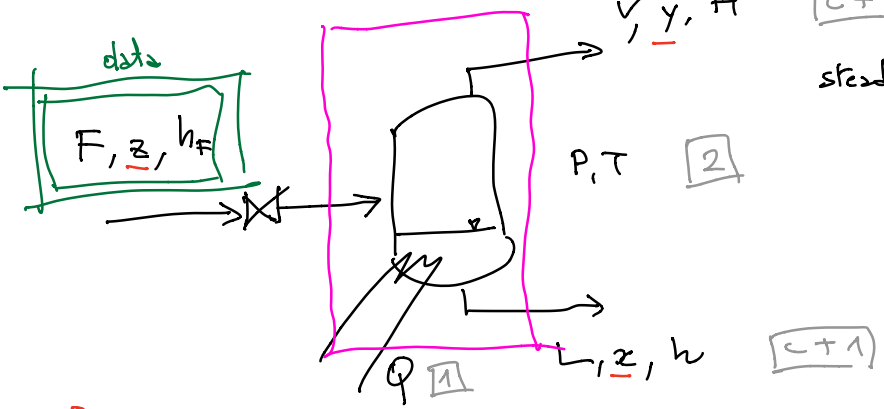
FLASH EVAPORATION

MULTICOMPONENT

$i = 1, \dots, C$

$\underline{z} = [z_1, \dots, z_C]^T$



mat. balances

$$F z_i = L x_i + V y_i \quad C \qquad i = 1, \dots, C$$

stoichiometric conditions

$$\begin{cases} \sum_{i=1}^{C} x_i = 1 \\ \sum_{i=1}^{C} y_i = 1 \end{cases} \quad 2$$

$\sum_i$ mat. bal.

$$F = L \sum_i x_i + V \sum_i y_i = L + V$$

L.V.E.

$$P y_i = p_i^v(T)\, x_i\, \gamma_i(T, P, \underline{x})$$

$$y_i = K_i x_i \quad C \qquad K_i(P, T, \underline{x}) = \frac{p_i^v(T)\, \gamma_i(T, P, \underline{x})}{P}$$

Enegr bal.

$$F h_F + Q = L h + V H \quad 1$$

$(2C+3 \text{ equations}) - (2C+5 \text{ variables}) = 2$ d.o.f.

(I) Isothermal flash $\rightarrow$ fixed P and T

$\hookrightarrow$ ideal liquid phase $\Rightarrow \gamma_i = 1$

$$K_i(T, P) = \frac{p_i^v(T)}{P} = \text{const} = K_i \gtrless 1$$

$$\sum_{i=1}^{C} (y_i - x_i) = 0$$

$$1 = \frac{L}{F} + \frac{V}{F}$$

$$\varphi = \frac{V}{F} \qquad \frac{L}{F} = 1 - \varphi$$

$0 \le \varphi \le 1$

$$z_i = (1-\varphi)x_i + \varphi y_i \overset{\text{we}}{=} \left((1-\varphi) + \varphi K_i\right) x_i$$

$$x_i = \frac{z_i}{1-\varphi+\varphi K_i} \qquad y_i = \frac{K_i z_i}{1-\varphi+\varphi K_i}$$

$$F(\varphi) = \sum_{i=1}^{C} \frac{z_i (K_i - 1)}{1-\varphi+\varphi K_i} = 0$$

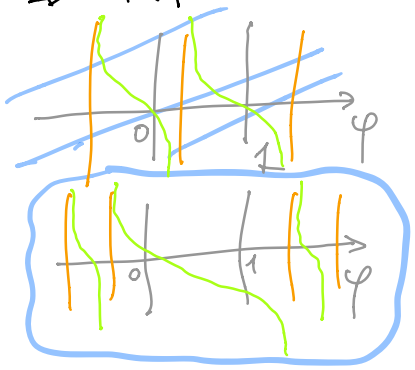
single nonlinear algebraic equation

$\varphi \to V \to L \to x_i, y_i \xrightarrow{\text{E.B.}} Q$

numerical solution : half-interval method, Newton method, secant method.

$$F'(\varphi) = \sum_{i=1}^{C} \frac{-z_i (K_i-1)^2}{(1+\varphi(K_i-1))^2} < 0 \quad \Rightarrow \quad F(\varphi) \text{ monotonically decreasing}$$

($1+\varphi(K_i-1) \gtrless 0$)

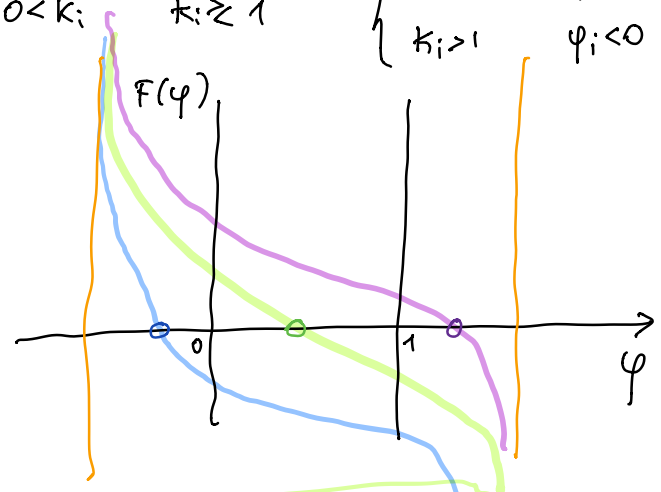


where are the vertical asymptotes ? → outside $0 \dots 1$

$$\varphi_i = \frac{1}{1-K_i} \qquad i = 1, \dots, C$$

$$\begin{cases} K_i < 1 & \varphi_i > 1 \\ K_i > 1 & \varphi_i < 0 \end{cases}$$

$0 < K_i \quad K_i \gtrless 1$



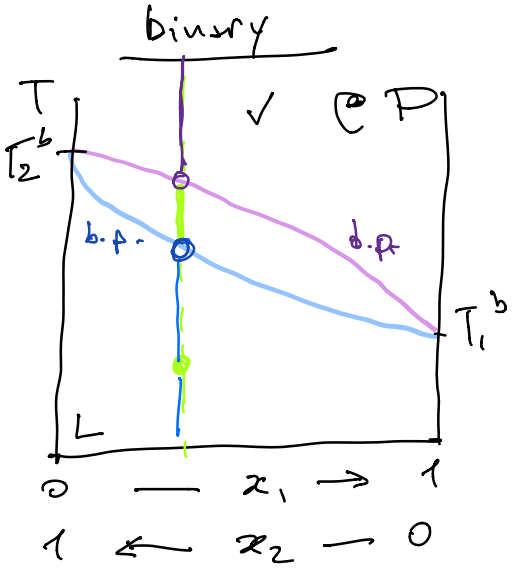
$$F(0) = \sum_i z_i (K_i - 1) > 0$$

$$F(1) = \sum_i z_i \left(1 - \frac{1}{K_i}\right) < 0$$

$F(0) < 0 \to \varphi < 0$

$F(1) > 0 \to \varphi > 1$

binary



T_{bp} is the minimal T where $\varphi = 0$

T_{dp} is the maximal T where $\varphi = 1$

$\varphi < 0$ under-cooled L

$\varphi = 0$ bubble point

$0 < \varphi < 1$ flash w/ LVE

$\varphi = 1$ dew point

$1 < \varphi$ superheated V

T ↓

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(1) bubble point calculation @ $P \Rightarrow$ flash $\begin{cases} P \\ V = 0 = \varphi \end{cases}$

$$F(0, T_{bp}) = \sum_{i=1}^{C} z_i \left(K_i(T_{bp}) - 1 \right) = 0 \rightarrow T_{bp} < T_{flash}$$

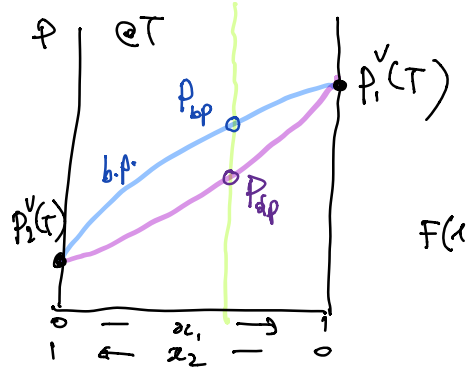
dew point calculation @ $P \Rightarrow$ flash $\begin{cases} P \\ \frac{V}{F} = 1 = \varphi \end{cases}$

$$F(1, T_{dp}) = \sum_{i=1}^{C} z_i \left(1 - \frac{1}{K_i(T_{dp})} \right) = 0 \rightarrow T_{dp} > T_{flash}$$

To determine the pressure : flash $\begin{cases} T \\ \varphi = 0 \text{ or } \varphi = 1 \end{cases}$

P_{bp}, P_{dp} are weighted averages of $p_i^v(T)$

binary



$$F(0, P_{bp}) = \sum_i z_i \left(\frac{p_i^v(T)}{P_{bp}} - 1 \right) = 0$$

$$P_{bp} = \sum_i z_i p_i^v(T)$$

$$F(1, P_{dp}) = \sum_i z_i \left(1 - \frac{P_{dp}}{p_i^v(T)} \right) = 0$$

$$\frac{1}{P_{dp}} = \sum_i \frac{z_i}{p_i^v(T)}$$

(3)

(III) flash : design. (1) @ T (2) $0.9\ F_{z_6} = L x_6$

↳ C = 6 1 is the most volatile, 6 is the least volatile

split factor : $S_i = \frac{V y_i}{L x_i} \overset{LVE}{=} \frac{V\, p_i^v(T)}{L\, P}$

mat. bal. $\begin{cases} F_{z_i} = L x_i + V y_i \\ \frac{F_{z_i}}{L x_i} = 1 + S_i \end{cases}$

$(L x_i) = \frac{F_{z_i}}{1+S_i}$ $\quad (V y_i) = F_{z_i} \frac{S_i}{1+S_i}$

$L x_6 = 0.9\, F_{z_6} = \frac{F_{z_6}}{1+S_6}$ $\quad 1 + S_6 = \frac{1}{0.9}$ $\quad S_6 = \frac{0.1}{0.9}$

$\frac{S_i}{S_6} = \frac{p_i^v(T)}{p_6^v(T)}$ $\quad S_i = \frac{0.1}{0.9} \frac{p_i^v(T)}{p_6^v(T)}$

$\Rightarrow (L x_i), (V y_i) \quad (i = 1, \dots, C)$

$\sum_{i=1}^{C} L x_i = L$ $\quad \sum_{i=1}^{C} V y_i = V \sum_{i=1}^{C} y_i = V$

$x_i = \frac{(L x_i)}{L}$ $\quad$ - - -

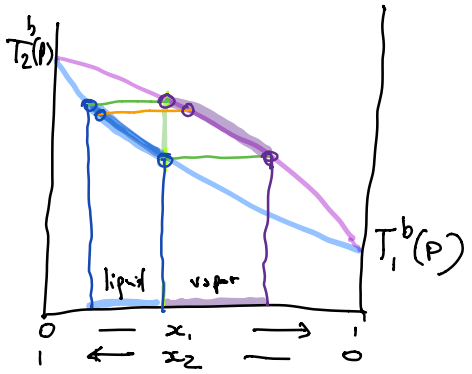
(IV) Non-ideal flash, $K_i(T, P, \underline{x}) = \frac{p_i^v(T)\, \gamma_i(T, P, \underline{x})}{P}$

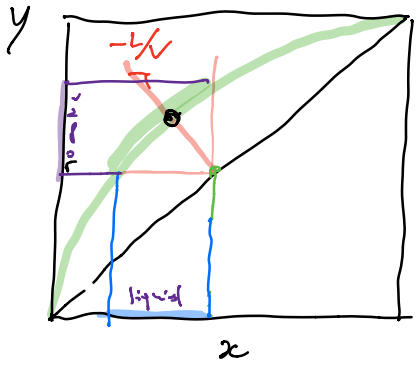
↳ iterative procedure

BINARY MIXTURES

comp. 1 more volatile
comp. 2 less volatile

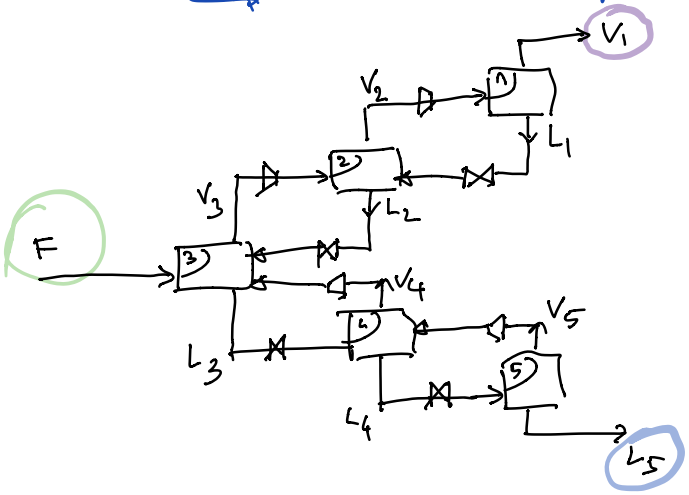
@ P

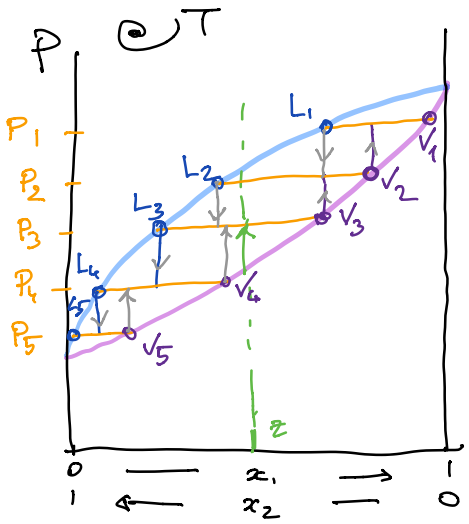




⇒ Limitations in terms of achievable compositions, or purities

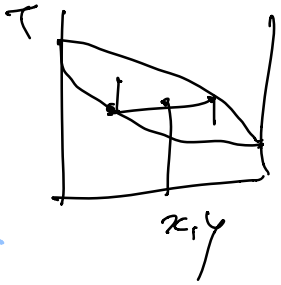
↳ cascade concept





cascade of flash operations at constant P

Ex. 5 flashes @ P



↳ distillation column