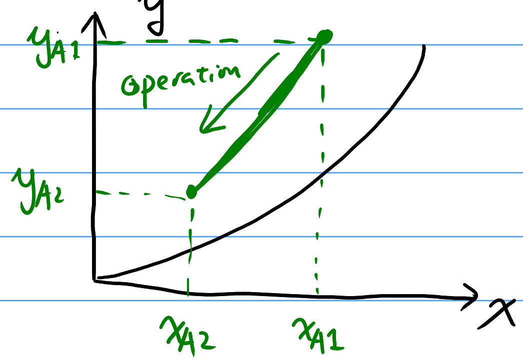
CHE 318 L23

Interphase Mass Transport

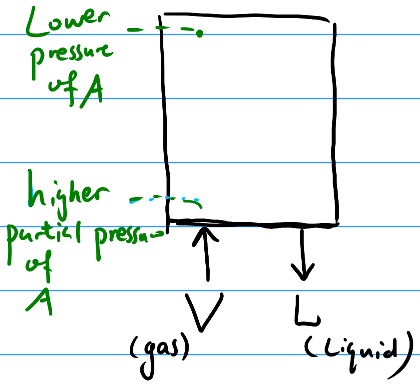
What can equilibrium diagram tell us?



Real industrial absorption tower

Gas inlet (x_{A1}, y_{A1})

outlet (x_{A2}, y_{A2})



— Absorption tower ⇒ operation line above eq. curve

— Stripping / extraction ⇒ below eq curve

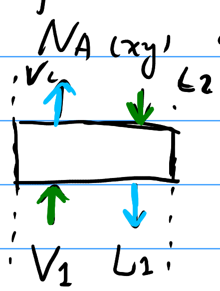
Q1: Can we know how in & outlet (x, y) are?

Q2: If Q1 solved, can we know $x(z)$ & $y(z)$?

Let's first study "why" is there an operation line

① Mass balance eq.

If control volume has 2 phases, we don't need N_A (xy) at all



L, V: molar flow rate kg mol/s

(A species + carrier gas/liq)

$$\text{In}|_{liq} + \text{In}|_{gas} = \text{Out}|_{liq} + \text{Out}|_{gas}$$

$$L_2 x_2 + V_1 y_1 = L_1 x_1 + V_2 y_2$$

The above eq uses the fact

[Total molar flow rate] × [molar frac] = [A molar flow rate]

$L = L' + Lx$ $\quad$ L' is usually constant (same as V')

$\uparrow$ Carrier flow $\quad$ $\uparrow$ A flow rate at x

Some relations $\quad x_1 = \dfrac{Lx_1}{L' + Lx_1} \qquad Lx_1 = \left(\dfrac{x_1}{1-x_1}\right) \underline{\underline{L_1}}$

Constant

$$L_1 = \left(\frac{1}{1-x_1}\right) L'$$

(resembles diffusion through stagnant B $\quad N_A \propto \dfrac{N_{A,EMCD}}{1-x}$)

Final mass balance eq depends on

$\begin{cases} (x, y) \Rightarrow \text{operation line} \\ L', V' \Rightarrow \text{constant flow} \end{cases}$

$$\boxed{L'\left(\frac{X_2}{1-X_2}\right) + V'\left(\frac{y_1}{1-y_1}\right) = L'\left(\frac{x_1}{1-x_1}\right) + V'\left(\frac{y_2}{1-y_2}\right)}$$

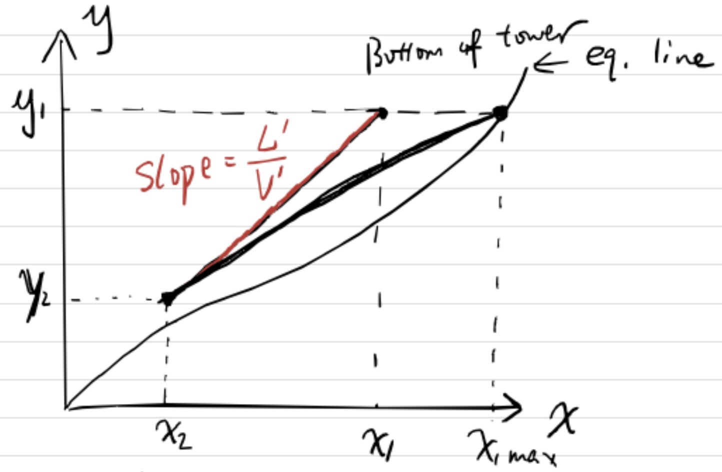
→ Gives the line (x, y) should sit at!

Some simplification $\quad 1 - x \simeq 1 \quad 1 - y \simeq 1$ (dilute)

$$L' x(z) + V' y_1 = L' x_1 + V' y(z)$$

$$y = \left(\frac{L'}{V'}\right) x + \left[y_1 - \left(\frac{L'}{V'}\right) x_1\right]$$

What does this mean?



Slope = $\frac{L'}{V'}$, if V' is fixed decreasing L' ⇒ flatter slope

$$\boxed{y = \left(\frac{L'}{V'}\right)x + \text{Const}}$$

Industrial problem:

usually know { gas inlet y_{A1}
{ desired gas outlet y_{A2}
{ Liquid inlet x_{A2}

fixed

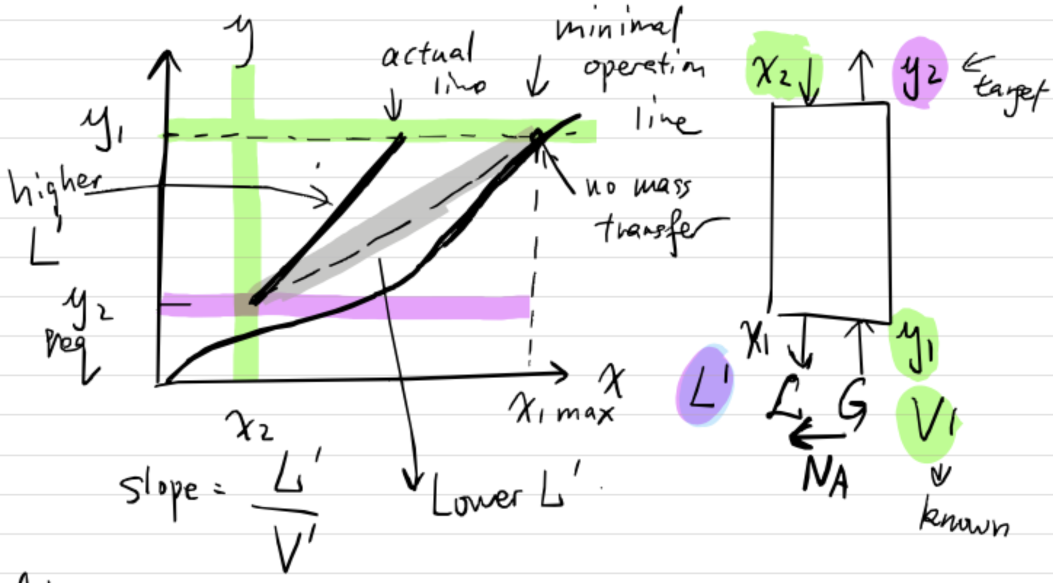
Find { x_{A1} ?
{ L' ?

Usually the task for design is

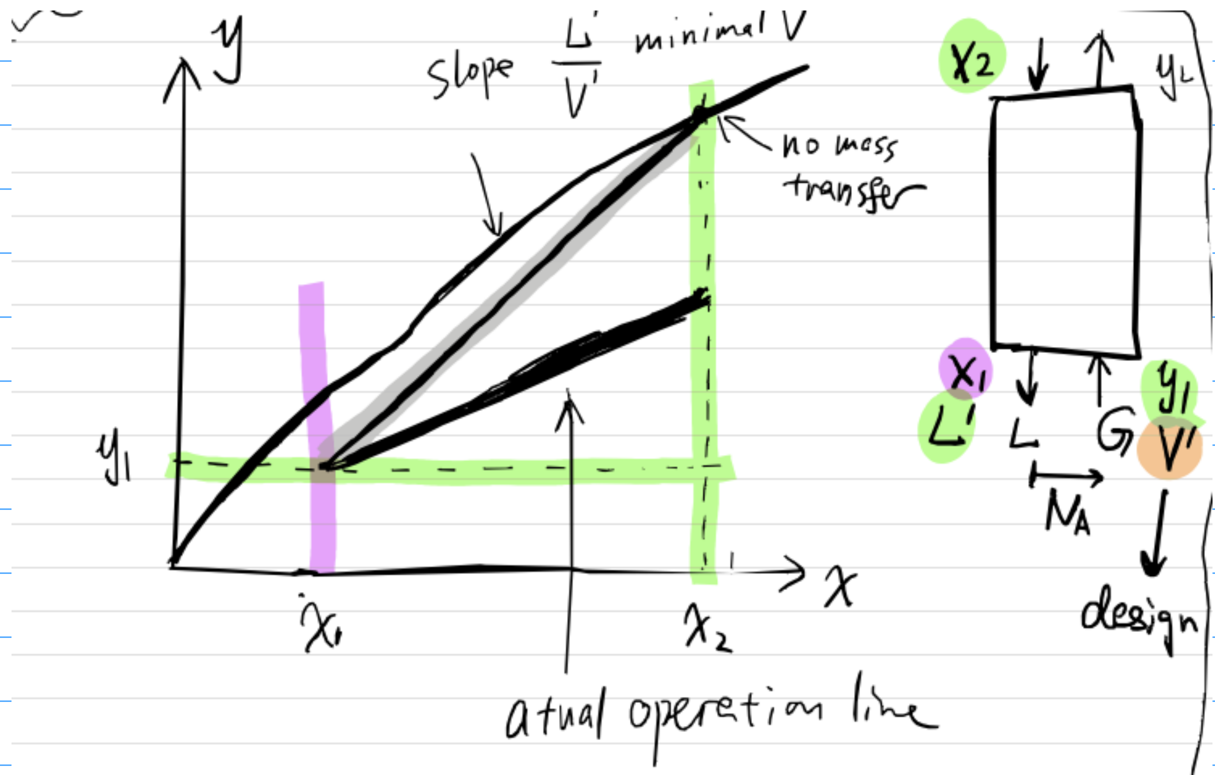
1) know y_{A1}, desired y_{A2}, x_{A2}, find the minimal Liquid rate L'

2) know y_{A1}, x_{A2}, & L', Solve y_{A2} (is y_{A2} lower than some threshold?)

Two Scenarios



Absorption tower

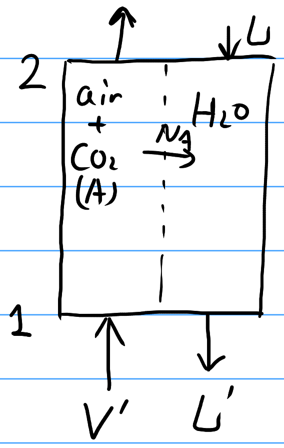


Stripping tower

Example Question

Henry's law $y_A = m x_A$

$m \uparrow$ less soluble in liquid



$V_1 = 100$ kgmol/h $\quad y_{A1} = 0.20$

$L' = 300$ kgmol/h water

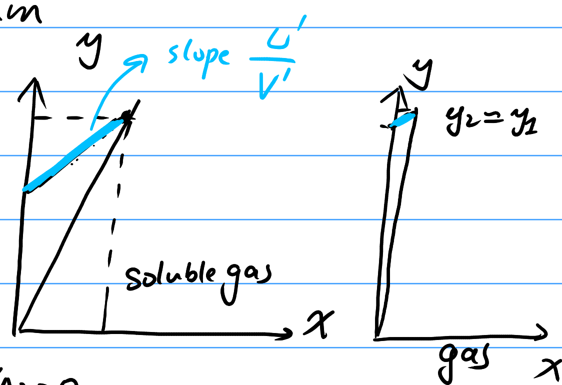
$V' = V_1 \cdot (1 - y_{A1}) = 80$ kgmol/L

For CO_2

$$L'\left(\frac{x_1}{1-x_1}\right) + V'\left(\frac{y_2}{1-y_2}\right) = \underset{300}{L'}\left(\frac{\overset{=0}{x_2}}{1-\underset{=0}{x_2}}\right) + \underset{80}{V'}\left(\frac{\overset{=0.20}{y_1}}{1-\underset{=0.20}{y_1}}\right)$$

If the outlet is at equilibrium

Eq: $y_A = 0.142 \times 10^4 x_A (CO_2)$



If (x_{A1}, y_{A1}) at equilibrium

$x_{A1} = 1.41 \times 10^{-4}$

Solving $\Rightarrow$ $y_{A2} = 0.20$ (no change) $x_{A2} = 0$

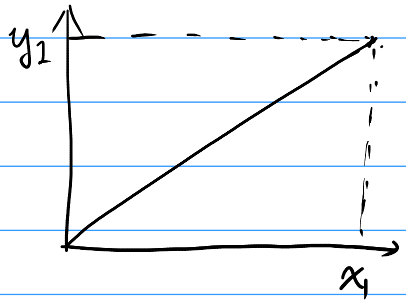
Now change to more soluble gas $\quad y_A = 10\, x_A$

$$\underset{300}{L'}\left(\frac{0.02}{1-0.02}\right) + \underset{80}{V'} \cdot \left(\frac{y_2}{1-y_2}\right) = \underset{300}{L'}\left(\frac{0}{1-0}\right) + \underset{80}{V'}\left(\frac{0.20}{1-0.20}\right)$$

$$\frac{y_2}{1-y_2} = 0.1735 \quad y_2 = 0.1478$$

Previous example has point 1 at equibrium

$\Rightarrow$ mininum Liquid flow

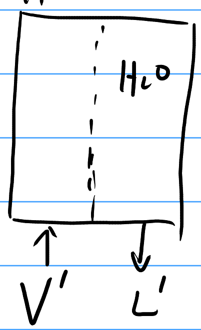


operation line slope

$$= \frac{L'}{V'}$$ we can know minimal L'

Example 2.

$A = C_2H_5OH$



$V_1 = 100$ kg mol/h $\quad y_1 = 2.2\%$

Desired recovery $\Rightarrow$ 90% $\Rightarrow V_2 = V_1 \cdot 0.10$

$y = 0.68x$

1) solve minimal flow rate L'
2) operation $L' = 1.5\, L'_{min}$

$$V' = V_1 \cdot (1 - y_1) = 100 \cdot (1 - 0.022) = 97.8 \text{ kg mol/h}$$

$$Vy_1 = 2.20 \text{ kg mol/h} \Rightarrow Vy_2 = 0.220 \text{ kg mol/h}$$

$$= V' \cdot \left(\frac{y_2}{1-y_2}\right)$$

$y_2 = 0.002244$

$$L'\left(\frac{x_2}{1-x_2}\right) + \overset{97.8}{V'}\left(\frac{\overset{0.022}{y_1}}{1-y_1}\right) = L'\left(\frac{x_1}{1-x_1}\right) + \overset{97.8}{V'}\left(\frac{\overset{0.002244}{y_2}}{1-y_2}\right)$$

$$x_1 = \frac{y_1}{0.68} = 0.03235$$

At this Condition $x_2 = 0$

Solve $L' = 59.24$ kg mol/h