Separation 1 Summary

2022 / 2023

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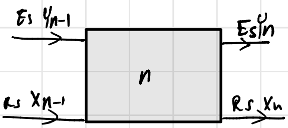
Midterm summary

Chapter 3 "Material Balances"

1) Co-current separation

operating Line:-



$$y_n = -\frac{R_s}{E_s} X_n + \frac{R_s X_{n-1} + E_s\ y_{n-1}}{E_s}$$

$$\boxed{\%\ \text{recovery} = \frac{X_{n-1} - X_n}{X_{n-1}}}$$

2) Counter current

operating line:-

$$y_n = \frac{R_s}{E_s} X_{n-1} + \frac{E_s\ y_{n-1} - R_s X_{n-2}}{E_s}$$

$$X_n = \frac{X_0}{\sum_{i=0}^{n} E^i}$$

$E \Rightarrow \frac{E_s}{R_s} \cdot KD$ → Same for All Stages.

$$\boxed{\%\ R = \frac{y_0 - X_n}{X_0}}$$

↓ for $E < 1$

$$\boxed{X_\infty = y_0(1 - E)}$$

valid for All E ✓

3) Cross flow:-

must dedict split factor

↳ then material Balance As you know.

⟹ if the streams are not splitted equally

E is different

but if they are + fresh solvent

$$X_N = \frac{X_{n-1} + \left(\frac{E_s}{R_s \cdot N}\ y_0\right)^{\text{zero if fresh}}}{\left(1 + \frac{E}{N}\right)^N}$$

example
$$X_2 = \frac{X_1 + \left(\frac{E_s}{R_s \cdot 2} \cdot y_0\right)}{\left(1 + \frac{E}{2}\right)^2}$$

at $n = \infty$

$$X_\infty = \frac{X_0}{e^E}$$ ← assume one stage!!

$$\%\ R \Rightarrow \frac{y_0 - X_n}{X_0} = \frac{(1+E)^N - 1}{(1+E)^N}$$

Also ⟹ in general case the splitted stream (E_s) substitute before splitting

Estimation number of stages required.

Special case ⇒ Both equilibrium and operating curves are straight line

Absorption

- if $R \to E$ i.e ⇒ O.L under the equilibrium line

(Extraction factor) $A = \frac{R_s}{E_s m}$ $m = \frac{y_{n+1}}{x_{n+1}}$ → slope of equilibrium line.

- if $E \to R$

(stripping factor) $\delta = \frac{1}{A}$ ← stripping process

⇒ from curve ⇒ knowing the others.

$$x_1 = (1 - K_2)/(K_1 - K_2)$$
$$x_2 = 1 - x_1$$
$$y_1 = (K_1 K_2 - K_1)/(K_2 - K_1)$$
$$y_2 = 1 - y_1$$
$$\Psi = \frac{V}{F} = \frac{z_1[(K_1 - K_2)/(1 - K_2)] - 1}{K_1 - 1}$$

$$X_1 = \frac{(1 - K_2)}{K_1 - K_2}$$

$$y_1 = \frac{(K_1 K_2 - K_1)}{K_2 - K_1}$$

$$\psi = \frac{z_1 \frac{(K_1 - K_2)}{1 - K_2} - 1}{K_1 - 1}$$

=> Review phase equilibrium

Chapter ②

y_A = mole fraction $= \frac{n_A}{n_T} = \frac{P_A}{P_T}$

Raoult's Law => vapor Liquid

$P_A = P_A^S \cdot x_A$ $\qquad$ $P_B = P_B^S \cdot (1-x_A)$

$P_T = P_A + P_B$

$\boxed{\gamma_A \Rightarrow \frac{y_A \cdot P_T}{x_A \cdot P_A^S}}$

$y_A = \frac{P_A}{P_T} \cdot x_A$

$P_A^S, P_B^S \Rightarrow$ Antoine eq.

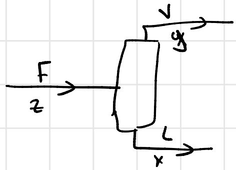
$x_A = \frac{P_T - P_B^S}{P_A^S - P_B^S}$

$H_L \Rightarrow [(C_L + \Delta T + M.W) + \Delta H_s]$

$H_V = y_A [C_{LA} \cdot \Delta T + M.W_A + \Delta H_{vapA} \cdot M.W_A] + (1-y_A)[C_{LB} \Delta T \cdot M.W_B + \Delta H_{vap} M.W_B]$

Flash distillation:- Chapter ⑤

① Binary mixtures "graphical methods"



$y = f(x_i)$

Material Balance:-

$F = V + L$

Component Balance (operating line)

$zF = yV + xL$

$\hookrightarrow y = -\frac{L}{V}x + \frac{zF}{V}$ $\quad \boxed{\psi = \frac{V}{L}}$

$$\boxed{y = \frac{(1-\psi)}{\psi}x + \frac{zF}{\psi}}$$

enthalpy + Material Balance:-

$F = V + L$

$H_F F + Q = H_V V + H_L L$

$$\boxed{-\frac{L}{V} = \frac{(H_L + (H_F + \frac{Q}{F}))}{(H_V + (H_F + Q_F))} = \frac{y-z}{x-z}}$$

$L \Rightarrow x \Rightarrow H_L$
$V \Rightarrow y \Rightarrow H_V$
$F \Rightarrow z \Rightarrow H_F + \frac{Q}{F}$

② flash calculations =>

A) Isothermal

given => $F, \vec{z}_F, P_F, T_F$

required => $L, V, \vec{z}, \vec{x}, \vec{y}, T_V, T_L, P_V, P_L, Q$

1) $P_V = P_L$

$T_V = T_L$

$1 - \sum z_i = 1$

2) finding ψ by

Case 1

either $\sum y_i = 1$ or $\sum x_i = 1$

by assume ψ by assume ψ

and $y_i = \frac{z_i K_i}{1 + \psi(K_i - 1)}$ $\quad x_i = \frac{z_i}{1 + \psi(K_i - 1)}$

Check $\sum x_i = 1$ or $\sum y_i = 1$

if not → $\uparrow \psi$ if $\sum \frac{y_i}{x_i} > 1$

→ $\downarrow \psi$ if $\sum \frac{y_i}{x_i} < 1$

Case 2

Combine the eq $\sum x_i$ and $\sum y_i$
we'll obtain Rachford Rice equation

$$\sum \frac{z_i(K_i-1)}{1+\psi(K_i-1)} = 0$$

assume a value of ψ
and find it until $\sum = 0$

3) Finding Q ⇒ provided that T_F, or P_F are specified
by Energy Balance

$$Q + H_F \cdot F = H_L L + H_V V$$
$$Q = H_L \cdot L + H_V \cdot V - H_F \cdot F$$

B) Adiabatic flash
* Assume T then do the isothermal flash calculation

at each T ⇒ evaluate Q by energy balance

$$Q = H_L \cdot L + H_V \cdot V - H_F \cdot F$$
↳ This have to equal to zero

⊛ Dew and bubble point Calculation

There are two types

1) Dew/Bubble pressure (given T, x or y)

2) dew/bubble Temperature (given P_T and x or y)

1) Dew / Bubble pressure

bubble pressure

given T, x, z

A) evaluate P_{sat} from Antoine equation

B) finding $P_T = \sum x_i P_{sat}$

C) finding $y_i \Rightarrow \frac{x_i P_i^{sat}}{P}$

$\boxed{\sum y_i = 1} \Rightarrow$

dew pressure

given T, y_i

A) evaluate P_{sat} from Antoine equation

B) finding $P_T = \sum \frac{1}{\sum \frac{y_i}{P_i}}$

C) finding $x_i \Rightarrow \frac{y_i P}{P_i^{sat}}$

$\boxed{\sum x_i = 1}$

2) Dew / bubble T

Bubble point

$x_i \Rightarrow \sum z_i K_i = 1$

$\Psi = 0$ if so $\Rightarrow$ bubble point

$\boxed{1 - \sum z_i K_i = 0}$

if $\sum z_i K_i < 1$

The mixture is not rich enough in vapor

because $K_i < 1 \Rightarrow$

but if $\sum z_i K_i = 1$

we are @ bubble point

or $\sum \frac{K_k}{K_j} \cdot z_k \overset{?}{=} \frac{1}{K_j}$

dew point

$y_i = \frac{z_i}{K_i} \Rightarrow$ if $\sum \frac{z_i}{K_i} = 1$

we are @ dew point

$\Psi = 1 \Rightarrow 1 - \sum \frac{z_i}{K_i} = 1$

so, if $\sum \frac{z_i}{K_i} > 1$ we have a super heated mixture

or $\sum \frac{y_k}{\alpha_{kj}} = K_j$