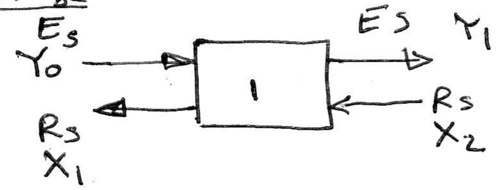
Calculations Based on total immiscibility of carrier solvents (A and B).

For simple ternaries on solute free basis:

- Y: mass ratio of solute in Extract (E phase).
- X: mass ratio of solute in Raffinate (R phase).

Simple Single Stage



MB: $R_s(X_2 - X_1) = E_s(Y_1 - Y_0)$

for fresh solvent $Y_0 = 0$

$R_s(X_2 - X_1) = E_s Y_1$

At eqm $Y = mX$

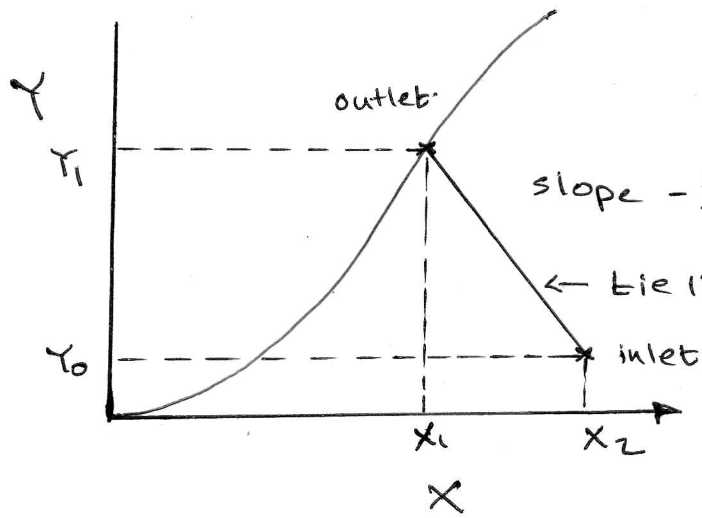
m: partition coefficient

: at any value of X = tangent to curve at that point

$Y_1 = m X_1$

$$\therefore \boxed{\frac{X_2}{X_1} = m\frac{E_s}{R_s} + 1}$$

Extraction Ratio



slope $-\frac{R_s}{E_s} = \frac{Y_1 - Y_0}{X_1 - X_2}$

% Recovery (% Extraction) $= \frac{X_2 - X_1}{X_2} \times 100$

X_1: OUT
X_2: IN.

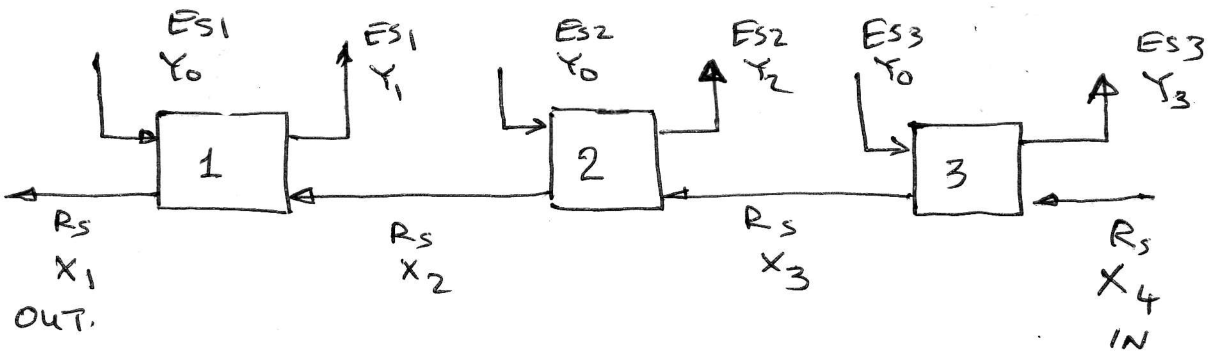
$E = m\frac{E_s}{R_s}$ Extraction factor.

$$\therefore \frac{X_2}{X_1} = (E + 1)$$

$$\Rightarrow \boxed{\frac{X_1}{X_2} = \frac{1}{(E+1)}} = \frac{X_{OUT}}{X_{IN}}$$

Simple multiple contact (Repeated application of Solvent. Crossflow)

consider 3 contacts for example.



Increase range of extraction ratio and enables production of extracts of different concentration.

$$\text{Extraction ratio} = \frac{X_4}{X_1}$$

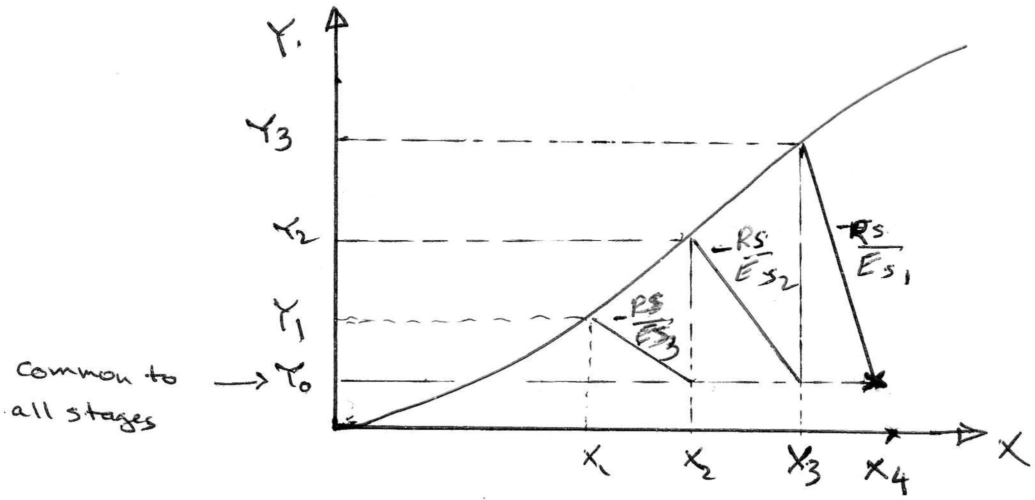
$$\Rightarrow \quad \frac{X_4}{X_1} = \frac{X_4}{X_3} \times \frac{X_3}{X_2} \times \frac{X_2}{X_1}$$

$$= \left(m\frac{E_{S1}}{R_S}+1\right)\left(m\frac{E_{S2}}{R_S}+1\right)\left(m\frac{E_{S3}}{R_S}+1\right).$$

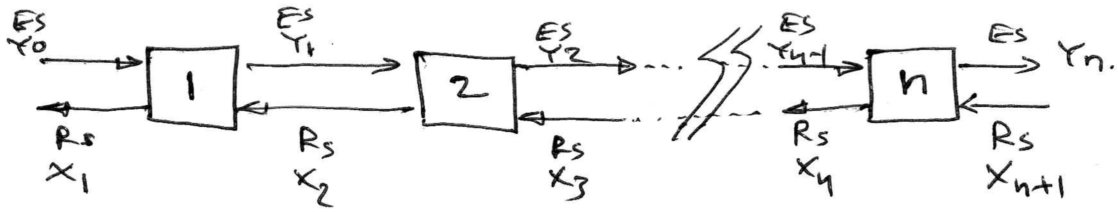
Special case $E_{S1} = E_{S2} = E_{S3} = E_0 = \dfrac{\text{Total Solvent}}{\text{No. of stages.}}$

$m = \text{const.}$

$$\therefore \frac{X_4}{X_1} = \left(m\frac{E_0}{R_S}+1\right)^3$$



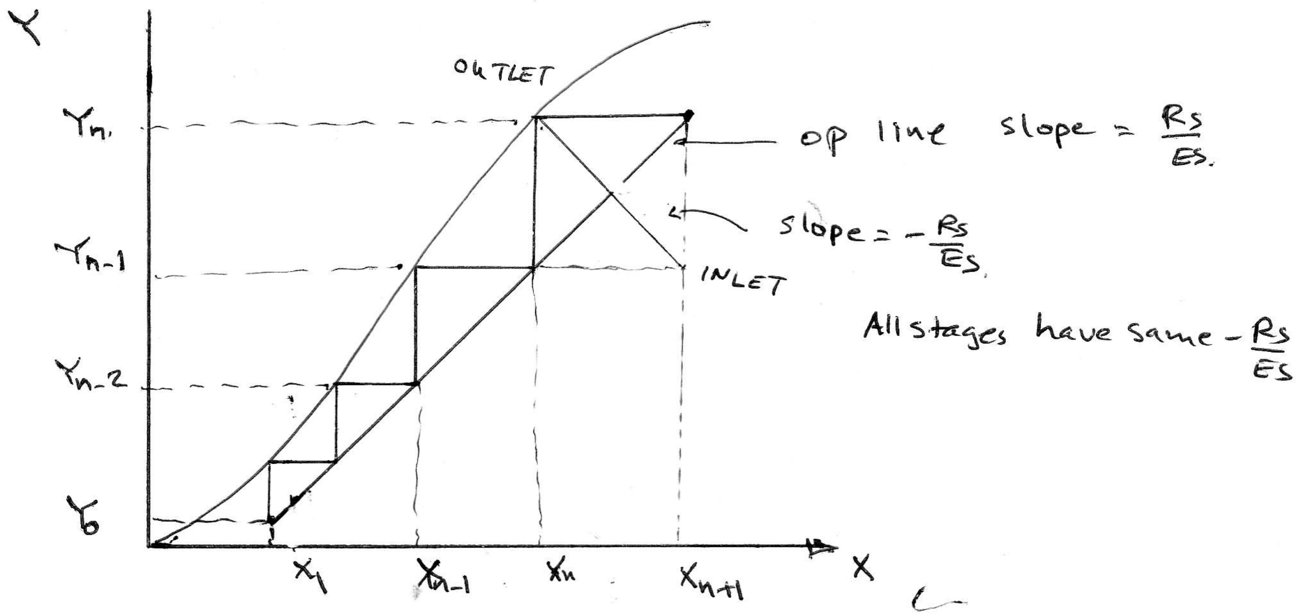
Continuous Counter Current Extraction:



From solute mass balances on each stage.

Extraction ratio = $\dfrac{X_{n+1}}{X_1}$

$$\frac{X_{n+1}}{X_1} = \frac{\left(m\frac{E_S}{R_S}\right)^{n+1} - 1}{m\frac{E_S}{R_S} - 1}$$



Impure solvent ie recycled solvent

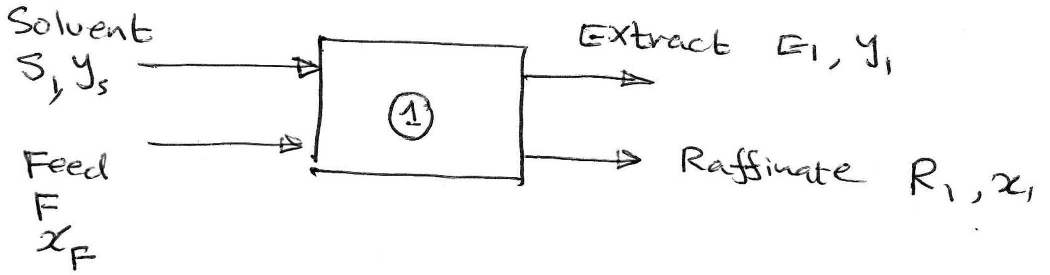
$Y_0 \neq 0$

Extraction ratio = $\dfrac{X_{n+1}}{X_1} = \left[\dfrac{\left(m\frac{E_S}{R_S}\right)^{n+1} - 1}{\left(m\frac{E_S}{R_S}\right) - 1}\right] - \dfrac{E_S}{R_S}\dfrac{Y_0}{X_1}\left[\dfrac{\left(m\frac{E_S}{R_S}\right)^{n} - 1}{\left(m\frac{E_S}{R_S}\right) - 1}\right]$

if $\dfrac{E_S}{R_S} > 1$

General Case:

Single stage contacting:



F: Feed stream – contains diluent (A) + solute (C)

S_1: Solvent stream to stage: generally contains small amounts of A and C dissolved in solvent (Recycled)

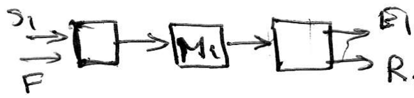
CASE:

Known variables: $F, S_1, x_{CF}, x_{AF}, y_{C,S}, y_{AS}$ (solute: x_{CF}, $y_{C,S}$; Diluent: x_{AF}, y_{AS})

Unknown or desired: E_1, R_1 and outlet stream compositions

8 variables.

$F + S_1 \xrightarrow{\text{Mixing}} M_1 \longrightarrow E_1 + R_1$



Mixture M_1 is a two phase mixture

Equations:

Overall balance

$$F + S_1 = M_1 = E_1 + R_1 \quad (1)$$

Component balances:

C-balance:

$$x_{CF} F + y_{CS} S = y_{C1} E_1 + x_{C1} R_1 \quad (2)$$

A-balance

$$x_{AF} F + y_{AS} \cdot S = y_{A1} \cdot E_1 + x_{A1} R_1 \quad (3)$$

Equilibrium: Solute is distributed between two phases

$$y_{CE} = m\, x_{CR} \quad (4)$$

y_{AE} : obtained from Extract saturation curve (Knowing y_{CE} from tie line data). (5)

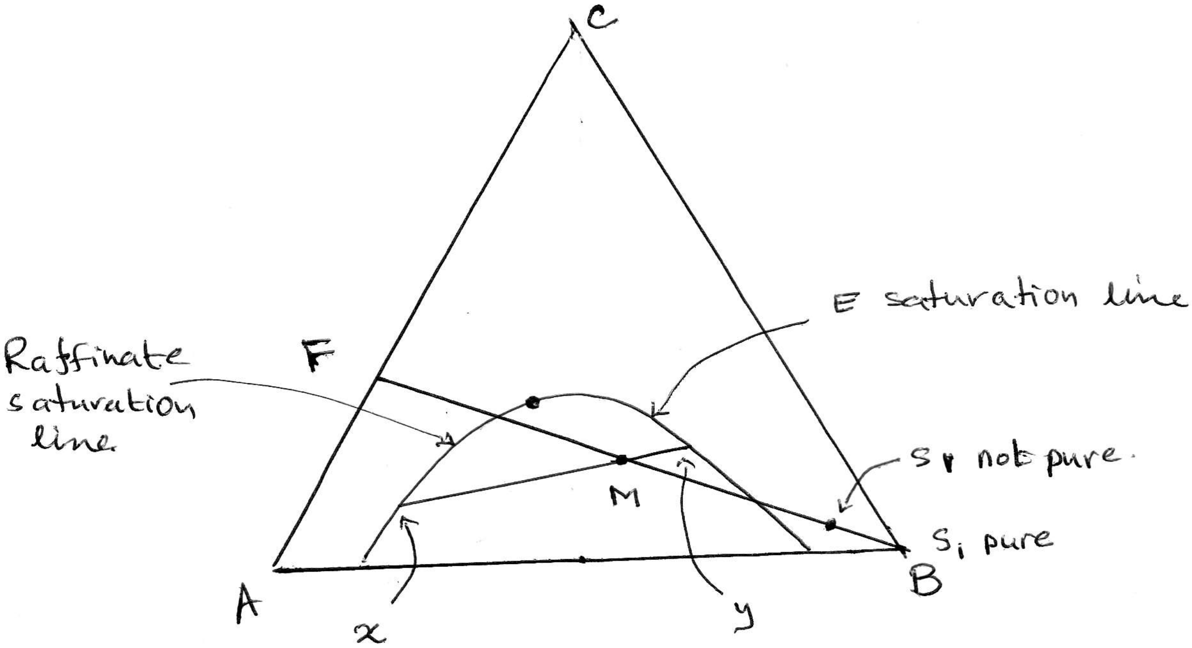
x_{AR} : obtained from Raffinate saturation curve (Knowing y_{CR} from tie line). (6)

$\sum x_{iR} = 1$ (7)

$\sum y_{iE} = 1$ (8)

Solve system of equations (numerically).

<u>Graphical Solution:</u>



1. Locate points F and S (Known compositions).
2. $F + S_1 \rightarrow M_1$. M_1 must be within the two phase region. It may be determined by:
   - lever rule (not recommended)
   - Calculating the composition of point M_1 which falls on the line $\overline{FS_1}$

$$x_{M_1} = \frac{F \cdot x_F + S_1 y_S}{F + S_1}$$

If composition of M_1 is given, then reqd. S_1 is

$$\frac{S_1}{F} = \frac{x_F - x_{M_1}}{x_{M_1} - y_S}$$

3. Mixture M_1 will separate into E_1 (y_1) in equilibrium with R_1 (x_1). Usually y_1 and x_1 are not known apriori; therefore a tie line that passes through M_1 must be found by trial and error, consequently y_1 and x_1 are determined.

4. Quantities E_1 and R_1 are then calculated as follows:

$$E_1 = M_1 \times \frac{(x_{M_1} - x_1)}{(y_1 - x_1)}$$

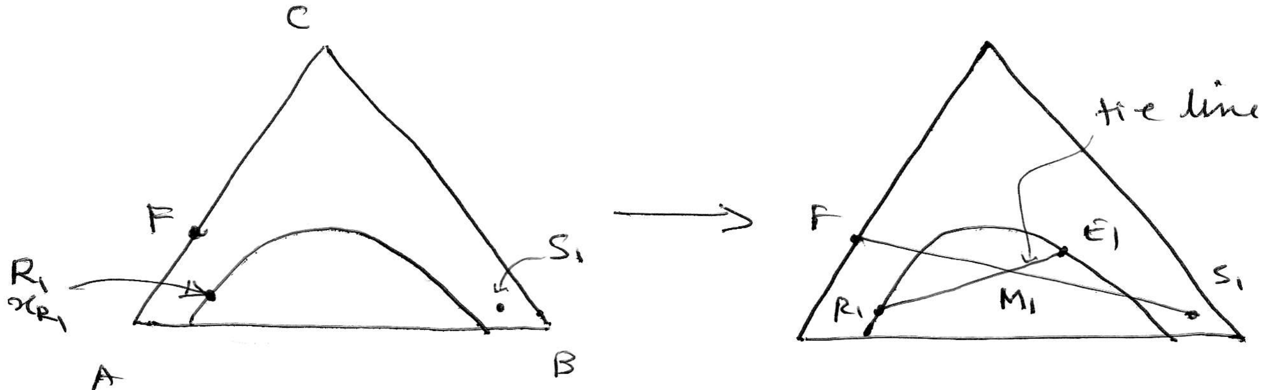
$$R_1 = M_1 - E_1$$

Case 2:

Known: F, x_F, y_S (solute), $x_{A,F}$, $y_{A,S}$ x_{R_1}

Required S, E_1, R_1 and outlet stream compositions.

Graphical solution:



Given

Steps: - Draw tie line through R_1
- tie line intersects with $\overline{FS_1}$ at M_1
- Find S_1 (calculation or lever rule).
- E_1
- R_1
- compositions.

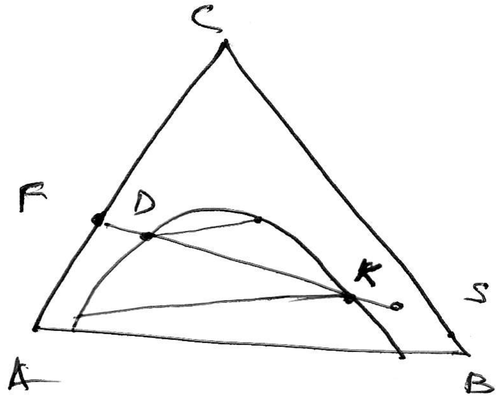
Notes:

① If solvent stream is pure then $y_{B,S_1} = 1$ and point S_1 would be at the B apex.

② For a given feed and solvent concentrations, the minimum amount of solvent required to form with F a 2ϕ mixture would be given by point "D", and the maximum amount of solvent allowable for 2ϕ mixture is given by point "K."

Min solvent → very small amount of extract

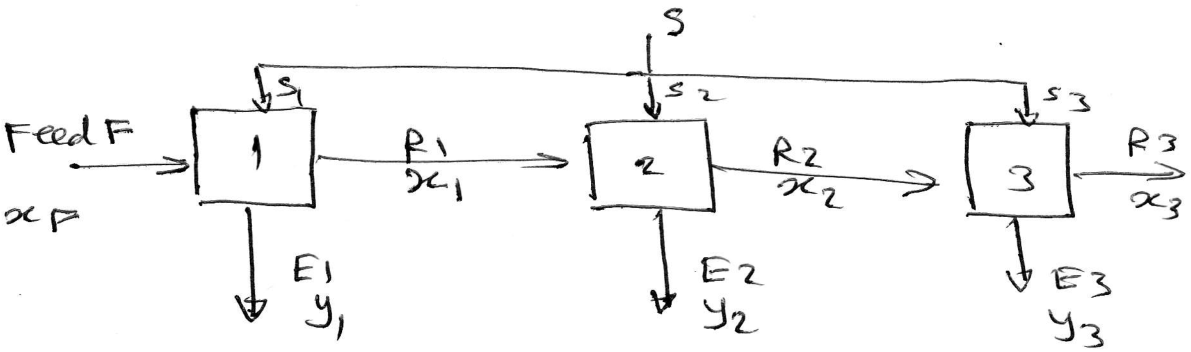
Max solvent → very small amount of Raffinate



③ Same analysis can be carried out on solute [redacted] free basis.

Cross Flow Contacting:

- Fresh solvent is fed to each stage
- Raffinate from one stage is fed to the subsequent stage
- Amount of solvent for each stage may be different
- Stages may be operated at different temperatures



The same analyis applied to single stage is used for each stage, thus:

- Each stage has an M point
- For each stage E and R are obtained by trial and error (in finding a tie line).
- All stages have a common S point, since the same solvent is used but fed in different amounts.
- Operating possibility: - Same $\frac{E}{S}$ ratio for each stage
  - Same amount of solvent
  - Different amounts of solvents