1. Problem 27.2-1

   A is acetic acid.

   B is water.

   C is isopropyl ether.

   x is aqueous phase.

   y is organic phase.

Fit 4$^{\text{th}}$ order polynomials to equilibrium data in Appendix A.3-24. Then,

$$\begin{aligned}
x_B &= f_1(x_A) \\
x_C &= f_2(x_A) \\
y_A &= f_3(x_A) \\
y_B &= f_4(x_A) \\
y_C &= f_5(x_A)
\end{aligned}$$

The compositions in the two phases are related by functions of the composition of acetic acid in the aqueous phase.

Assume that the two outlets are in equilibrium. Write component mass balances.

$$\begin{aligned}
x_{A,0}L_0 &= x_{A,N}L_N + y_{A,1}V_1 \\
x_{B,0}L_0 &= x_{B,N}L_N + y_{B,1}V_1 \\
y_{C,N+1}V_{N+1} &= x_{C,N}L_N + y_{C,1}V_1 \\
x_{A,0} &= 0.35 \\
x_{B,0} &= 0.65 \\
y_{C,N+1} &= 1 \\
L_0 &= 400 \\
V_{N+1} &= 400
\end{aligned}$$

Put mass balances in terms of $x_{A,N}$, V_1, and L_N and solve.

$$\begin{aligned}
0.35 \cdot 400 &= x_{A,N}L_N + f_3(x_{A,N})V_1 \\
0.65 \cdot 400 &= f_1(x_{A,N})L_N + f_4(x_{A,N})V_1 \\
400 &= f_2(x_{A,N})L_N + f_5(x_{A,N})V_1
\end{aligned}$$

Solve the system of equations

$$\boxed{\begin{aligned} L_N &= 342.8 \text{ kg} \\ V_1 &= 457.2 \text{ kg} \\ x_{A,N} &= 0.254 \\ x_{B,N} &= 0.714 \\ x_{C,N} &= 0.032 \\ y_{A,1} &= 0.115 \\ y_{B,1} &= 0.033 \\ y_{C,1} &= 0.845 \end{aligned}}$$

Percent removed

$$\eta = \frac{x_{A,0}L_0 - x_{A,N}L_N}{x_{A,0}L_0}$$

$$\eta = \frac{140 - 87}{140}$$

$$\boxed{\eta = 37.8\%}$$

2. Problem 27.4-2

   Naming convetions are the same as the solution to Problem 2 (27.2-1).

   Fit 4$^{\text{th}}$ order polynomials to equilibrium data in Appendix A.3-24. Then,

$$\begin{aligned} x_B &= f_1(x_A) \\ x_C &= f_2(x_A) \\ y_B &= f_3(y_A) \\ y_C &= f_4(y_A) \end{aligned}$$

   The outlet streams leave at equilibrium.

$$\begin{aligned} x_{A,0}L_0 &= x_{A,N}L_N + y_{A,1}V_1 \\ x_{B,0}L_0 &= x_{B,N}L_N + y_{B,1}V_1 \\ L_0 + V_{N+1} &= L_N + V_1 \\ x_{A,0} &= 0.25 \\ x_{B,0} &= 0.75 \\ x_{A,N} &= 0.03 \\ y_{C,N+1} &= 1 \\ L_0 &= 200 \\ V_{N+1} &= 600 \end{aligned}$$

   Rearrange mass balances in terms of L_N, V_1, and $y_{A,1}$

$$\begin{aligned} 0.25 \cdot 200 &= 0.03L_N + y_{A,1}V_1 \\ 0.75 \cdot 200 &= f_1(0.03)L_N + f_3(y_{A,1})V_1 \\ 200 + 600 &= L_N + V_1 \end{aligned}$$

   Solve the system of equations

$$\boxed{\begin{aligned} L_N &= 130.3 \text{ kg/h} \\ V_1 &= 669.7 \text{ kg/h} \\ x_{B,N} &= 0.957 \\ x_{C,N} &= 0.013 \\ y_{A,1} &= 0.354 \\ y_{B,1} &= 0.194 \\ y_{C,1} &= 0.504 \end{aligned}}$$

3. 27.4-9

   A - nicotine

   B - kerosene

   C - water

   Assume dilute and that kerosene and water are perfectly imiscible.

$$
\begin{aligned}
V_{N+1} &= 100 \\
y_{A,N+1} &= 0.014 \\
y_{B,N+1} &= 0.986 \\
V' &= V_{N+1}\left(1 - y_{B,N+1}\right) = 100 \cdot (1 - 0.986) \\
V' &= 98.6
\end{aligned}
$$

   90% removal of nicotine

$$
\begin{aligned}
x_{A,N} L_N &= 0.9 \cdot 1.4 \\
y_{A,1} V_1 &= 0.1 \cdot 1.4 \\
y_{B,1} V_1 &= 98.6
\end{aligned}
$$

   Solve V_1 mass balance

$$
y_{A,1} = 0.00142
$$

   Organic inlet and aqueous outlet are in equilibrium.

   From equilibrium data in Example 27.4-3, at $y_{A,N+1} = 0.014$

$$
x_{A,N} = 0.015
$$

   Mass balance for $L'_{\min}$

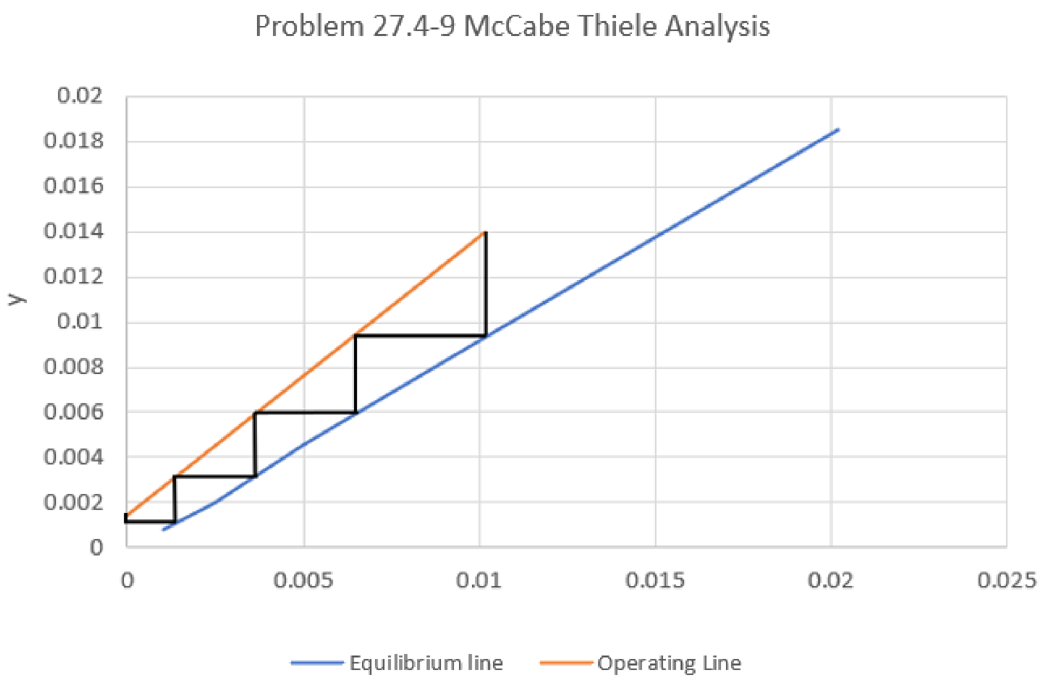
$$
\begin{aligned}
L'_{\min}\frac{x_0}{1 - x_0} + V'\frac{y_{N+1}}{1 - y_{N+1}} &= L'_{\min}\frac{x_N}{1 - x_N} + V'\frac{y_1}{1 - y_1} \\
L'_{\min}\frac{0}{1 - 0} + 98.6 \cdot \frac{0.014}{1 - 0.014} &= L'_{\min}\frac{0.015}{1 - 0.015} + 98.6 \cdot \frac{0.00148}{1 - 0.00148} \\
L'_{\min} &= 81.8 \text{ kg/h} \\
L' &= 1.5 L'_{\min} \\
L' &= 122.7 \text{ kg/h}
\end{aligned}
$$

   From mass balance at L'

$$
\begin{aligned}
x_0 &= 0 \\
y_{N+1} &= 0.014 \\
x_N &= 0.0102 \\
y_1 &= 0.00142
\end{aligned}
$$

   Assume dilute and a straight operating line.

   Plot operating and equilibrium line at step off stages.



Last stage does not fully reach operating line. $\boxed{N \approx 3.8}$

4. Problem 31.2-2

$$
\begin{aligned}
B_0 &= 75 \\
A_0 &= 2.5 \\
C_0 &= 22.5 \\
N_N &= 1.5 \\
N_N &= \frac{B_N}{M_{A+C,N}} \\
1.5 &= \frac{75}{M_{A+C,N}} \\
M_{A+C,N} &= 50 \\
L_N &= B_N + M_{A+C,N} \\
&\boxed{L_N = 125 \text{ kg}}
\end{aligned}
$$

By overall balance:

$$
\begin{aligned}
&\boxed{V_1 = 75 \text{ kg}} \\
M_{A+C,M} &= 25 + 100 = 125 \\
y_{A,1} &= \frac{2.5}{125} \\
&\boxed{y_{A,1} = 0.02} \\
y_{C,1} &= 1 - 0.02 \\
&\boxed{y_{C,1} = 0.98} \\
x_{A,N} &= \frac{50 \cdot 0.02}{125} \\
&\boxed{x_{A,N} = 0.008} \\
x_{C,N} &= 1 - 0.008 - \frac{75}{125} \\
&\boxed{x_{C,N} = 0.392}
\end{aligned}
$$

5. Problem 31.3-1

$$B = 2000$$
$$N_N = 1.85$$

Constant overflow

$$L_N = \frac{B}{N_N}$$
$$L_N = \frac{2000}{1.85} = 1081$$
$$A_N = 120$$
$$C_N = L_N - A_N$$
$$C_N = 1081 - 120 = 961$$

Liquid phase of slurry outlet

$$y_{A,N} = \frac{120}{1081}$$
$$\boxed{y_{A,N} = 0.111}$$

Mass balance on A

$$A_0 + A_{N+1} = A_N + A_1$$
$$800 + 20 = 120 + A_1$$
$$A_1 = 700$$

Mass balance on C

$$C_0 + C_{N+1} = C_N + C_1$$
$$50 + 1310 = 961 + C_1$$
$$C_1 = 398$$

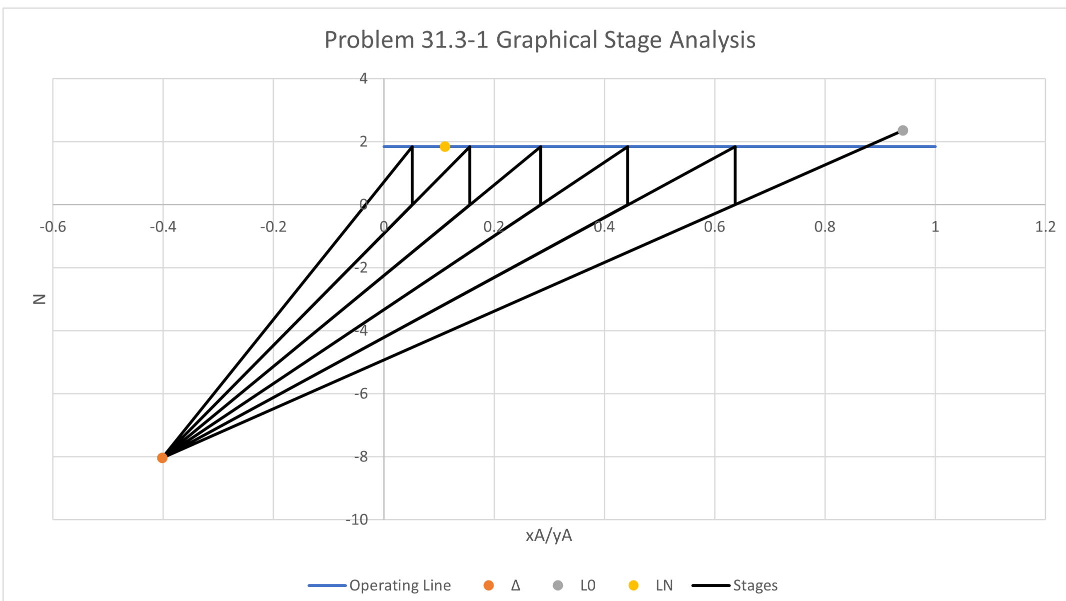
Solvent outlet

$$x_{A,1} = \frac{A_1}{A_1 + C_1}$$
$$x_{A,1} = \frac{700}{700 + 398}$$
$$\boxed{x_{A,1} = 0.637}$$

Stage analysis:

$$x_{A\Delta} = \frac{L_0 y_{A,0} - V_1 x_{A,1}}{L_0 - V_1}$$
$$x_{A\Delta} = \frac{850 \cdot 0.941 - 1098 \cdot 0.637}{850 - 1098}$$
$$x_{A\Delta} = -0.401$$
$$N_\Delta = \frac{B}{L_0 - V_1}$$
$$N_\Delta = \frac{2000}{850 - 1098}$$
$$N_\Delta = -8.03$$

The operating line is constant at $N = 1.85$. Plot operating line, start and end points, and Δ point and step off stages graphically.



Start point falls between stage 4 and 5. $\boxed{N \approx 4.4}$