1. Problem 22.1-2

From Appendix A.3

$$
\begin{aligned}
H_{\mathrm{CO_2}} &= 0.186 \cdot 10^4 \\
C_{\mathrm{CO_2}} &= 0.9 \cdot 10^{-4} \\
x_A &= \frac{C_A/M_A}{1/M_B + C_A/M_A} \\
M_{\mathrm{CO_2}} &= 44 \\
M_{\mathrm{Water}} &= 18 \\
P_{\mathrm{CO_2}} &= H_{\mathrm{CO_2}} x_{\mathrm{CO_2}} \\
P_{\mathrm{CO_2}} &= 0.186 \cdot 10^4 \cdot \frac{0.9 \cdot 10^{-4}/44}{1/18 + 0.9 \cdot 10^{-4}/44} \\
\boxed{P_{\mathrm{CO_2}} &= 0.0685 \text{ atm}}
\end{aligned}
$$

2. Problem 22.1-4

Diagram:

$$
\begin{aligned}
L'\frac{x_0}{1-x_0} + V'\frac{y_2}{1-y_2} &= L'\frac{x_1}{1-x_1} + V'\frac{y_1}{1-y_1} \\
x_0 &= 0 \\
y_0 = \frac{1.52 \cdot 10^4}{2.026 \cdot 10^5} &= 0.075 \\
L' &= 2.2 \\
V' &= (1-y_0)V \\
V' = (1-0.075) \cdot 5.7 &= 5.27
\end{aligned}
$$

From Figure 22.1-1:

$$
\begin{aligned}
H_{SO_2} &= 29.6 \\
P_A &= Hx_A \\
y_A &= \frac{H}{P}x_A \\
H' = \frac{29.6}{2.026 \cdot 10^5} \cdot 101325 &= 14.8 \\
5.27 \cdot \frac{0.075}{1-0.075} &= 2.2 \cdot \frac{x_1}{1-x_1} + 5.27\frac{14.8x_1}{1-14.8x_1} \\
0 &= 2.2 \cdot \frac{x_1}{1-x_1} + 5.27\frac{14.8x_1}{1-14.8x_1} - 5.27 \cdot \frac{0.075}{1-0.075}
\end{aligned}
$$

Solve for x_1

$$
\begin{aligned}
&\boxed{x_1 = 0.00495} \\
y_1 &= 14.8 \cdot 0.00495 \\
&\boxed{y_1 = 0.0733} \\
L_1 = \frac{L'}{1-x_1} &= \frac{2.2}{1-0.00495} \\
&\boxed{L_1 = 2.21 \text{ kg mol}} \\
V_1 = \frac{V'}{1-y_1} &= \frac{5.7}{1-0.0733} \\
&\boxed{V_1 = 5.69 \text{ kg mol}}
\end{aligned}
$$

3. Problem 22.5-1

Stage balances:

$$L'\frac{x_0}{1-x_0}+V'\frac{y_2}{1-y_2}=L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}$$
$$L'\frac{x_1}{1-x_1}+V'\frac{y_3}{1-y_3}=L'\frac{x_2}{1-x_2}+V'\frac{y_2}{1-y_2}$$
$$L'\frac{x_2}{1-x_2}+V'\frac{y_4}{1-y_4}=L'\frac{x_3}{1-x_3}+V'\frac{y_3}{1-y_3}$$
$$V'\frac{y_2}{1-y_2}=L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}$$
$$V'y_2=\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)-y_2\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)$$
$$V'y_2+y_2\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)=\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)$$
$$y_2=\frac{\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)}{V'+\left(L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}\right)}$$
$$y_2=\left(\frac{V'}{L'\frac{x_1}{1-x_1}+V'\frac{y_1}{1-y_1}-L'\frac{x_0}{1-x_0}}+1\right)^{-1}$$
$$y_3=\left(\frac{V'}{L'\frac{x_2}{1-x_2}+V'\frac{y_2}{1-y_2}-L'\frac{x_1}{1-x_1}}+1\right)^{-1}$$
$$y_4=\left(\frac{V'}{L'\frac{x_3}{1-x_3}+V'\frac{y_3}{1-y_3}-L'\frac{x_2}{1-x_2}}+1\right)^{-1}$$

Fit VLE data in Appendix A.3-19 to 4^{th} order polynomial

$$y_A(x_A)=Ax_A^4+Bx_A^3+Cx_A^2+Dx_A+E$$
$$A=2.99092125\cdot10^5$$
$$B=-2.26812714\cdot10^4$$
$$C=642.305650$$
$$D=26.9838344$$
$$E=-2.85407304\cdot10^{-3}$$
$$y_A(x_A)=2.99\cdot10^5x_A^4-2.27\cdot10^4x_A^3+642.31x_A^2+26.98x_A-2.85\cdot10^{-3}$$

Constants:

$$
\begin{aligned}
x_0 &= 0 \\
L' &= \frac{6000}{18} \\
L' &= 333.33 \\
V' &= \frac{150}{28.97} \\
V' &= 5.178 \\
y_4 &= 0.2
\end{aligned}
$$

Algorithm to solve for y_1:

(1) Guess y_1

(2) Solve for x_1 using:

$$y_1(x_1) = 2.99 \cdot 10^5 x_1^4 - 2.27 \cdot 10^4 x_1^3 + 642.31 x_1^2 + 26.98 x_1 - 2.85 \cdot 10^{-3}$$

(3) Solve for y_2 using:

$$y_2 = \left(\frac{V'}{L' \frac{x_1}{1-x_1} + V' \frac{y_1}{1-y_1} - L' \frac{x_0}{1-x_0}} + 1 \right)^{-1}$$

(4) Solve for x_2 using:

$$y_2(x_2) = 2.99 \cdot 10^5 x_2^4 - 2.27 \cdot 10^4 x_2^3 + 642.31 x_2^2 + 26.98 x_2 - 2.85 \cdot 10^{-3}$$

(5) Solve for y_3 using:

$$y_3 = \left(\frac{V'}{L' \frac{x_2}{1-x_2} + V' \frac{y_2}{1-y_2} - L' \frac{x_1}{1-x_1}} + 1 \right)^{-1}$$

(6) Solve for x_3 using:

$$y_3(x_3) = 2.99 \cdot 10^5 x_3^4 - 2.27 \cdot 10^4 x_3^3 + 642.31 x_3^2 + 26.98 x_3 - 2.85 \cdot 10^{-3}$$

(7) Solve for y_4 using:

$$y_4 = \left(\frac{V'}{L' \frac{x_3}{1-x_3} + V' \frac{y_3}{1-y_3} - L' \frac{x_2}{1-x_2}} + 1 \right)^{-1}$$

(8) Check that the y_4 calculated equals the y_4 specification from the problem. If they are not equal, return to step 1. Once they are equal, y_1 is solved for.

Using this algorithm, $\boxed{y_1 = 0.01127107}$.

4. Problem 22.5-4

Table of data from Appendix A.3-22, VLE data for Ammonia in water at 293 K

x_A	y_A
0.137	0.235
0.175	0.342

$$L'\frac{x_0}{1-x_0} + V'\frac{y_{N+1}}{1-y_{N+1}} = L'\frac{x_N}{1-x_N} + V'\frac{y_1}{1-y_1}$$

$$x_0 = 0.005$$

$$y_1 = 0.02$$

$$y_{N+1} = 0.25$$

$$x_N = \frac{0.175-0.137}{0.342-0.235}\cdot(0.25-0.235)+0.137$$

$$x_N = 0.142$$

$$L'_{min} = L'$$

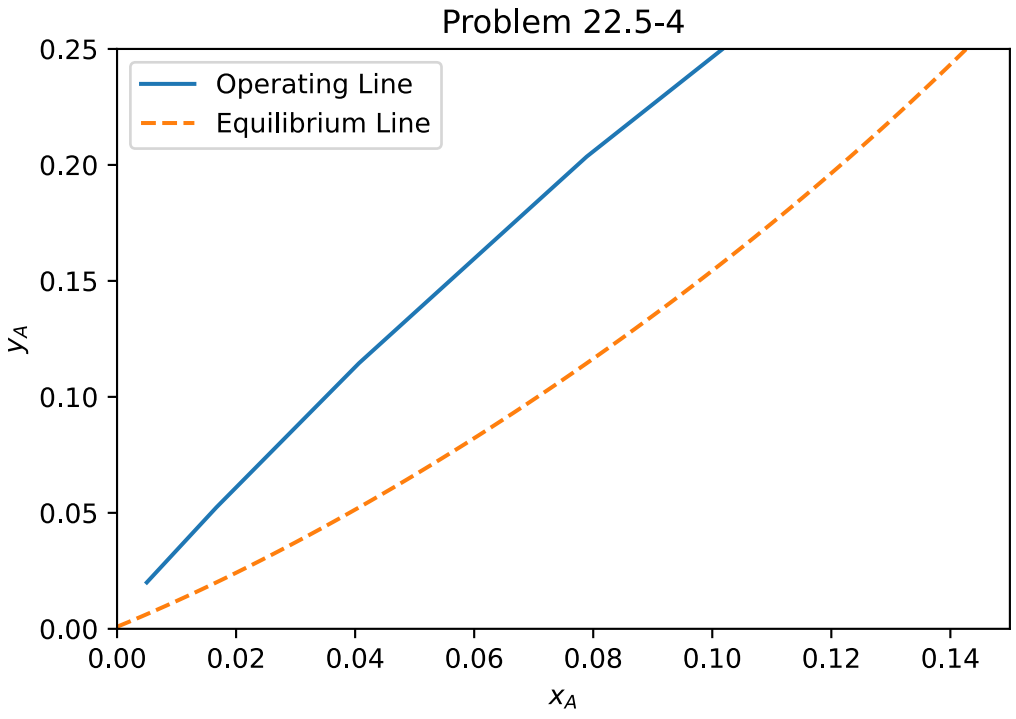
$$V' = 181.4\cdot(1-0.25)$$

$$L'_{min}\frac{0.005}{1-0.005} + 181.4\cdot(1-0.25)\cdot\frac{0.25}{1-0.25} = L'_{min}\frac{0.142}{1-0.142} + 181.4\cdot(1-0.25)\cdot\frac{0.02}{1-0.02}$$

Solve for L'_{min}

$$\boxed{L'_{min} = 264.56 \text{ kg mol/h}}$$

Plot:



5. Problem 22.5-5

$$\begin{aligned} x_0 &= 0.04 \\ y_{N+1} &= 0 \\ y &= 25x \\ x_N &= 0.002 \\ y &= 25 \cdot x \\ V &= 11.42 \\ L &= 300 \end{aligned}$$

Solve for y_1 from overall mass balance

$$\begin{aligned} L'\frac{x_0}{1-x_0} + V'\frac{y_{N+1}}{1-y_{N+1}} &= L'\frac{x_N}{1-x_N} + V'\frac{y_1}{1-y_1} \\ 300 \cdot (1-0.04) \cdot \frac{0.04}{1-0.04} + 11.42\frac{0}{1-0} &= 300 \cdot (1-0.04) \cdot \frac{0.002}{1-0.002} + 11.42\frac{y_1}{1-y_1} \\ y_1 &= 0.5 \end{aligned}$$

Finding number of stages

Calculate x_n from y_n starting at y_1

$$x_n = \frac{y_n}{25}$$

Then calculate y_{n+1} from

$$L'\frac{x_{n-1}}{1-x_{n-1}} + V'\frac{y_{n+1}}{1-y_{n+1}} = L'\frac{x_n}{1-x_n} + V'\frac{y_n}{1-y_n}$$

Repeat the above steps until x_n is less than the x_N specification, $x_N = 0.002$

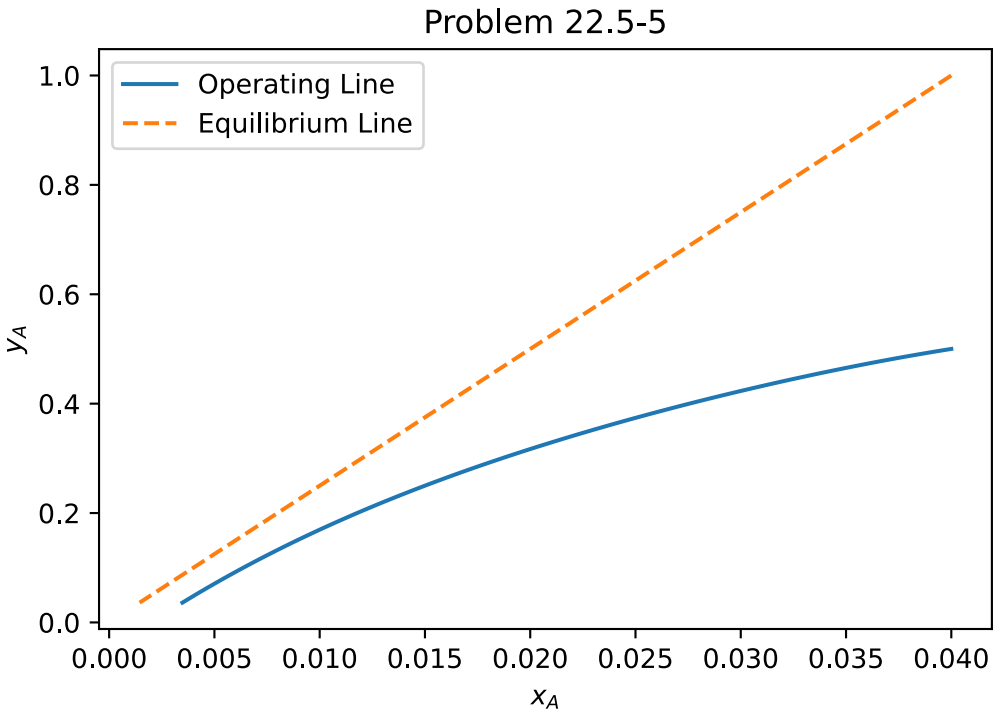
Find intermediate stage

$$\begin{aligned} N_i &= \frac{x_N - x_{n-1}}{x_n - x_{n-1}} \\ N_i &= \frac{0.002 - 0.003481}{0.001448 - 0.003481} = 0.728 \end{aligned}$$

Add N_i to the stage for x_{n-1}

$$\begin{aligned} N &= 5 + 0.728 \\ \boxed{N &= 5.728} \end{aligned}$$

Plot:


Problem 22.5-5
Operating Line
Equilibrium Line
1.0
0.8
0.6
0.4
0.2
0.0
y_A
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
x_A