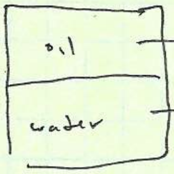
Tyler Bradley | ENVE 660 | HW 3 | 2/14/18

1) $C_{B,oil,0} = 18\ kg/m^3$

$C_{Bw,0} = 0\ kg/m^3$

$\chi_{B,oil} = 0.02\ \frac{mol\ B}{mol\ solution}$



$\rightarrow V_{oil} = 0.3\ m^3$

$- V_w = 200\ L$

Assume

- oil is ideal solution
- steady state
- $V_i = V_f$

$MW_B = 78\ \frac{g}{mol} = 0.078\ \frac{kg}{mol}$

$\rho_B = 8.76 \times 10^2\ kg/m^3$

$$\chi_B = \frac{C_B}{\frac{\rho_B}{MW_B}} = \frac{C_B}{\rho_B} MW_B$$

a) MB: don't include $C_{B,oil}$

$$\cancel{\frac{dM}{dt}}^{0} = Mass_i - Mass_f = \cancel{C_{Bw,0}}^{0} V_w + C_{Boil,0} V_{oil} - (C_{Bw} V_w + C_{Boil} V_{oil})$$

$$C_{Boil,0} V_{oil} = C_{Bw} V_w + C_{B,oil} V_{oil} \qquad C_{B,oil} = \frac{\chi_B}{MW_B} \rho_B$$

$$\boxed{C_{Boil,0} V_{oil} = C_{Bw} V_w + \chi_B \rho_B \left(\frac{1}{MW_B}\right) V_{oil}}$$

b) $C_{Bw} = ?$

$$C_{Bw} = \frac{\left(C_{B,oil,0} V_{oil} - \chi_B \rho_B \left(\frac{1}{MW_B}\right) V_{oil}\right)}{V_w}$$

$$C_{Bw} = \frac{\left(\frac{1}{0.078\ \frac{kg}{mol}}\right)(18\ kg/m^3)(0.3\ m^3) - (0.02)\left(8.76 \times 10^2\ \frac{kg}{m^3}\right)\left(\frac{1}{0.078\ \frac{kg}{mol}}\right)(0.3\ m^3)}{(200\ L)\left(\frac{1\ m^3}{1000\ L}\right)}$$

$$\boxed{C_{Bw} = 9.23\ \frac{mol}{m^3}}$$

c) $C_{B,oil} = ?$

$$C_{B,oil} = \chi_B \rho_B \left(\frac{1}{MW_B}\right) = (0.02)(8.76 \times 10^2\ kg/m^3)\left(\frac{1\ mol}{0.078\ kg}\right)$$

$$\boxed{C_{B,oil} = 224\ \frac{mol}{m^3}}$$

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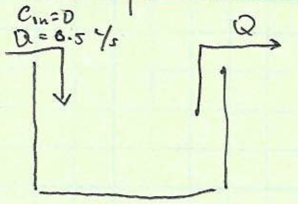

$Q_{in} = Q_{out}$

a) Mass residue initial = 15 g
residue solubility = 0.001 g/L
↳ $C_{out} = 0.001$ g/L

$$\frac{dM}{dt} = Q_{in}\cancel{C_{in}}^{0} - Q_{out}C_{out}$$

$$\int_{15}^{0} dM = \int_{0}^{t} -Q_{out}C_{out}\, dt$$

$$M\Big]_{15g}^{0} = -\left(0.5\tfrac{L}{s}\right)\left(0.001\,g/L\right)\, t\Big]_0^t$$

$$-15g = -$$

$$\boxed{t = 30{,}000\ s = 8.3\ hrs}$$

b) if $C_{in} = 2.5 \times 10^{-4}$ g/L what is M @ t=5

$$\frac{dM}{dt} = (Q_{in}C_{in} - Q_{out}C_{out}) = 0.5\tfrac{L}{s}\left(2.5\times10^{-4}\tfrac{g}{L} - 0.001\tfrac{g}{L}\right)$$

$$\int_{15}^{M} dM = \left(-0.000375\tfrac{g}{s}\right)\left(\tfrac{60\ s}{1\ min}\right)\left(\tfrac{60\ min}{1\ hr}\right)\int_0^5 t$$

$$M - 15g = -1.35(5) = -6.75g$$

$$M = 15 - 6.75\ g$$

$$\boxed{M = 8.25\ g}$$

c) $T_A = 50°C$
$P_A = 1$ atm
$Q_A = 1\ \frac{L}{s}$
$P_A^0 = 0.2$ atm
$R = 0.08206\ \frac{L\cdot atm}{mol\cdot K}$
$V = 2L$
$MW = 10\,g/m$

$PV = nRT$

$$\frac{n}{V} = \frac{P}{RT} = \frac{0.2\ atm}{\left(0.08206\frac{L\cdot atm}{mol\cdot K}\right)(323\ K)}$$

$$\frac{n}{V} = \left(0.0075\ \frac{mol}{L}\right)\left(\frac{10\ g}{mol}\right) = 0.0755\ \frac{g}{L}$$

Assume $Q_{A,in} = Q_{A,out}$

$$\frac{dM}{dt} = Q_A\cancel{C_{in}}^{0} - Q_A C_{out}$$

$$\int_{15}^{M} dm = -\left(1\tfrac{L}{s}\right)\left(0.0755\tfrac{g}{L}\right)\int_0^t dt$$

$$-15g = \left(-0.0755\ \tfrac{g}{s}\right)t$$

$$\boxed{t = 198\ s}$$

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(3) $A \leftrightarrow B$ $\qquad C_A^* = \frac{C_B}{K_{eq}} \qquad K_{eq} = \frac{k_A}{k_B} \qquad \hat{C}_A = C_A^* - C_A$

a) Find T_{char} $\qquad K_{eq} = 0.25$, $k_A = 0.4\ min^{-1}$

$$\frac{dC_A}{dt} = -k_A C_A + k_B C_B \qquad \frac{dC_B}{dt} = -k_B C_B + k_A C_A$$

$$\hat{C}_A = C_A^* - C_A \rightarrow d\hat{C}_A = dC_A^* - dC_A$$

$$dC_A^* = \frac{dC_B}{K_{eq}}$$

$$d\hat{C}_A = \frac{1}{K_{eq}} dC_B - dC_A \Rightarrow \frac{d\hat{C}_A}{dt} = \frac{1}{K_{eq}}\frac{dC_B}{dt} - \frac{dC_A}{dt}$$

$$\frac{d\hat{C}_A}{dt} = \frac{-k_B C_B}{K_{eq}} + \frac{k_A C_A}{K_{eq}} + k_A C_A - k_B C_B$$

$$= -k_B C_A^* + k_B C_A + k_A C_A - \frac{k_A}{K_{eq}} C_B$$

$$= -k_B(C_A^* - C_A) + k_A C_A - k_A C_A^*$$

$$= -k_B(\hat{C}_A) - k_A(C_A^* - C_A)$$

$$\frac{d\hat{C}_A}{dt} = -\hat{C}_A(k_A + k_B)$$

$$\int_{\hat{C}_{A_0}}^{\hat{C}_A} \frac{d\hat{C}_A}{\hat{C}_A} = -(k_A + k_B)\int_0^t dt$$

$$\ln\left(\frac{\hat{C}_A}{\hat{C}_{A_0}}\right) = -(k_A + k_B)t \Rightarrow \hat{C}_A = \hat{C}_{A_0} e^{-(k_A + k_B)t}$$

$$t_{char} = k^{-1} = (k_A + k_B)^{-1} = \left(0.4\ min^{-1} + \frac{0.4\ min^{-1}}{0.25}\right)^{-1} =$$

$$\boxed{t_{char} = 0.5\ min}$$

b) $C_{A_0} = 500\ \frac{mol}{L}$ $\qquad C_{B_0} = 55\ \frac{mol}{L}$ $\qquad$ Find $\hat{C}_A(t = \frac{t_{char}}{2})$

$$\hat{C}_A = \hat{C}_{A_0} e^{-(2)t}$$

$$\hat{C}_{A_0} = C_{A_0}^* - C_{A_0} \qquad C_{A_0}^* = \frac{C_{B0}}{K_{eq}} = \frac{55\ \frac{mol}{L}}{0.25} = 229.17\ \frac{mol}{L}$$

$$\hat{C}_{A_0} = 229.17\ \frac{mol}{L} - 500\ \frac{mol}{L} = -271\ \frac{mol}{L}$$

$$\hat{C}_A(t = 0.25) = -271\ \frac{mol}{L}\ e^{-2(0.25)}$$

$$\boxed{\hat{C}_A(t = 0.25) = -164.37\ \frac{mol}{L}}$$

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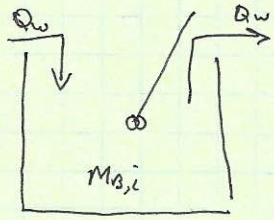

V_w = constant

$C_{B,in} = 0$

$C_{B,out}$ = solubility of benzene

MB

Assume: steady-state

$$\frac{dM}{dt} = Q_{in}\cancel{C_{in}}^{\,0} - Q_{out} C_{out}$$

$$\int_{M_{B,i}}^{M_B(t)} dM = -Q_w C_{B,out} \int_0^t t$$

$$\boxed{M_B(t) = M_{B,i} - Q_w C_{B,out}\, t}$$

t when $M_B(t) = 0$

$$0 = M_{B_i} - Q_w C_{B,out}\, t$$

$$\boxed{t = \frac{M_{B_i}}{Q_w C_{B,out}}}$$

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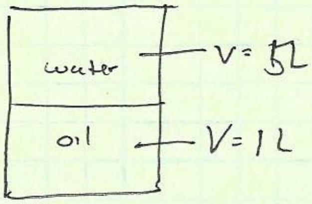

$\gamma_{BL} = 1$

χ_{B,L_i}

$C_{Bw,sol} = 1800\ mg/m^3$

$\rho_B = 0.88 \times 10^6\ g/m^3$

$MW_B = 78.114\ \frac{g}{mol}$

Assume: steady-state
$C_{B,w_i} = 0$

$X_{B_i} = \frac{C_{Bi}}{\rho_B} MW_B$

a) $\cancel{\frac{dM}{dt}}^{0} = Mass_i - Mass_f$

$= \cancel{C_{B,w_i}}^{0} V_w + C_{B,L_i} V_{BL} - (C_{Bw} V_w + C_{BL} V_L)$

$C_{B,L_i} V_L = C_{Bw} V_w + C_{BL} V_L$

$C_{B_i} = X_{B,i}\, \rho_B \left(\frac{1}{MW_B}\right)$

$X_{BL_i}\, \rho_B \left(\frac{1}{MW_B}\right) V_L - C_{Bw} V_w = C_{BL} V_L$

$C_{Bw} = C_{Bw,sol}\, X_{BL}$

$X_{BL_i}\, \rho_B \left(\frac{1}{MW_B}\right) V_L = C_{BL} V_L + C_{Bw,sol} (MW_B)\left(\frac{1}{\rho_B}\right) C_{BL} V_w$

$X_{BL} = \frac{C_{BL}}{\rho_B}$

$C_{Bw} = (C_{Bw,sol})(C_{BL})(MW_B)\left(\frac{1}{\rho_B}\right)$

$X_{BL_i}\left(0.88 \times 10^6 \frac{g}{m^3}\right)\left(\frac{1}{78.114 \frac{g}{mol}}\right)(1\ L)\left(\frac{1\ m^3}{1000\ L}\right) = \left[(1\ L)\left(\frac{1\ m^3}{1000\ L}\right) + \left(1.8 \frac{g}{m^3}\right)\left(\frac{1\ m^3}{0.88 \times 10^6\ g}\right)(5\ L)\left(\frac{1\ m^3}{1000\ L}\right)\right] C_{BL}$

$(0.000011\ mol)\, X_{BL_i} = (0.001\ m^3)\, C_{BL}$

$$\boxed{C_{BL} = 0.011\, X_{BL_i}}$$

b) $X_{BL,i} = 0.01$

$C_{BL} = \left(0.011 \frac{mol}{m^3}\right)(0.01)$

$$\boxed{C_{BL} = 1.126 \times 10^{-4}\ \frac{mol}{m^3}}$$