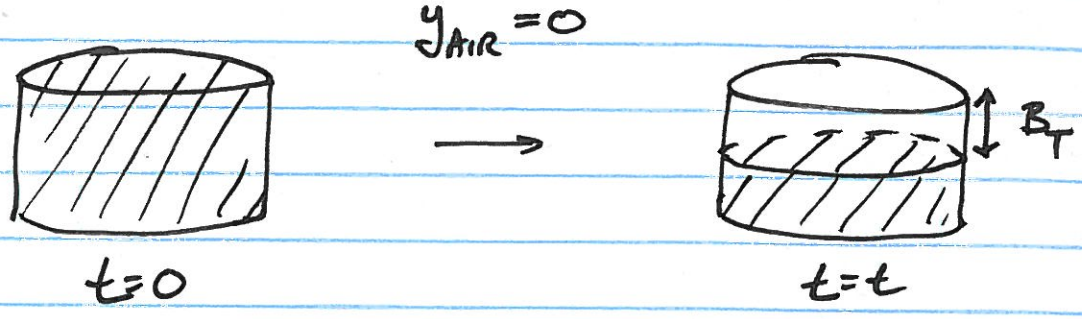
HW#7 - SPRING 2010

3.1 Headspace: Stagnant air @ 1atm + 0°C



BASIS: 100 moles liquid

⇒ 50 moles AL
50 moles AC
50+50 = 100 total

$n_{AL} = 25$ moles
$n_{AC} = ?$
$25 + n_{AC}$ = total

Raoult's Law:

$$y_i P = x_i P_i^{sat}$$

$P = 1\,atm = 101.3\,kPa$

$P_{AL}^{sat} = 1.62\ kPa$ @ 0°C
$P_{AC}^{sat} = 3.23\ kPa$ @ 0°C

} Greater driving force for acetate

Diffusivities:

$D_{AL\text{-}air} = 9.29 \times 10^{-6} \frac{m^2}{s}$
$D_{AC\text{-}air} = 6.45 \times 10^{-6} \frac{m^2}{s}$

} GAS PHASE

NOTES:

1) B_T NOT CONSTANT + UNKNOWN

2) CAN TREAT ALCOHOL + ACETATE INDEPENDENTLY

3) AREA UNKNOWN

4) CAN USE RATIOS TO ELIMINATE SOME UNKNOWNS

FICK'S LAW: (Stagnant ⇒ NO CONVECTION TERM)

$$N_{AL} = J_{AL}$$

ALCOHOL –

$$N_{AL} = J_{AL} = -C\, D_{AL\text{-}air} \frac{dy_{AL}}{dz}$$

ACETATE –

$$N_{AC} = J_{AC} = -C\, D_{AC\text{-}air} \frac{dy_{AC}}{dz}$$

} GAS PHASE MASS TRANSFER

⇒ Vapor phase mole fractions + Diffusivities

NEXT, INTEGRATE:

ALCOHOL –

$$N_{AL} \int_{B_T}^{0} dz = -C\, D_{AL\text{-}air} \int_{y_{AL}}^{0} dy_{AL}$$

$$N_{AL}(0 - B_T) = -c\, D_{AL\text{-}air}(0 - y_{AL})$$

$$-N_{AL} B_T = c\, D_{AL\text{-}air}\, y_{AL}$$

ACETATE – (Get similar expression)

$$-N_{AC} B_T = c\, D_{AC\text{-}air}\, y_{AC}$$

TAKE RATIO:

$$\frac{\cancel{-} N_{AL} \cancel{B_T}}{\cancel{-} N_{AC} \cancel{B_T}} = \frac{\cancel{c}\, D_{AL\text{-}air}\, y_{AL}}{\cancel{c}\, D_{AC\text{-}air}\, y_{AC}}$$

$$\Rightarrow \boxed{\frac{N_{AL}}{N_{AC}} = \frac{D_{AL\text{-}air}\, y_{al}}{D_{AC\text{-}air}\, y_{ac}}}$$

Interested in $n_{ac} + n_{aL}$ ... need some substitutions.

$$N_{AL} = \frac{dn_{AL}}{A\,dt} \qquad N_{AC} = \frac{dn_{ac}}{A\,dt}$$ } material balance

$$\Rightarrow \frac{N_{AL}}{N_{AC}} = \frac{dn_{AL}}{\cancel{A\,dt}} \Big/ \frac{\cancel{A\,dt}}{dn_{AC}} = \frac{dn_{AL}}{dn_{AC}}$$

FROM RAOULT'S LAW:

$$y_{AL} = \frac{P_{AL}^{sat}}{P} x_{AL} \qquad y_{AC} = \frac{P_{AC}^{sat}}{P} x_{AC}$$

DEFINITION OF x_i:

$$x_{AL} = \frac{n_{AL}}{n_{AL}+n_{AC}} \qquad x_{AC} = \frac{n_{AC}}{n_{AL}+n_{AC}}$$

SUBSTITUTE:

$$\frac{dn_{AL}}{dn_{AC}} = \frac{(D_{AL\cdot air})(P_{AL}^{sat})(1/P)}{(D_{AC\cdot air})(P_{AC}^{sat})(1/P)} \frac{n_{AL}}{(n_{AL}+n_{AC})} \Big| \frac{(n_{AL}+n_{AC})}{n_{AC}}$$

$$\Rightarrow \boxed{\frac{dn_{AL}}{dn_{AC}} = \frac{(D_{AL\cdot air})(P_{AL}^{sat})\, n_{AL}}{(D_{AC\cdot air})(P_{AC}^{sat})\, n_{AC}}}$$

SEPARATE + INTEGRATE:

$$\int_{50}^{25} \frac{dn_{AL}}{n_{AL}} = \frac{D_{AL\cdot air}}{D_{AC\cdot air}} \frac{P_{AL}^{sat}}{P_{AC}^{sat}} \int_{50}^{n_{AC}} \frac{dn_{AC}}{n_{AC}}$$

$$\ln\left(\frac{25}{50}\right) = \frac{(9.29\times10^{-6})}{(6.45\times10^{-6})} \Big| \frac{(1.62)}{(3.23)} \ln\left(\frac{n_{AC}}{50}\right)$$

$$-0.693 = 0.722 \ln\left(\frac{n_{Ac}}{50}\right)$$

$$\exp\left(\frac{-0.693}{0.722}\right) = \frac{n_{Ac}}{50}$$

$$n_{Ac} = 50\,(0.383) = \boxed{19.1 \text{ moles acetate} = n_{Ac}}$$

$$\boxed{n_{AL} = 25 \text{ moles alcohol}}$$

$$n_T = 44.1 \text{ moles}$$

$$\Rightarrow \boxed{\begin{aligned} X_{AL} &= 25/44.1 = 0.567 \\ X_{Ac} &= 19.1/44.1 = 0.433 \end{aligned}}$$