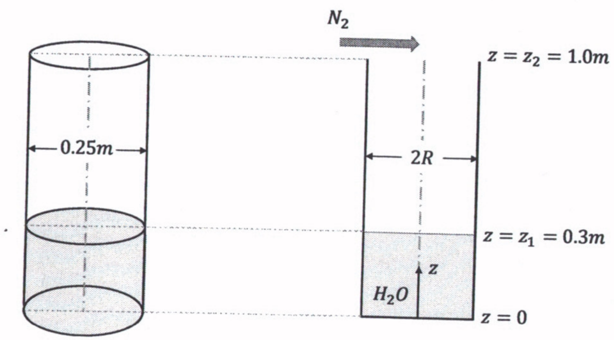
SOLVE

- Substitute into soln
- 2 eqns, 2 unknowns
- solve c_1, c_2
- obtain $x_A(z)$
  $N_{A,z}$

Solution:

QUICK START

Example: Water ($40^o C, 1.0\ atm$) slowly and steadily evaporates into nitrogen ($40^o C, 1.0\ atm$) from the bottom of a cylindrical tank as shown in the figure below. A stream of dry nitrogen flows slowly past the open tank. The mole fraction of water in the gas at the top opening of the tank is 0.02. **What is the rate of water evaporation?**



$$\left(\frac{1 - x_A}{1 - x_{A1}}\right) = \left(\frac{1 - x_{A2}}{1 - x_{A1}}\right)^{\frac{z - z_1}{z_2 - z_1}}$$

Or:

$$x_A = 1 - (1 - x_{A1})\left(\frac{1 - x_{A2}}{1 - x_{A1}}\right)^{\frac{z - z_1}{z_2 - z_1}}$$

Flux of water:

$$N_{Az} = c_1 = \frac{c\mathcal{D}_{AB}}{z_2 - z_1}\ln\left(\frac{1 - x_{A2}}{1 - x_{A1}}\right)$$
$$= 8.0 \times 10^{-5}\ mol/m^2 s$$

Rate of evaporation:

$$A_{xs}N_{Az} = 3.9 \times 10^{-6} mol/s$$

Note:

$$c = \frac{n}{V} = \frac{P}{RT}$$

See HW 3.13