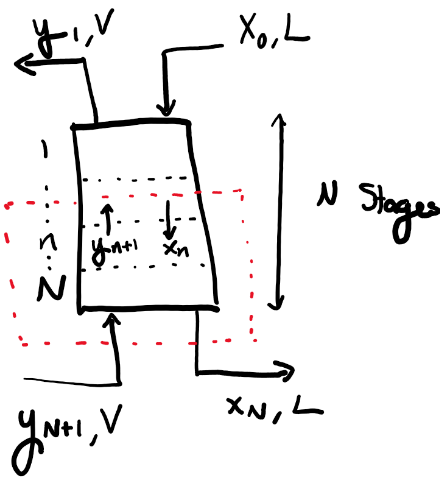
1)

a.



$$x_0 = 0$$
$$x_N = 0.05$$
$$y_{N+1} = 0.20$$
$$y_e = 1.90x_e$$
$$x_N L_N = 0.95 y_{N+1} V_{N+1}$$

Solve:

The material balances around the entire column are,

$$L_0 + V_{N+1} = L_N + V_1,$$

$$x_0 L_0 + y_{N+1} V_{N+1} = x_N L_N + y_1 V_1.$$

Rearranging,

$$V_1 = L_0 + V_{N+1} - L_N,$$
$$y_1 = \frac{x_0 L_0 + y_{N+1} V_{N+1} - x_N L_N}{V_1}.$$
$$\implies y_1 = \frac{x_0 L_0 + y_{N+1} V_{N+1} - x_N L_N}{L_0 + V_{N+1} - L_N}.$$

We have the condition that the oil flow rate is constant, i.e.,

$$(1 - x_0) L_0 = (1 - x_N) L_N,$$

or,

$$L_0 = \frac{1 - x_N}{1 - x_0} L_N.$$

Therefore,

$$y_1 = \frac{y_{N+1} V_{N+1} + \left(\frac{1 - x_N}{1 - x_0} x_0 - x_N \right) L_N}{V_{N+1} + \left(\frac{1 - x_N}{1 - x_0} - 1 \right) L_N},$$

or,

$$y_1 = \frac{y_{N+1} + \left(\frac{1-x_N}{1-x_0}x_0 - x_N\right)\frac{L_N}{V_{N+1}}}{1 + \left(\frac{1-x_N}{1-x_0} - 1\right)\frac{L_N}{V_{N+1}}}.$$

In this example, $x_0 = 0$, thus,

$$y_1 = \frac{y_{N+1} - \frac{x_N L_N}{V_{N+1}}}{1 - \frac{x_N L_N}{V_{N+1}}}.$$

$x_N L_N / V_{N+1}$ may be solved for,

$$\frac{x_N L_N}{V_{N+1}} = 0.95 y_{N+1} = (0.95)(0.20) = 0.19,$$

giving,

$$y_1 = \frac{0.20 - 0.19}{1 - 0.19} = 0.0123.$$

The operating line may now be plotted since $(x_0, y_1) = (0, 0.0123)$ and $(x_N, y_{N+1}) = (0.05, 0.20)$ are known.

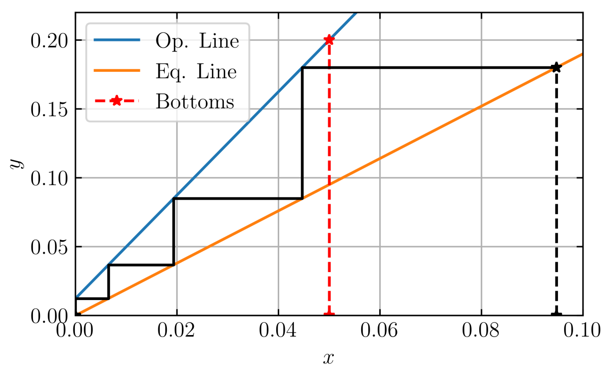


Figure 1: Acetone-Oil Absorption

Thus, at least $\boxed{N = 4}$ stages are required.

b.

Since the acetone output concentration must remain the same, the intercept of the operating line must remain the same while the slope, L_N/V_{N+1}, will change. If the operating line intersects the outlet exactly, we must have,

$$y_{N+1} = 1.90 x_N.$$

Rearranging the material balance,

$$y_1\left(1-\frac{x_N L_N}{V_{N+1}}\right)=y_{N+1}-\frac{x_N L_N}{V_{N+1}},$$

$$\frac{L_N}{V_{N+1}}=\frac{y_{N+1}-y_1}{x_N\left(1-y_1\right)}.$$

Imposing the intersection condition,

$$\frac{L_N}{V_{N+1}}=\frac{Kx_N-y_1}{x_N\left(1-y_1\right)}=\frac{(1.90)(0.05)-0.0123}{(0.05)(1-0.0123)}=1.67.$$

Alternatively, the slope of the minimum operating line can be calculated as $L_N/V_{N+1}=1.65$.

$$\begin{aligned}L_0&=(1-x_N)L_N\\&=(1-x_N)1.67V_{N+1}\\&=(0.95)(1.67)(100\text{ mol/hr})=159\text{ mol/hr}.\end{aligned}$$

Therefore,

$$\boxed{L_{min}=159\text{ mol/hr}}.$$

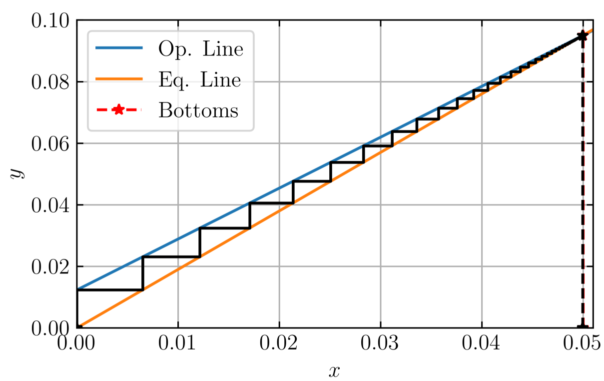


Figure 2: Acetone-Oil Absorption with Minimum Oil