Homework problem 1

A three component feed (100 mole/hr, saturated vapor feed) containing three species (#1, #2, #3) are to be separated by distillation. Feed composition is as following:
#1: 20%, #2: 40%, #3: 40%

Desired recovery for #2 in distillate is 95%. Assume constant relative volatility. NK does not go to bottom.

$$\alpha^{12} = 2 \qquad \alpha^{31} = 0.25 \qquad x_D^{(HK)} = 0.1$$

1. Identify light key (LK), heavy key (HK), and non-key (NK).
2. Calculate B and D flow rates.
3. Calculate compositions of distillate and bottom (all three components).
4. Calculate minimum number of stages by the Fenske method.

Solution to homework problem

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1. Lets look at volatility based on α: #1 is the most volatile, #3 is least volatile

#2 is specified and goes predominantly to the distillate. This makes #2 as LK.

HK seems to be only 10% in distillate. It can not be #1 which does not partition. So #3 is HK.

This makes #1 as LNK

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2. Lets write the equations for fractional recovery

#1 It does not partition. Fractional recovery in distillate is 1.

$$1 = \frac{Dx_D^1}{Fz_1} \qquad \Rightarrow Dx_D^1 = 1Fz_1 = 100 * 0.2 = 20$$

#2

$$0.95 = \frac{Dx_D^2}{Fz_2} \qquad \Rightarrow Dx_D^2 = 0.95Fz_2 = 0.95 * 100 * 0.4 = 38$$

#3

$$x_D^3 = 0.1 \qquad \Rightarrow Dx_D^3 = 0.1D$$

Adding above three, we get $Dx_D^1 + Dx_D^2 + Dx_D^3 = 58 + 0.1D \qquad \Rightarrow D(x_D^1 + x_D^2 + x_D^3) = 58 + 0.1D$

$$\Rightarrow D = 58 + 0.1D \qquad \Rightarrow D = 64.4$$

$$\Rightarrow B = F - D = 35.6$$

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3. Composition

$$Dx_D^1 = 20 \qquad \Rightarrow x_D^1 = 20/D = 0.31 \qquad x_D^3 = 0.1$$

$$\Rightarrow x_D^2 = 1 - 0.31 - 0.1 = 0.59$$

fractional recovery of #2 in bottom is 100-95 = 5%

$$\Rightarrow 0.05 = \frac{Bx_B^2}{Fz_2} \qquad \Rightarrow x_B^2 = 0.05Fz_2/B = 0.05 * 100 * 0.4/35.6 = 0.056$$

Since #1 does not partition, rest in bottom is #3

$$\Rightarrow x_B^3 = 1 - x_B^2 = 0.944$$

3. Fractional recovery of 3 in bottom = $\frac{Bx_B^3}{Fz_3} = \frac{35.6 * 0.944}{40} = 84\,\%$

$$N_{min} = \frac{\ln\left[\left(\frac{FR_D^2}{1 - FR_D^2}\right)\left(\frac{FR_B^3}{1 - FR_B^3}\right)\right]}{\ln \alpha^{23}}$$

$$\alpha^{12} = 2 \qquad \alpha^{31} = 0.25 \qquad \alpha^{23} = 1/\alpha^{12} * 1/\alpha^{31} = 1/2 * 1/0.25 = 2$$

$$N_{min} = \frac{\ln\left[\left(\frac{0.95}{0.05}\right)\left(\frac{0.84}{0.16}\right)\right]}{\ln 2} = 6.6$$

~7 stages

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Homework problem 2

SO_2 is absorbed from nitrogen gas using alkaline absorbent using 2 meter tall packed column absorber with a cross-sectional area of 0.5 m^2. The inlet absorbent is pure. The outlet absorbent contains 1 mol% SO_2. The concentration of SO_2 in inlet nitrogen is 20%. The total absorbent inlet flow rate is 100 mole/minute. The total gas inlet flow rate is 10 mole/minute. Equilibrium relationship is given below. Calculate the concentration of SO_2 in the exit air stream.

$$y^*_{N+1} = 3x_N \qquad y^*_1 = 10x_0$$

$$h = \left(\frac{G_C}{K_y a A}\right) \frac{y_{N+1} - y_1}{(y - y^*)_{N+1} - (y - y^*)_1} \ln\left[\frac{(y - y^*)_{N+1}}{(y - y^*)_1}\right]$$

$$h = 2$$

$$x_0 = 0 \qquad y^*_1 = 0$$

$$y_{N+1} = 0.2$$

$$x_N = 0.01 \qquad y^*_{N+1} = 0.03$$

$$G = \frac{G_C}{1 - y_{N+1}} \qquad G_C = G(1 - y_{N+1}) = 10(1 - 0.2) = 8$$

$$L = \frac{L_A}{1 - x_0} \qquad L_A = L(1 - x_0) = 100$$

$y_{N+1} = 0.2$ $x_N = 0.01$ $x_0 = 0$ $G_c = 8$ $L_A = 100$

Overall balance to calculate y_1

$$\left(L\right)_N x_N - \left(L\right)_0 x_0 = \left(G\right)_{N+1} y_{N+1} - \left(G\right)_1 y_1$$

$$\frac{L_A}{1-x_N} x_N - \frac{L_A}{1-x_0} x_0 = \frac{G_C}{1-y_{N+1}} y_{N+1} - \frac{G_C}{1-y_1} y_1$$

$$\frac{G_C}{1-y_1} y_1 = \frac{G_C}{1-y_{N+1}} y_{N+1} - \frac{L_A}{1-x_N} x_N + \frac{L_A}{1-x_0} x_0$$

Substituting the values, we get

$$\frac{8}{1-y_1} * y_1 = \frac{8}{1-0.2} * 0.2 - \frac{100}{1-0.01} * 0.01 + \frac{100}{1-0} * 0 \qquad \Rightarrow y_1 = 0.126$$

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