Exercise Problem 1

$$N_{\min} = \frac{\ln\left[\left(\frac{FR_D^{(1)}}{1-FR_D^{(1)}}\right)\left(\frac{FR_B^{(2)}}{1-FR_B^{(2)}}\right)\right]}{\ln\left(\alpha_{average}^{(12)}\right)}$$

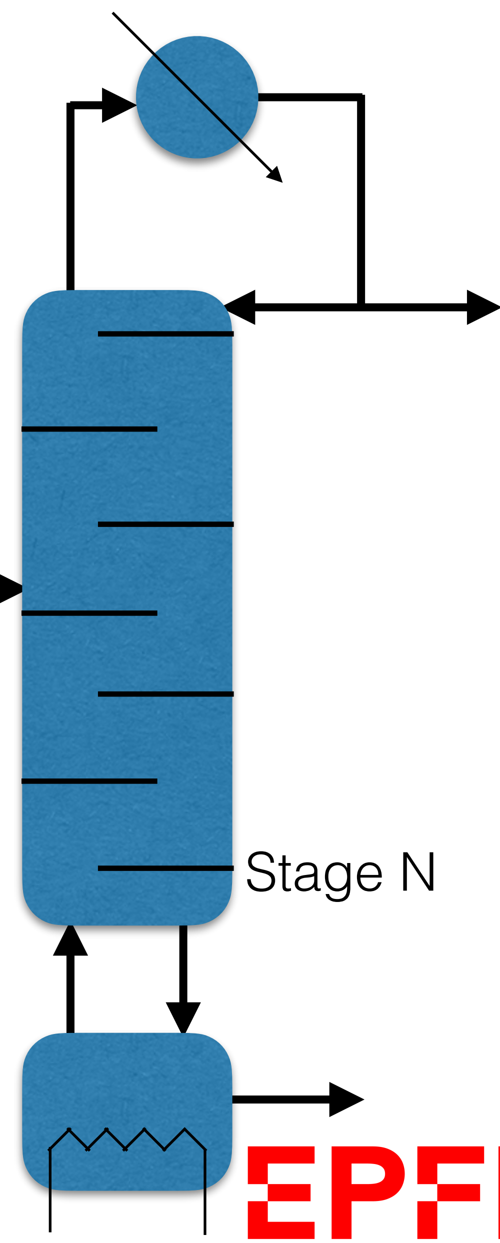
Find minimum number of stages using Fenske equation.

What is expected fractional recovery of benzene in distillate and bottom.

$$FR_D^{(3)} = \frac{\left(\alpha_{average}^{(32)}\right)^{N_{\min}}}{\left(\alpha_{average}^{(32)}\right)^{N_{\min}} + \left(\frac{FR_B^{(2)}}{1-FR_B^{(2)}}\right)}$$

Find fractional recovery of benzene in distillate and bottom

		% in feed
Benzene	80.1 °C	40%
Toluene	110. 6 °C	30%
Cumene	152.4 °C	30%



$$FR_D^{(Toluene)} = 95\%$$

$$\alpha_{average}^{(Benzene-Toluene)} = 2.25$$

$$\alpha_{average}^{(Cumene-Toluene)} = 0.21$$

$$FR_B^{(Cumene)} = 95\%$$

Component 1: Toluene (LK), **Component 2: Cumene (HK),** **Component 3: Benzene (LNK)**

$$N_{\min} = \frac{\ln\left[\left(\dfrac{FR_D^{(1)}}{1-FR_D^{(1)}}\right)\left(\dfrac{FR_B^{(2)}}{1-FR_B^{(2)}}\right)\right]}{\ln\left(\alpha_{average}^{(12)}\right)} = \frac{\ln(95/5)(95/5)}{\ln(1/0.21)} = 3.8$$

$$\alpha^{(12)} = \frac{k_1}{k_2} = \frac{1}{\frac{k_2}{k_1}} = \frac{1}{\alpha^{(21)}} = 1/0.21$$

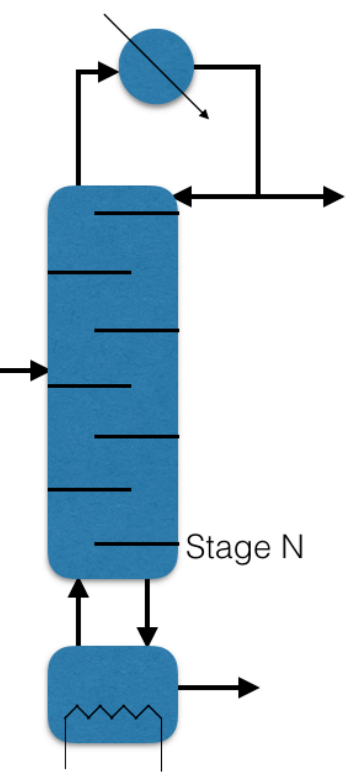
$$FR_D^{(3)} = \frac{\left(\alpha_{average}^{(32)}\right)^{N_{\min}}}{\left(\alpha_{average}^{(32)}\right)^{N_{\min}} + \left(\dfrac{FR_B^{(2)}}{1-FR_B^{(2)}}\right)}$$

$$\alpha^{(32)} = \frac{k_3}{k_2} = \frac{\frac{k_3}{k_1}}{\frac{k_2}{k_1}} = \frac{\alpha^{(31)}}{\alpha^{(21)}} = \frac{2.25}{0.21} = 10.71$$

$$= \frac{10.71^{3.8}}{10.71^{3.8} + 0.95/0.05} = 0.997$$

$$FR_B^{(3)} = 1 - FR_D^{(3)} = 0.003$$

			% in feed
3	Benzene	80.1 °C	40%
1	Toluene	110. 6 °C	30%
2	Cumene	152.4 °C	30%



$$FR_D^{(Toluene)} = 95\%$$

$$\alpha_{average}^{(Benzene-Toluene)} = 2.25$$

$$\alpha_{average}^{(Cumene-Toluene)} = 0.21$$

$$FR_B^{(Cumene)} = 95\%$$

Exercise Problem 2

A three component feed (100 mole/hr, saturated vapor, LNK 3%, LK 50%, HK 47%) is to be separated in a distillation column. Desired recovery for LK in distillate is 90%. Assume constant relative volatility.

$D = 50\ \text{mole/hr}$ $\qquad \alpha^{(LNK,HK)} = 10$ $\qquad \alpha^{(HK,LK)} = 0.4$

1. Calculate minimum number of stages by the Fenske method.
2. If R = 2 R_{min}, and R_{min} =2, calculate the number of stages by Gilliland method.

$$N_{\min} = \frac{\ln\left[\left(\frac{FR_D^{(1)}}{1-FR_D^{(1)}}\right)\left(\frac{FR_B^{(2)}}{1-FR_B^{(2)}}\right)\right]}{\ln\left(\alpha_{average}^{(12)}\right)}$$

$$FR_D = \frac{D * x_D}{Fz} \qquad \Rightarrow x_D^{(LK)} = 0.9 * 100 * 0.5/50 = 0.9 \qquad \Rightarrow B = 100 - 50 = 50\ \text{mole/hr}$$

$$1 - FR_D = \frac{B * x_B}{Fz} \qquad 0.1 = \frac{50 * x_B^{(LK)}}{100 * 0.5} \qquad \Rightarrow x_B^{(LK)} = 0.1 \qquad \Rightarrow x_B^{(HK)} = 0.9$$

$$\Rightarrow FR_B^{(HK)} = \frac{0.9 * 50}{100 * 0.47} = 95.7\,\%$$

$$\alpha^{(LK,HK)} = 1/\alpha^{(HK,LK)} = 2.5 \qquad N_{min} = \ln(0.9/0.1 * 0.957/0.043)/\ln(2.5) = 5.8$$

EPFL

R = 2 R_{min}, and R_{min} =2

$$\frac{R - R_{min}}{R+1} = \frac{4-2}{4+1} = 0.4$$

$N = 8.71$ implying 9 stages

$$\Rightarrow \frac{N - N_{min}}{N+1} = 0.3$$