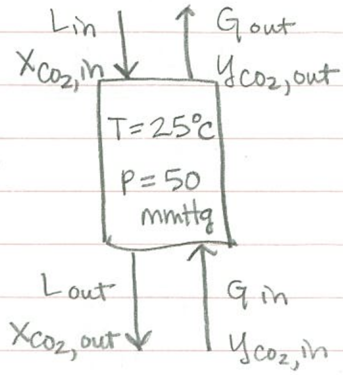
D16 Chapter 12

Countercurrent Stripping Column

- dissolved CO_2 in a liquid
  water feed (L) @ 25°C, 1atm
  ↳ in EQ with CO_2 @ 1atm (0.035 vol% CO_2)
- stripping gas (G) is N_2 gas
  saturated with pure water @ 25°C



Assume:
(i) N_2 insoluble in H_2O
(ii) Ideal gas (vol% = mol%)
Data found in Table 12-1

Goal: Remove 95% of initial CO_2 in water feed.

a) Calculate inlet & outlet mol fracs of CO_2 in water.

① Since the water feed is in equilibrium with air (which contains 0.035 vol% CO_2) at P_{total} = 1 atm, we can find $x_{CO_2,in}$ using:

$$x_{CO_2} = \frac{P_{tot}}{H'_{CO_2}} y_{CO_2}$$ Henry's Law: eqn. 12-3

where $y_{CO_2} = 0.00035$ ← change % to a fraction!
$P_{tot} = 1$ atm
$H_{CO_2} = 1640$ atm (from Table 12-1 @ 25°C)

$$\Rightarrow x_{CO_2,in} = \frac{1}{1640}(0.00035) \Rightarrow \boxed{x_{CO_2,in} = 2.14 \times 10^{-7}}$$

* use scientific notation!

② We designated that we desire 95% of the CO_2 in the feed to be removed in the N_2 gas, leaving 5% of CO_2 to exit in the liquid water phase.

$$x_{CO_2,out} = x_{CO_2,in}(1-0.95) = 2.14\times10^{-7}(0.05) \Rightarrow \boxed{x_{CO_2,out} = 1.07 \times 10^{-8}}$$

NOTE: $x_{CO_2,out}$ is small enough to meet the stripping requirement

b) Determine $\left(\frac{L}{G}\right)_{max}$. If $L = 1\ \frac{kgmol}{h}$, find G_{min} (corresponds to $(L/G)_{max}$)

③

$$\left(\frac{L}{G}\right)_{max} = \frac{y_{CO_2,max} - y_{CO_2,in}}{x_{CO_2,in} - x_{CO_2,out}}$$

④ Solve for $y_{CO_2,max}$ using Henry's Law : eqn. 12-3

$$y_{CO_2,max} = \frac{H_{CO_2}}{P_{tot}} x_{CO_2,in}$$

$H_{CO_2} = 1640$ atm from step ①

$P_{tot} = P_{column} = 50\ mmHg\left(\frac{1}{760}\right) = 0.0661\ atm$

$$y_{CO_2,max} = \frac{1640\ atm}{0.066\ atm}(2.14 \times 10^{-7}) \Rightarrow y_{CO_2,max} = 5.32 \times 10^{-3}$$

⑤ Solve for $\left(\frac{L}{G}\right)_{max}$ using eqn. in step ③

$$\left(\frac{L}{G}\right)_{max} = \frac{5.32 \times 10^{-3} - 0}{2.14 \times 10^{-7} - 1.07 \times 10^{-8}} \Rightarrow \boxed{\left(\frac{L}{G}\right)_{max} = 2.62 \times 10^{4}}$$

⑥ Find G_{min} using $\left(\frac{L}{G}\right)_{max}$ & $L = 1$ kgmol/h.

$$G_{min} = L\left(\frac{L}{G}\right)^{-1}_{max} = \frac{1\ \frac{kgmol}{hr.}}{2.62 \times 10^{4}} \Rightarrow \boxed{G_{min} = 3.82 \times 10^{-5}\ kgmol/h.}$$

→ see plot below for Part b.

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c) Find $y_{CO_2,out}$ & N = # stages needed, if $G = 1.5G_{min}$

⑦ Calculate slope $\left(\frac{L}{G}\right)_{max}$ based on new value for G:

$$\left(\frac{L}{G}\right)_{max,new} = \frac{L}{1.5G_{min}} = \left(\frac{L}{G}\right)_{max,old} \cdot \frac{1}{1.5} = \frac{2.62\times10^4}{1.5}$$

$$\Rightarrow \left(\frac{L}{G}\right)_{max} = 17470$$

⑧ Determine $y_{CO_2,out}$ using the stripping column operating line equation:

$$y_{CO_2,out} = \frac{L}{G}x_{CO_2,in} + \left[y_{CO_2,in} - \frac{L}{G}x_{CO_2,out}\right] \qquad \text{eqn. 12-40}$$

⑨ Since $y_{CO_2,in} = 0$, eqn. 12-40 can be simplified:

$$y_{CO_2,out} = \frac{L}{G}\left(x_{CO_2 in} - x_{CO_2 out}\right)$$

$$\Rightarrow \quad = 17470\left(2.14\times10^{-7} - 1.07\times10^{-8}\right)$$

$$\boxed{y_{CO_2,out} = 3.55\times10^{-3}}$$

sanity check: $y_{CO_2,out}$ should be less than theoretical $y_{CO_2,max}$ ✓

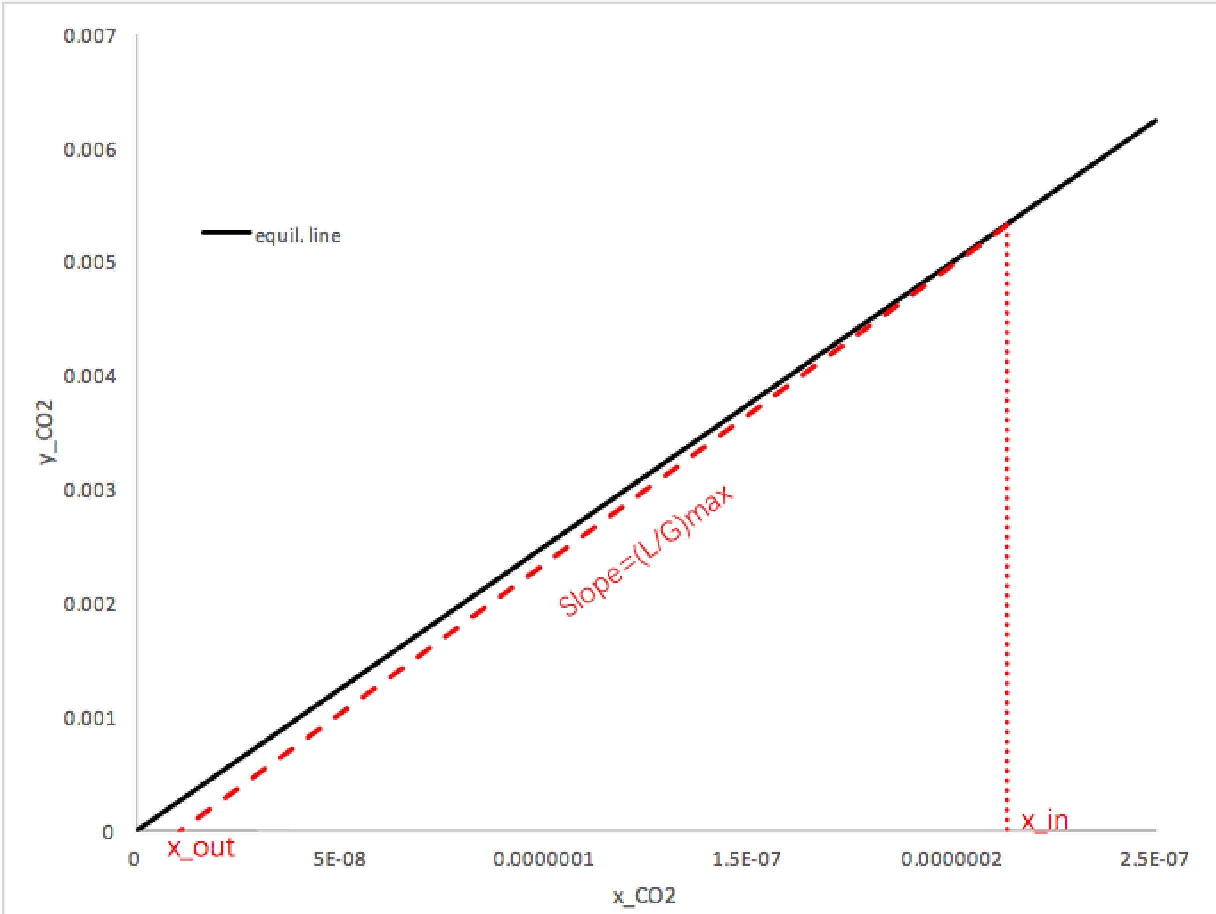
McCabe-Thiele Method:

⑩ Plot both the equilibrium line (based on Henry's Law, eqn. 12-3) and the operating line (eqn. 12-40)
Stair step from $x_{CO_2,in}$ along OL. → see plot below for Part c.

Kremser Method: this method is allowed since OL & EL are linear
Use eqn. 12-29 to solve for N

either method: $\boxed{N = 6 \text{ stages}}$

Part b)



0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
y_CO2
equil. line
Slope=(L/G)max
x_out
x_in
0
5E-08
0.0000001
1.5E-07
0.0000002
2.5E-07
x_CO2

Part c) McCabe-Thiele Method