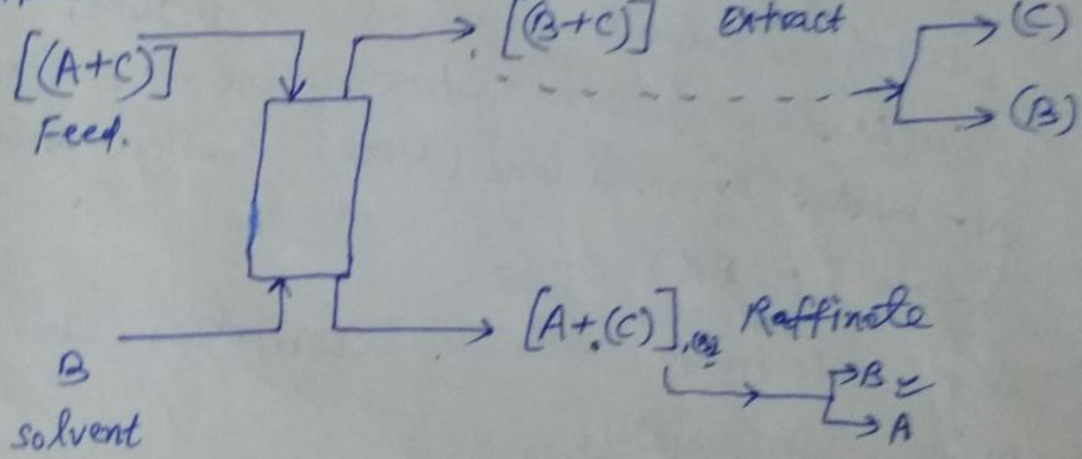
Date
13/08/2018

Liquid-Liquid Extraction

Liquid-Liquid extraction is a mass transfer operation in which a solution (solute with carrier liquid) is brought into intimate contact with a second immiscible or slightly miscible liquid (solvent) in order to transfer solute from the feed to the solvent. The two liquid phases that have different densities are then separated.

- The solute rich phase is called (solvent stream) the extract. The residual feed stream that may have a little of solute left in it is called the raffinate.



An extraction process involves four major steps.

(I) Bringing the feed and solvent into intimate contact.

(II) Separate the extract and raffinate phases that have different densities

(III) Removal and recovery of the solute from the extract phase by distillation, evoperation, crystallization etc.

(IV) Removal and recovery of solvent from each phase usually by distillation.

The separation of a liquid mixture or solution by distillation is operationally simpler than extraction. In a typical LLE process, only about 15% of the capital cost goes towards the extractor and the remaining 85% goes towards the distillation column and other equipments for solvent recovery and product purification.

Examples of LLE:

(I) Extraction of aromatics (BTX)

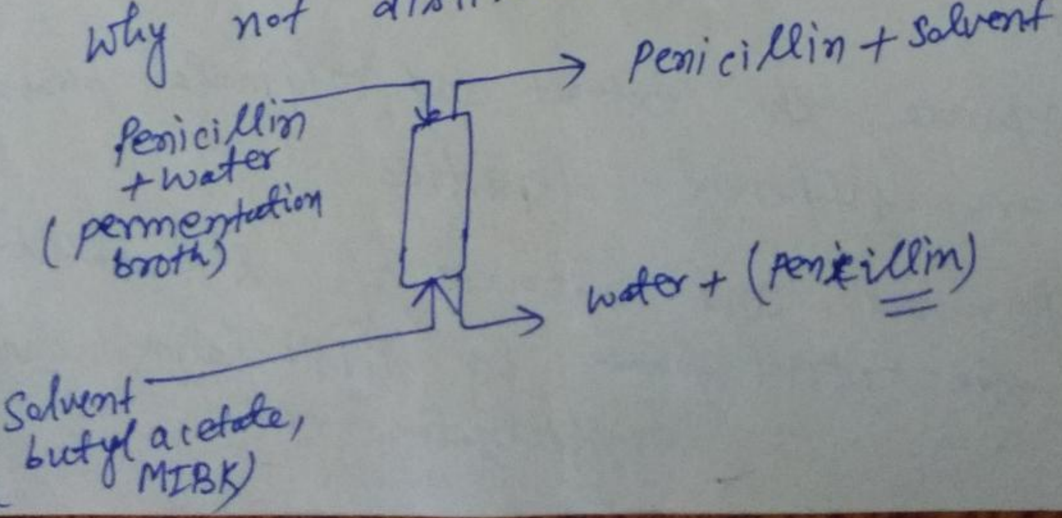
BTX removal from kerosene & jet fuels using solvents such as furfural, Sulphalane (Tetrahydrothiophene-1,1-dioxide) N-methyl pyrrolidone (NMP), methyl-Isobutyl ketone (MIBK) etc.

→ They selectively remove aromatics and wikely polar compounds.

(II) Recovery and concentration of Antibiotics by solvent extraction

why not distillation?

for eg



Liquid-liquid Equilibrium (LLE) data generating ②

Liquid-liquid Extraction system contains at least three components: the solute (C), the carrier liquid in the feed (A), and the extracting solvent (B).

(Give example of penicillin or BTX)

Often no. of components may be more than 3

(i) The carrier may have more than one liquid

(ii) More than ~~two~~ one solute may be present in the feed

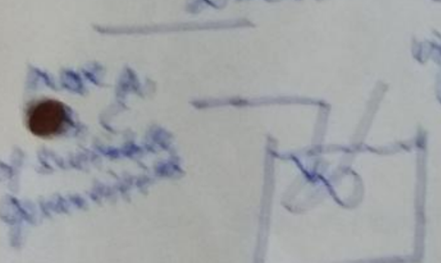
with some amount of solute (C)

(iii) solvent may be impure or may be mixed with other solvents

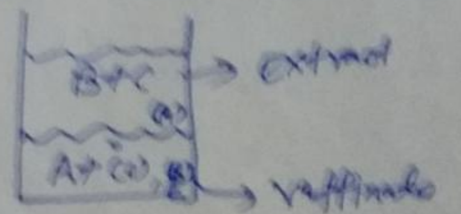
But here we will ~~only~~ focus on ternary ~~LLE~~ systems

Experimental determination of liquid-liquid equilibrium Data:

vigorous mixing for long time to ensure equilibrium condition reached



(equilibrium cell at constant temp.)



separate by decantation

The mole/mass fractions of A, B, and C is then calculated in both of the phases.

Tabulate the data

Extract	Raffinate
y_A, y_B, y_C	x_A, x_B, x_C
⋮	⋮

and plotted ~~[illegible]~~ on a suitable graph

Classification of ternary systems

~~The solute (C)~~ Among three components (A), (B), and (C) three binary mixtures may be formed.

A-B, B-C, and C-A.

Among these mixture solute C is ~~must be available~~ present in both of phases (Mandatory)

i.e in feed : A-C
and Extract B-C

Depending on the miscibility behavier of A-B, the ternary LLE can be classified as

(i) The carrier (A) and solvent (B) are practically immiscible. The equilibrium in such a system may be represented in the form of a 'x-y' plot.

(ii) A & B are partially miscible. Such system is called type-I ternary system. About 75% ternary liquids falls under this category.

(iii) Both solute (C) and carrier (A) have limited miscibility with the solvent
i.e. pairs B-C, & A-B are partially miscible.

It means that not only carrier A, but also solute C is partially miscible in solvent B.

Graphical representation of liquid - liquid equilibrium data

③

It is not possible to represent a phase or the equilibrium of two phases in contact in terms of the three concentrations using normal rectangular coordinate system

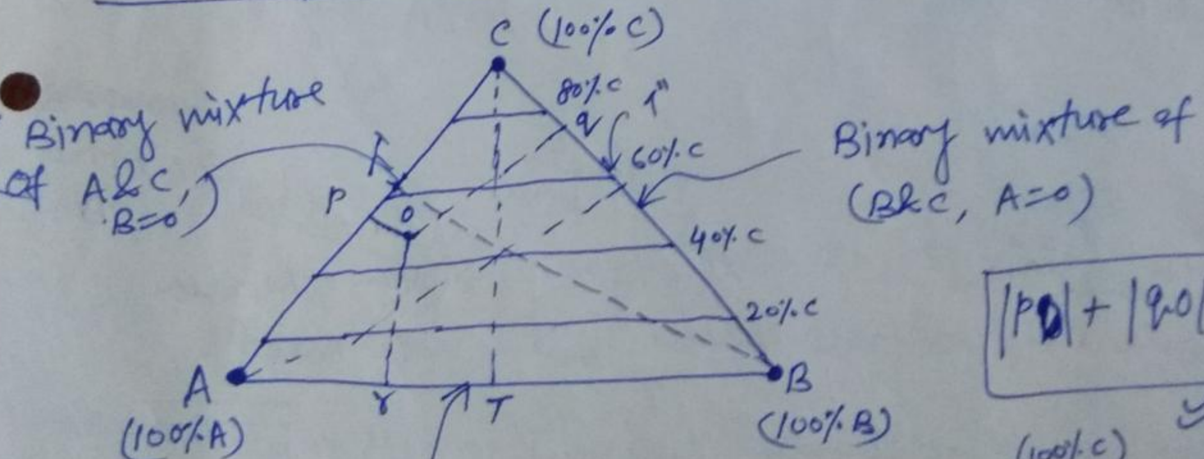
There are three main ways through which the concentrations of ternary mixture represented.

(a) Equilateral triangular diagram

(b) A right angle triangular diagram in which only two concentrations are plotted.

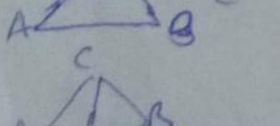
(c) Using the mass/mole fraction of solute and that of solvent in the two phases on solvent free basis using rectangular co-ordinate

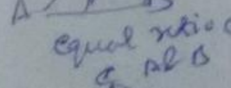
(a) Equilateral Triangular diagram:-



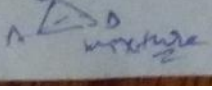
$$\boxed{|PO| + |qO| + |rO| = |CT|}$$

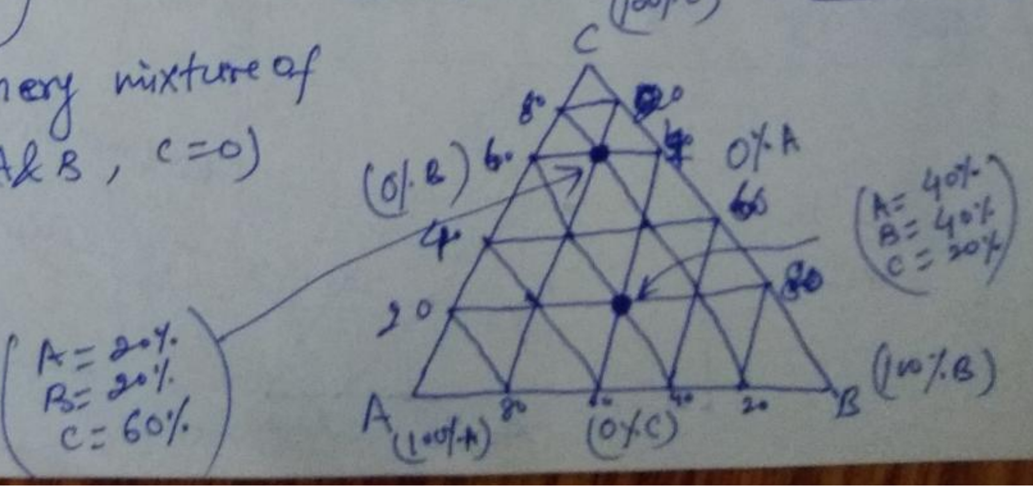
$$\boxed{CT = AT'' = BT'}$$



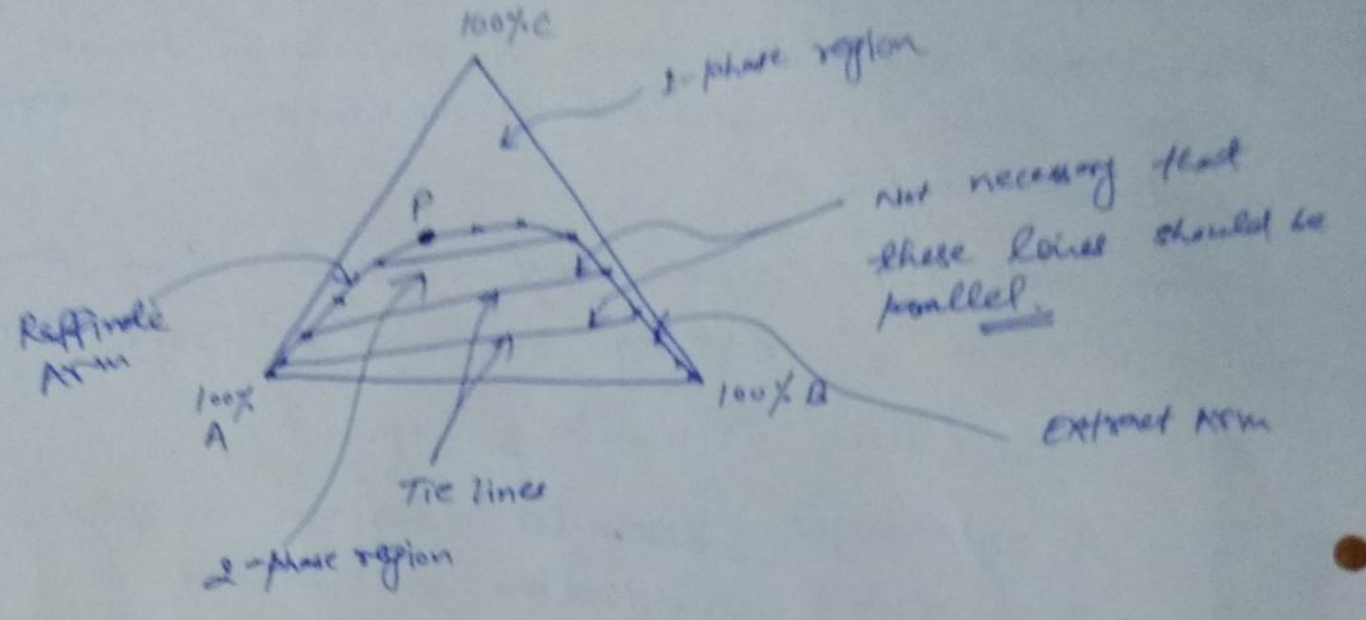


equal ratio of A & B

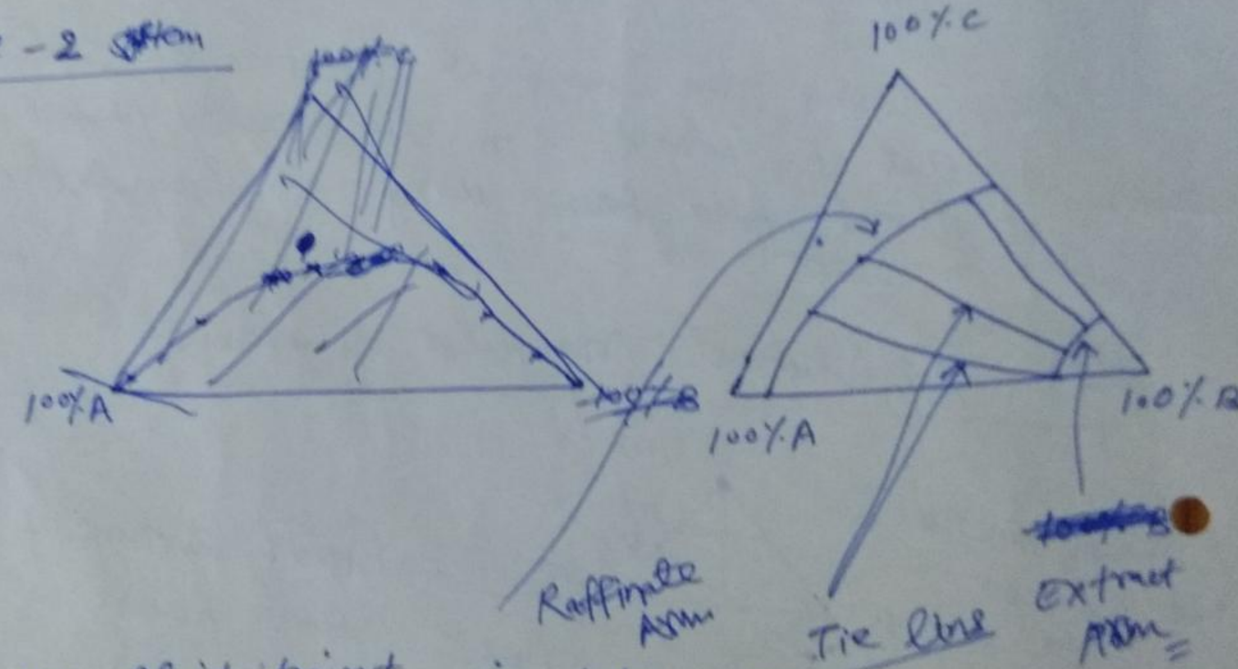




Liquid-liquid equilibrium data presentation in the equilateral triangular co-ordinates for type-1 system

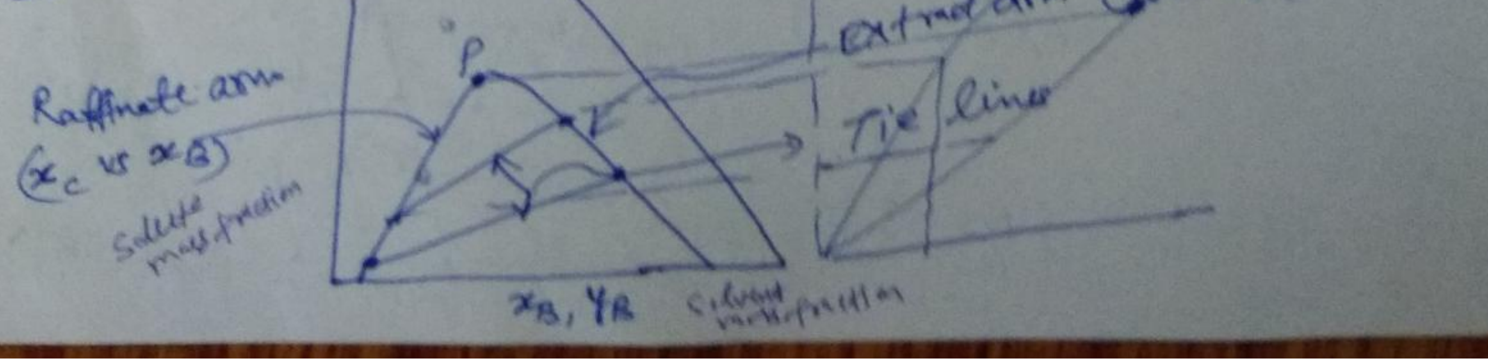


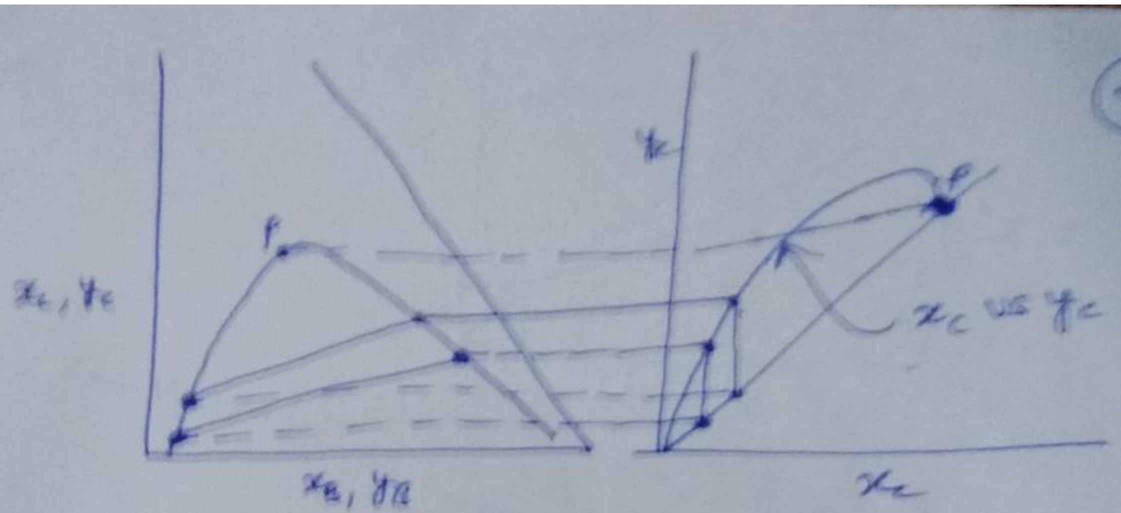
For type-2 system



No plait point in type-2 system because raffinate and extract phases do not meet.

(b) right-angled triangular diagram (In this any two compositions can be used usually solvent and solute conc. are used)





* In right-angled trianglar diagram the mass fraction of the solute in the two phases at equilibrium are plotted against the corresponding mass fractions of the solvent.

A, B, C
x_A, $\underbrace{x_B, x_c}$ in raffinate
y_A, $\underbrace{y_B, y_c}$ in extract
→ for raffinate
→ for extract

(C) Rectangular plot of the solute and of the solvent mass fractions in the two phases on solvent-free basis

A, B, C we have three components

x_A, x_B, x_c are three mass fractions in raffinate

y_A, y_B, y_C are three mass fractions in extract.

Now for the solvent free basis, Now mass fractions will be:—

For solute in raffinate

$$X = \frac{x_c}{x_A + x_c}$$

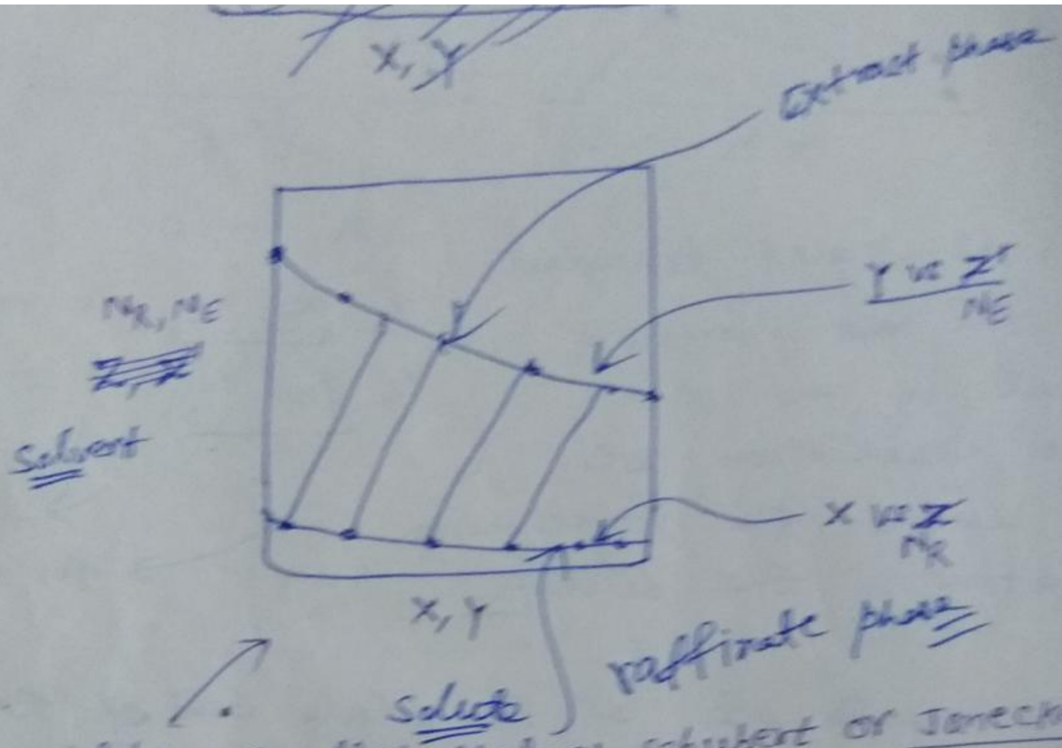
For extract

$$Y = \frac{y_c}{y_A + y_c}$$

For solvent in raffinate

$$N_R = \frac{x_B}{x_A + x_c}$$

$$N_E = \frac{y_B}{y_A + y_c}$$

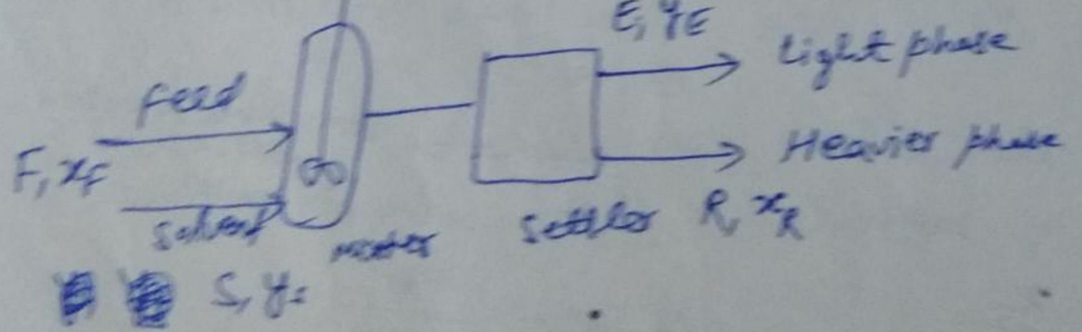


Such plots are called Maloney-Schubert or Janecke diagram

Stage-wise Extraction

- → Single-stage operation
- → Multi-stage operation
  - Cross current
  - Counter-current (in general)

Single-Stage operation



where F, S, E, and R are amount / flowrate of feed, solvent, extract and raffinate, respectively and x_F, y_S, y_E, and x_R are corresponding mass / mole fractions of solute

Overall MB

$$F + S = E + R = M$$

Solute balance

$$F x_F + S y_S = E y_E + R x_R = M x_M$$

x_M is mass fraction of solute in mixture

$$x_M = \frac{F x_F + S y_S}{M} = \frac{F x_F + S y_S}{F+S}$$

$$x_M = \frac{F x_F + S y_S}{F+S}$$

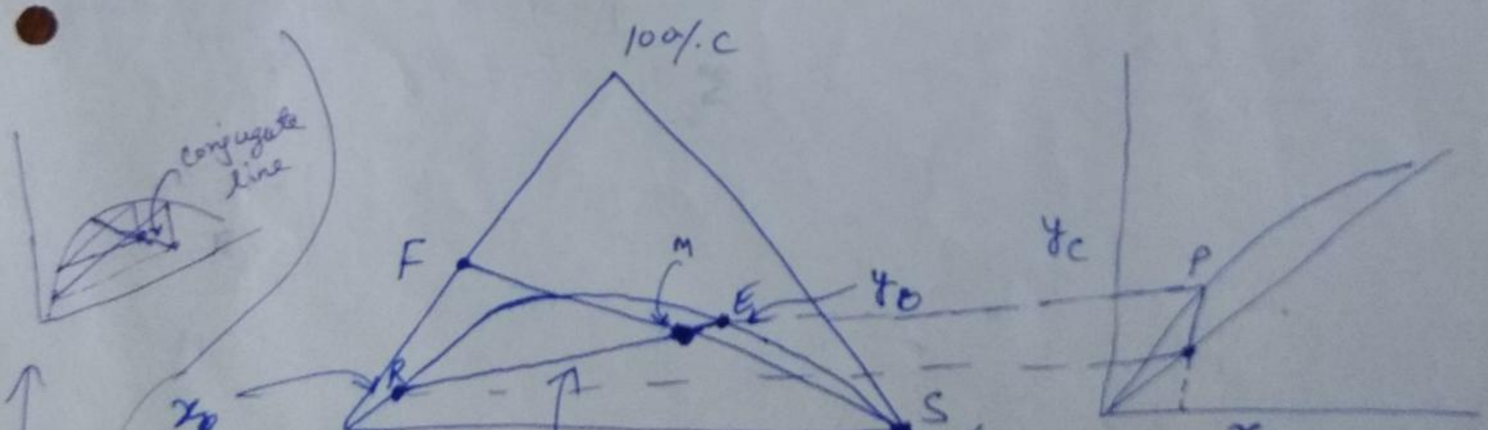
or

$$\boxed{\frac{F}{S} = \frac{x_M - y_S}{x_F - x_M}}$$

And

$$R x_R + E y_E = M x_M = (R+E) x_M$$

$$\boxed{\frac{E}{R} = \frac{x_M - x_R}{y_E - x_M}}$$



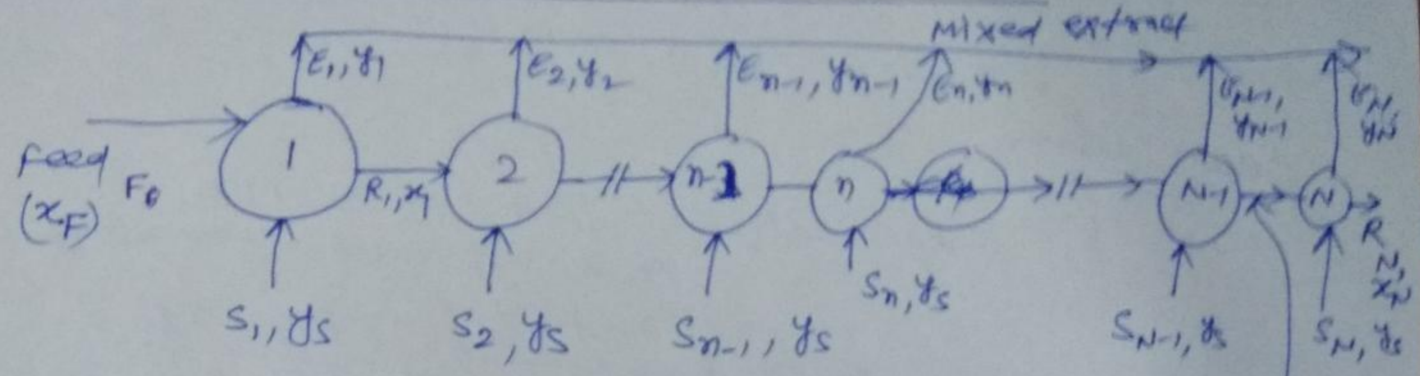
Also describle How to get tie lines from few tie lines using conjugate line

By error and trial method the line is stright and passes through point M

After getting (x_1, y_1) we can calculate E_1 and R_1

$$E_1 = \frac{M(x_M - x)}{(y - x)}, \quad \underline{R = M - E}$$

Multi-stage cross-current Extraction



Suppose there are N- stages

Overall Mass balance for nth stage

$$R_{n-1} + S_n = M_n = E_n + R_n$$

Mass balance of component C

$$R_{n-1}\, x_{n-1} + S_n y_S = M_n\, x_{M,n} = E_n y_n + R_n x_n$$

For First stage

$$F + S_1 = E_1 + R_1 = M_1$$

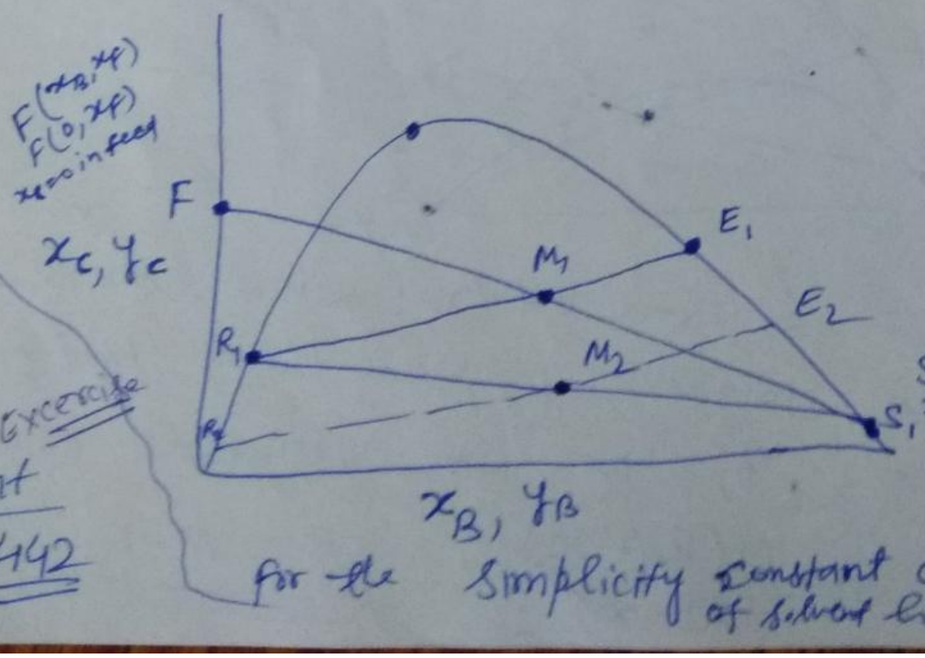
$$x_{M,1} = \frac{F x_F + S_1 y_S}{F + S_1}$$ or measure the ratio of $\left(\frac{F}{S}\right)$ no need measure only ratio

For second stage

$$R_1 + S_2 = E_2 + R_2 = M_2$$

$F(0, x_F)$
$S(y_B, 0)$

$x_{C,M_1} =$ -



$S(y_B, y_C)$

May be $S_1 = S_2$

Solve example 8.1 & 8.2 8.3 & 8.4 B.K. Dutta Excercise

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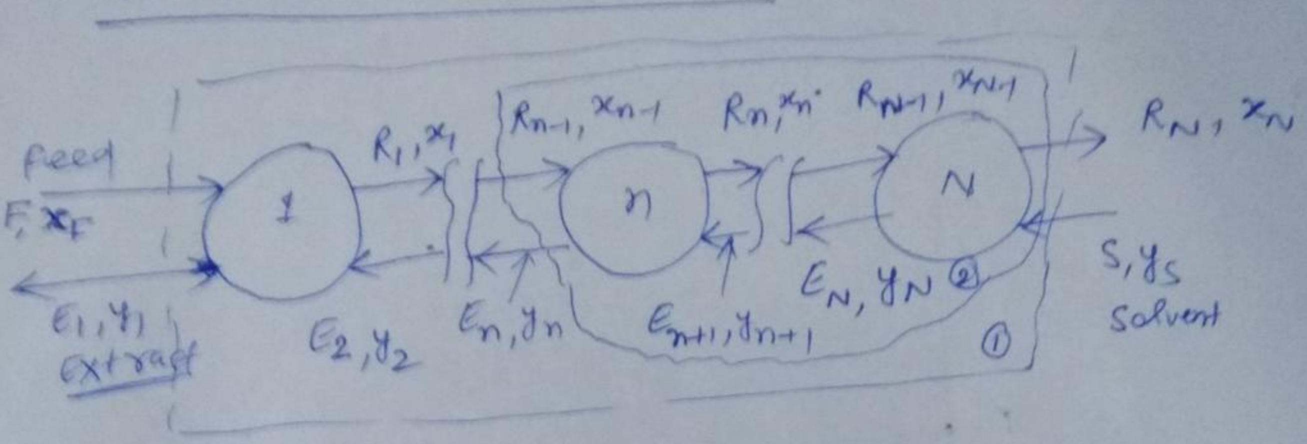
solvent rich phase is extract so $S_1(y_B, y_C)$

for the simplicity constant composition of solvent has been taken

Countercurrent Extraction -



Total MB of entire unit (over Envelope-1)

$$F + S = E_1 + R_N = M \quad — ①$$

Total solute balance

$$F x_F + S y_S = E_1 y_1 + R_N x_N = M x_M \quad - ②$$

Total MB of Envelope-2

$$R_{n-1} + S = E_n + R_N \quad — ③$$

Solute balance:-

$$R_{n-1} x_{n-1} + S y_S = E_n y_n + R_N x_N \quad - ④$$

From equation ①

$$E_1 - F = S - R_N = \Delta$$

From equation ③

$$E_n - R_{n-1} = S - R_N = \Delta$$

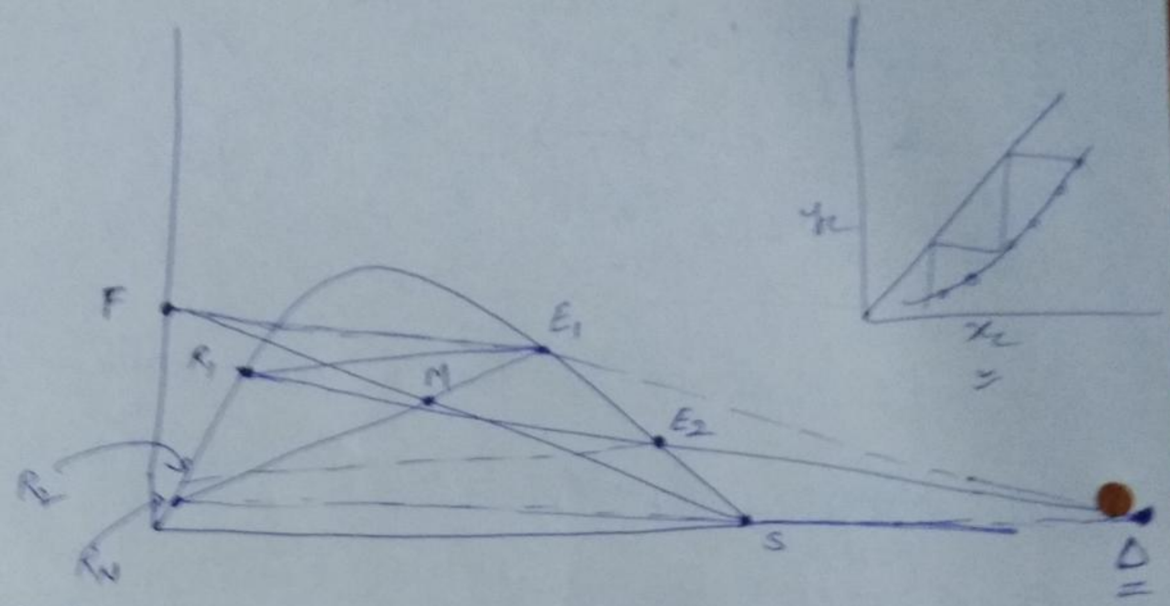
$E_2 - R_1 = S - R_N$
$E_3 - R_2 = S - R_N$

where Δ is a difference point lying on the line FE_1 extended and also on line $R_N S$ extended.

For ideal stages

E_n and R_n are in equilibrium

$$E_2 - R_1 = S - R_N = \Delta$$



solve 8.3 & 8.4 → Assignment

LLE Equipments

① (1) The Mixer-settler
(2) centrifugal Extractor
(3) spray Tower
(4) Packed extraction column
(5) Rotary-Agitated Extraction Columns

} Read from book

Selection of Extractors

③ choice of solvent

Important factors are:-

Q
(a) Fluid properties
(b) ~~[illegible]~~ Residence time of extractor
(c) Cost and maintaince of the equipments
(d) The no. of Theoretical stage required.
(e) Throughputs and phase ratio
(f) settling characteristics of the L-L dispersion
(g) presence of suspended solids (h) Available space

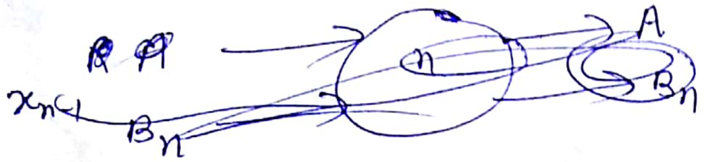
When the solvent and carrier is completely immiscible, computation becomes simplified. The solute concentrations are expressed on a C-free basis.

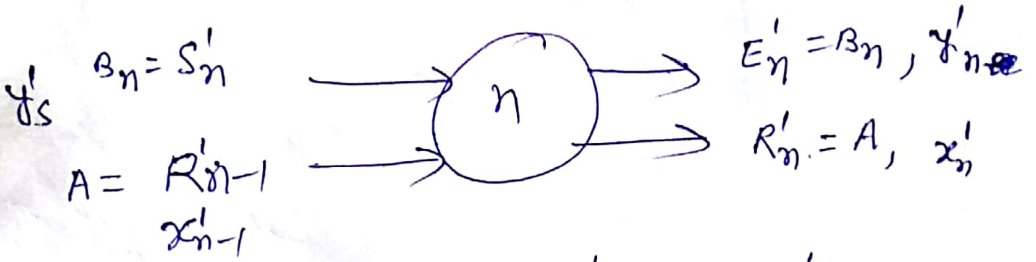
The raffinate contains only A & C
The extract contains only B & C

If feed contains A kg of carrier
and solvent contains B kg of solvent
then extract contains B kg
And raffinate contains A kg

~~for~~ the solute balance for any nth stage

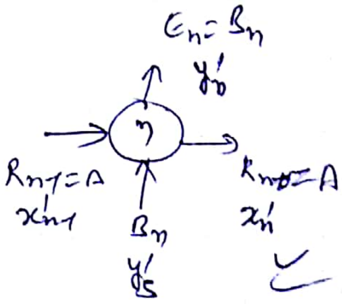
$x' = \frac{x_c}{1-x_c}$, $y' = \frac{y_c}{1-y_c}$

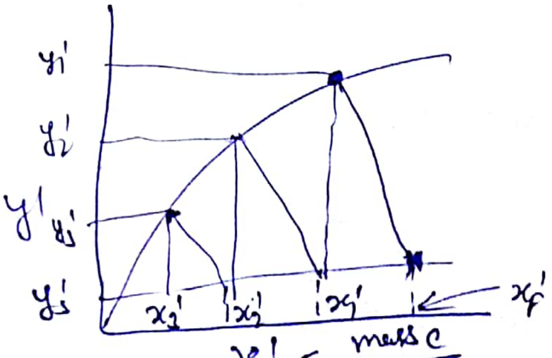




$$x'_{n-1} A + y'_s B_n = y'_n B_n + x'_n A$$

$$-\frac{A}{B_n} = \frac{y'_s - y'_n}{x'_{n-1} - x'_n}$$





$y' = \frac{\text{mass C}}{\text{mass B}}$

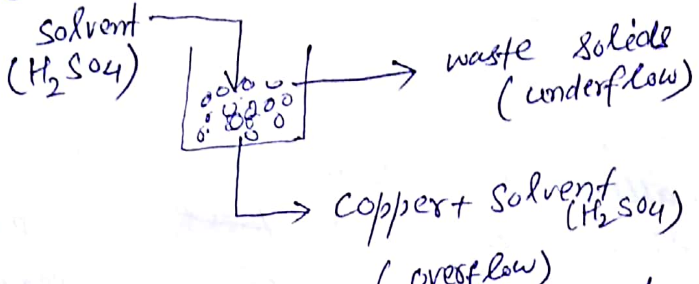
$x' = \frac{\text{mass C}}{\text{mass A}}$

Solid-Liquid Extraction (Leaching)

Solid-liquid extraction is the process for removing soluble constituents of a solid material using a suitable solvent.

Generally, soluble material is the target product, and inert solid residue is a by-product or just a solid waste.

eg. Extraction of copper from its ores.



There are four steps are involved in leaching process:-

(I) Intimate contact of solid feed with the solvent
(II) Separation of solution from the solid
(III) Separation of the solvent
(IV) Recovery of the solvent from the moist solids

This process is different from dissolution as in dissolution approx. all of the solids are dissolved in the solvent whereas in leaching only soluble solute is dissolved ~~into~~ to the solvent and a substantial part of the solid does not dissolve.

Parameters on the leaching depends

(I) Physical characteristics of the solid

- porous or non porous
- Shape and size
- separation difficulties (Sometimes) → for e.g. ~~Phosphorus~~ phosphate industries for H_3PO_4 production

(II) Solvent

Solvent should be able to dissolve most of the solute ~~with~~ ~~[illegible]~~ with high selectivity

(III) Temperature:-

Diffusivity ~~coef~~ of solute in solid as well as its miscibility with the solvent increases with temperature. Viscosity of solvent becomes less at increased temperature, so the solvent can easily penetrate into the pores of the solids. So extraction extraction rate is increased with increase in temperature

(IV) Agitation:-

Agitation cause the increase of the mass transfer coefficient. Solid particles maybe ~~break~~ break up into smaller particles causing a settling problem.

If the solid particles offer the controlling resistance, the effect of agitation ~~is not much~~ on the extraction rate is not effective.

Solid - liquid equipments

(I) Fixed bed contactor

(II) Dispersed contact in an agitated tank

- → Batch mode
- → Continuous mode

Based on the contacting patterns various equipments are used.

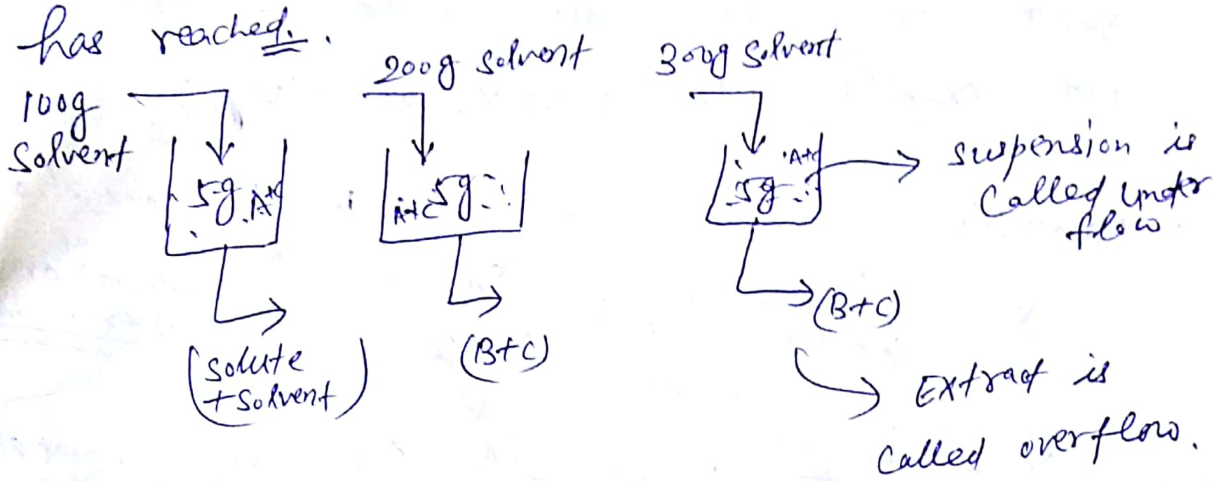
(I) Batch equipment

(II) Continuous contact equipment

- → The Bollman extractor
- → the Hildebrand "
- → Bonotto "
- → Continuous Horizontal basket extr
- → Continuous belt & rotocel extractor

Solid - Liquid Extraction Equilibrium

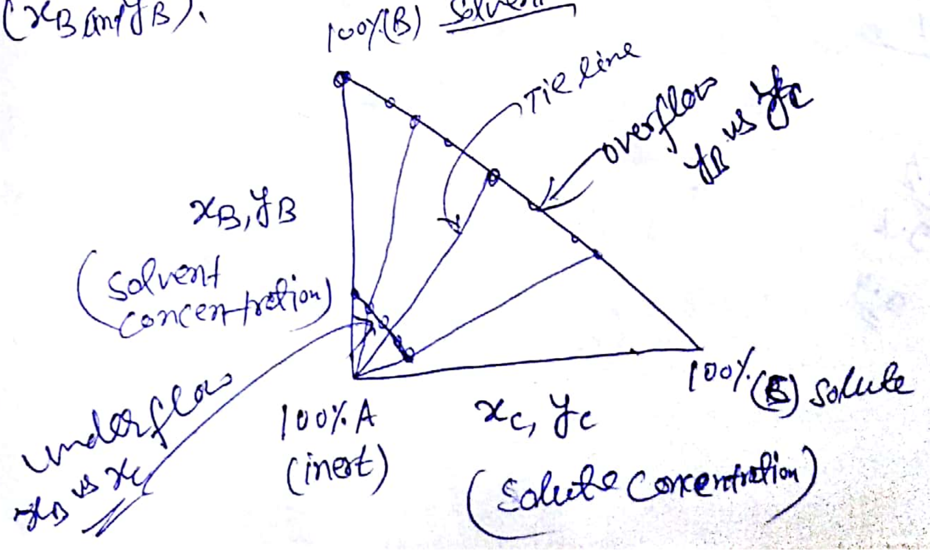
The equilibrium for SLE is obtained by mixing a known amount of solid in different amounts of solvent for some specified time to ensure equilibrium has reached.



Generally two methods are used to represent SLE equilibrium data.

(1) Triangular Diagram :-

In this method a right-angled triangle is formed and mass fractions of solute streams (x_c, y_c) are plotted against the solvent concentrations (x_B and y_B).



(ii) The Ponchon-Savarit Diagram

In this method, the mass ratio z of the inert or carrier A to that of B and C together is plotted against the mass fraction of the solute on A-free basis in both underflow and overflow (i.e Z vs X_c and Z' vs Y_c).

In LLE Z and Z' are mass fraction of B (solvent) on B-free basis

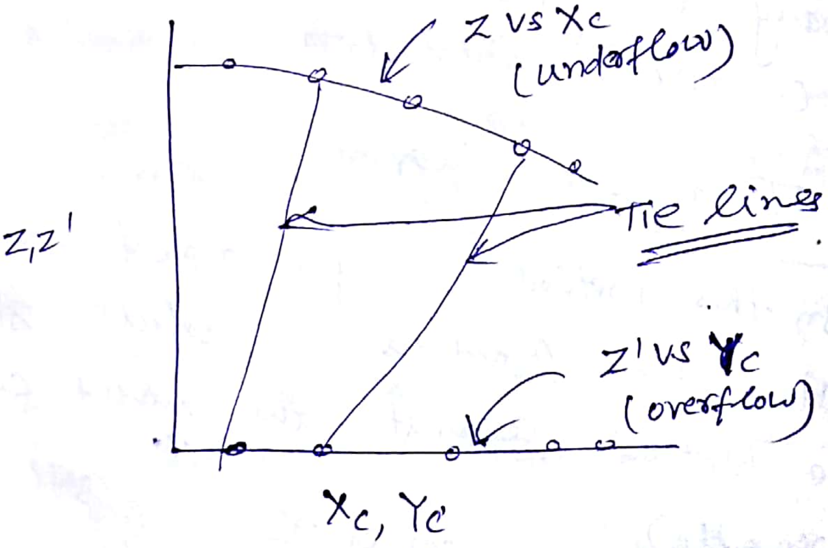
Underflow

$$X_c = \frac{x_c}{x_B + x_c}, \quad Z = \frac{x_A}{x_B + x_c}$$

overflow

$$Y_c = \frac{y_c}{y_B + y_c}, \quad Z' = \frac{y_A}{y_B + y_c}$$

in overflow amount of inert is very low



Assignment

Example: 9.1

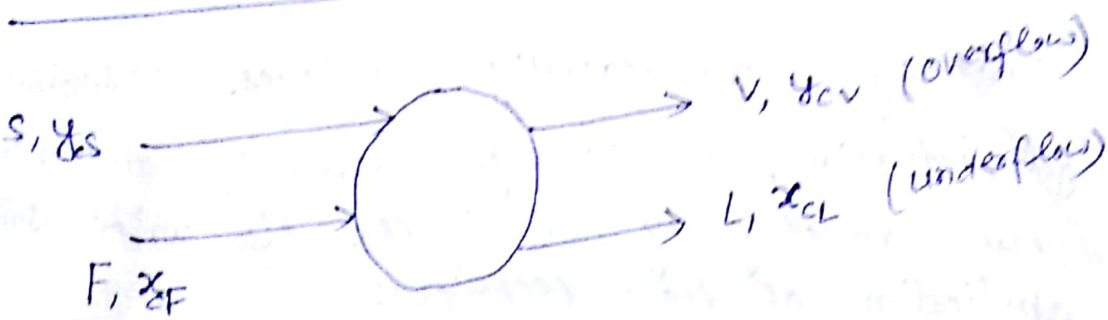
B.K. Dutta

9.2

9.3

9.4

Solid-liquid Extraction in a single batch contact



Single stage batch contact

Total Mass balance

$$F + S = V + L = M$$ (M is total mass of two stream)

Solute balance

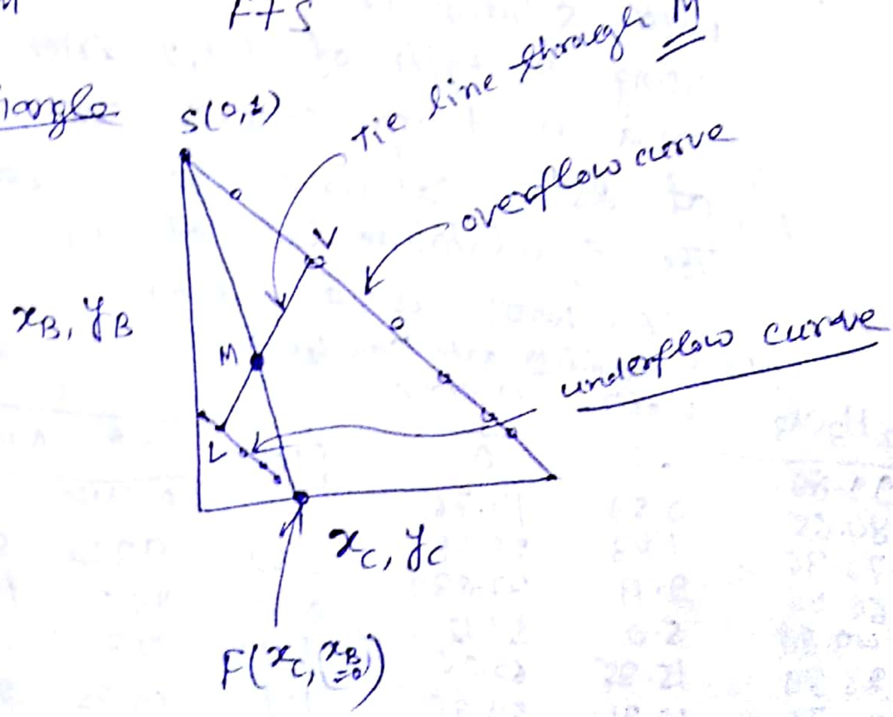
$$F(x_c)_F + S(y_c)_S = L(x_c)_L + V(y_c)_V = M(x_c)_M$$

$$(x_c)_M = \frac{F(x_c)_F + S(y_c)_S}{F+S}$$

Using right triangle

$S = S(y_c, y_B, \ldots)$

$\boxed{S = (y_c, y_B) = (0,1)}$

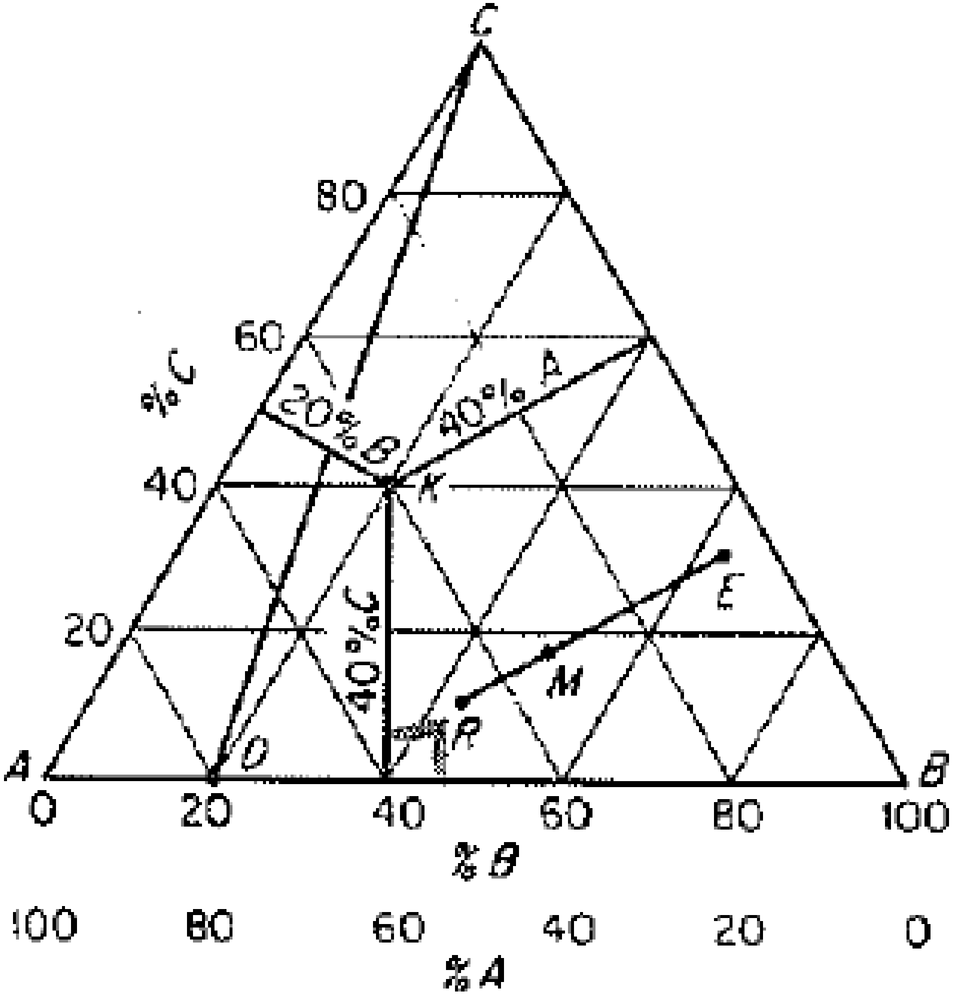


Liquid Liquid Extraction

Feed + Solvent (immiscible) = Extract (solvent Rich)+ Raffinate (diluent rich)

- Applications:
- Separation of dilute aqueous solution as it is economic compared to distillation
- Heat sensitive material as it is low temperature process – long chain fatty acids from vegetable oils compared to high vacuum distillation
- More economic compared to chemical method –Uranium& Vanadium, Hafnium & Zirconium, Tungsten & Molybdenum, purification of copper, phosphoric acid boric acid
- Close boiling mixtures like aromatic and paraffinic hydrocarbons
- From complex mixtures like penicillin

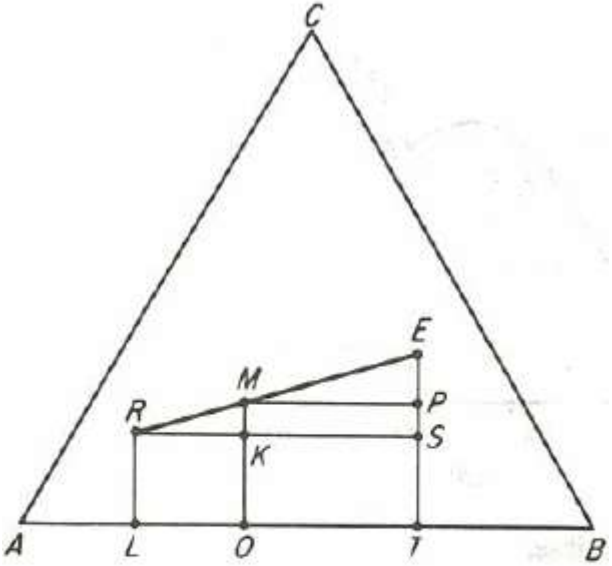
Equilateral triangular diagram



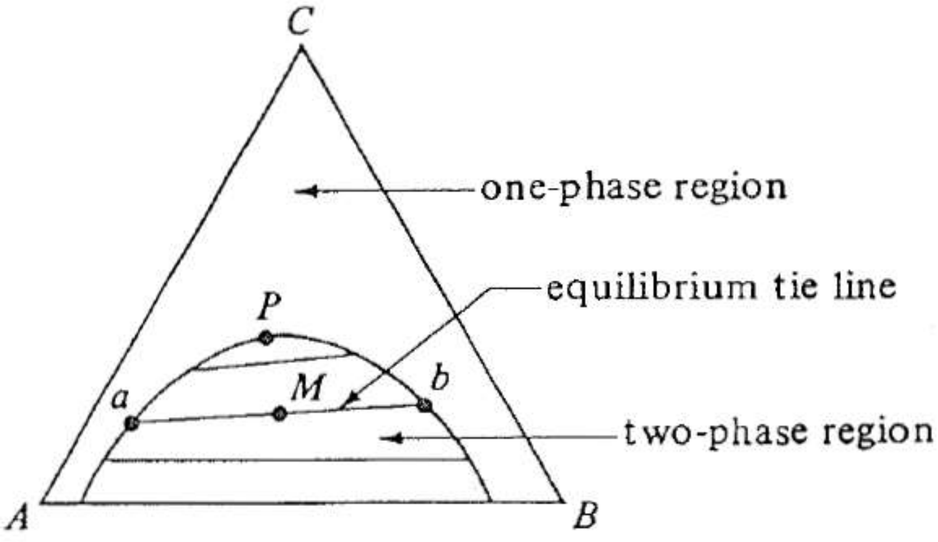
- If R kg of R is mixed with E kg of E. The resulting composition will lie on line RE at M:

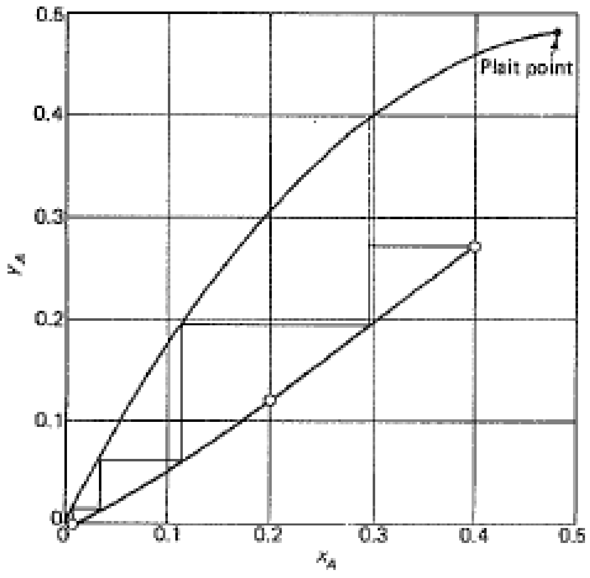
$$\frac{R}{E} = \frac{line\ ME}{line\ lRM} = \frac{x_E - x_M}{x_M - x_R}$$

- C added to original Mixture at D varies along line DC.

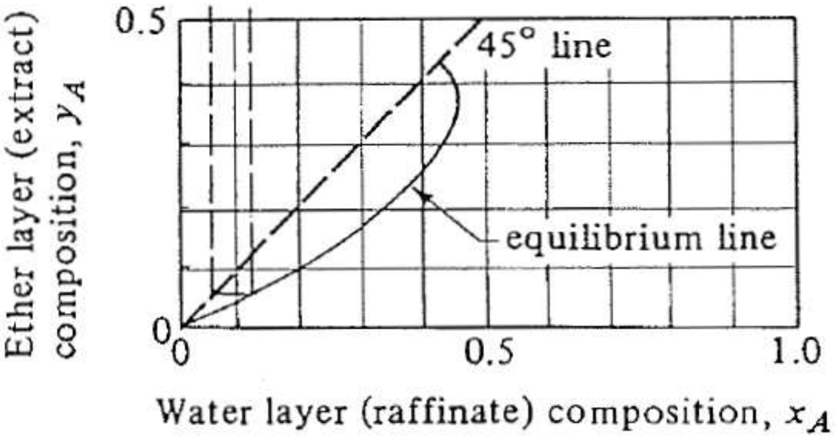


- $R + E = M$
- $Rx_R + Ex_E = Mx_M$
- $Rx_R + Ex_E = Rx_M + Ex_M$
- $\frac{R}{E} = \frac{x_E - x_M}{x_M - x_R} = \frac{EP}{PS} = \frac{ME}{RM}$

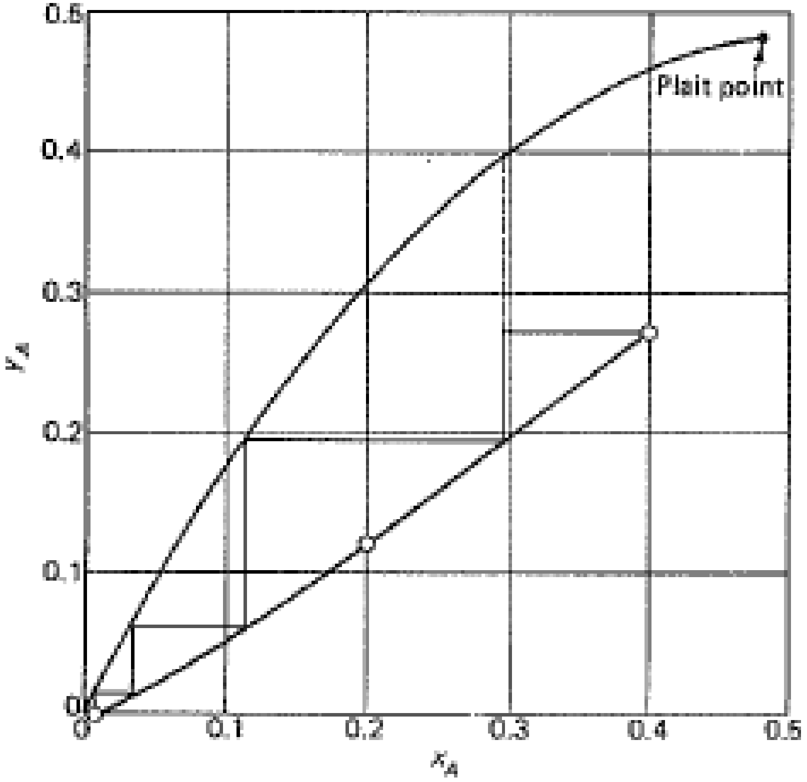




- Let A = diuent,B= solvent and C= solute
- Equilibrium diagram – Extract curve
- Raffinate curve [
- P= Plait point
- ab=tie line end point gives composition in extract phase and raffinate phase
- Composiiton in raffinate x
- Compostion in extract y

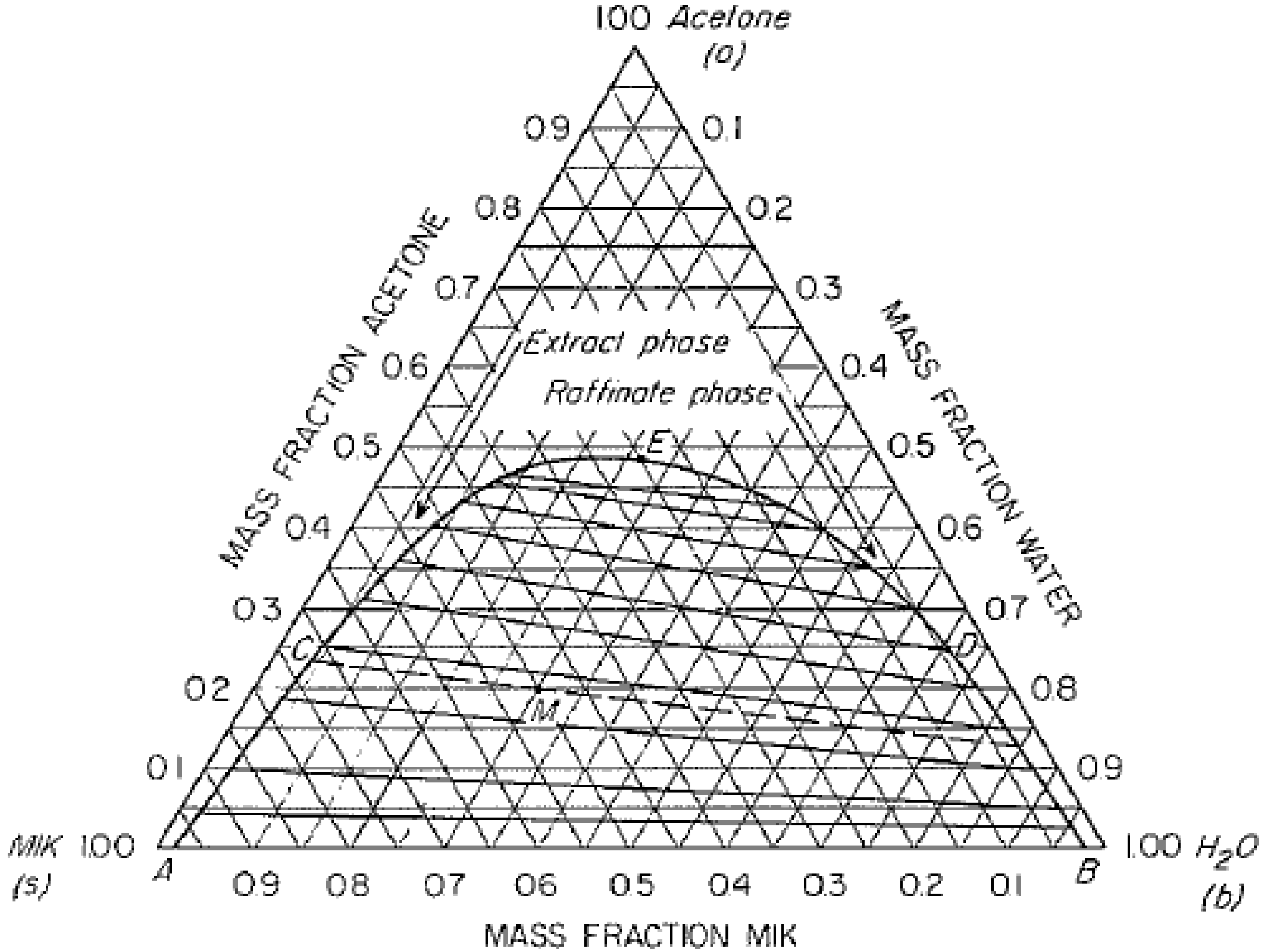


Ether layer (extract) composition, y_A
0.5
0
45° line
equilibrium line
0
0.5
1.0
Water layer (raffinate) composition, x_A



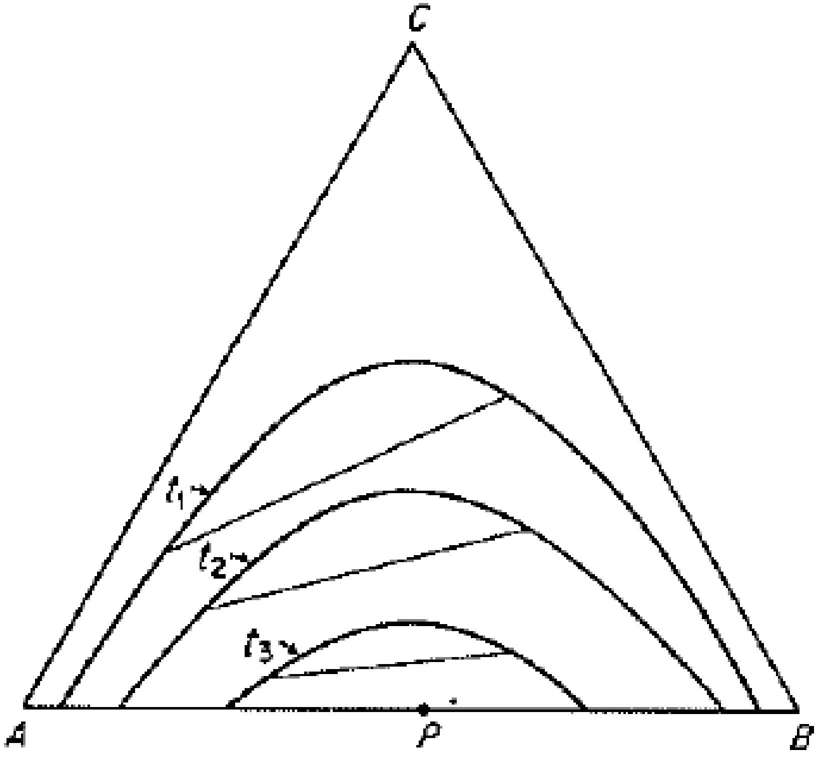
0.5
0.4
0.3
0.2
0.1
0
y_A
Plait point
0
0.1
0.2
0.3
0.4
0.5
x_A

System one pair partially miscible two pairs fully miscible



One pair partially miscible A-B two pairs fully miscible A-C and B-C

- Effect of temperature on equilibrium diagram
- t3>t2>t1
- As temperature increases region of homogeneity increases



Two pairs partially miscible A-B and B-C one pair fully miscible A-C

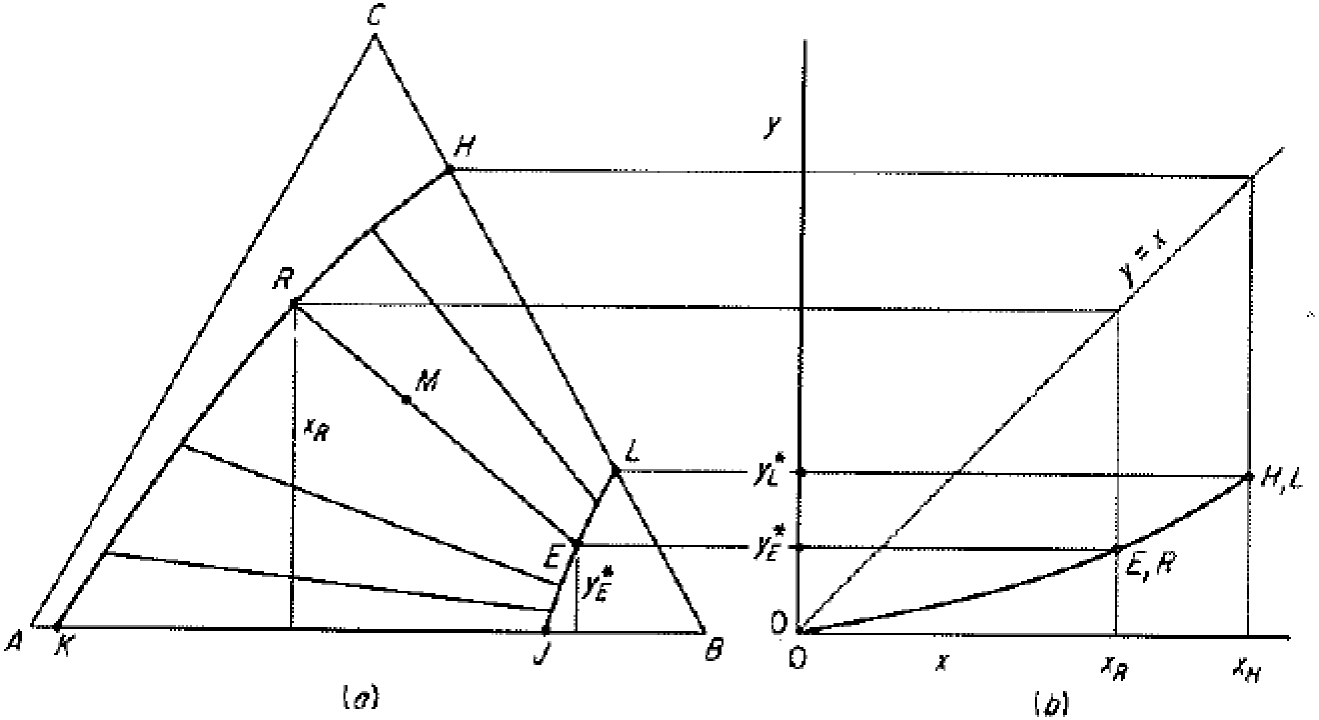
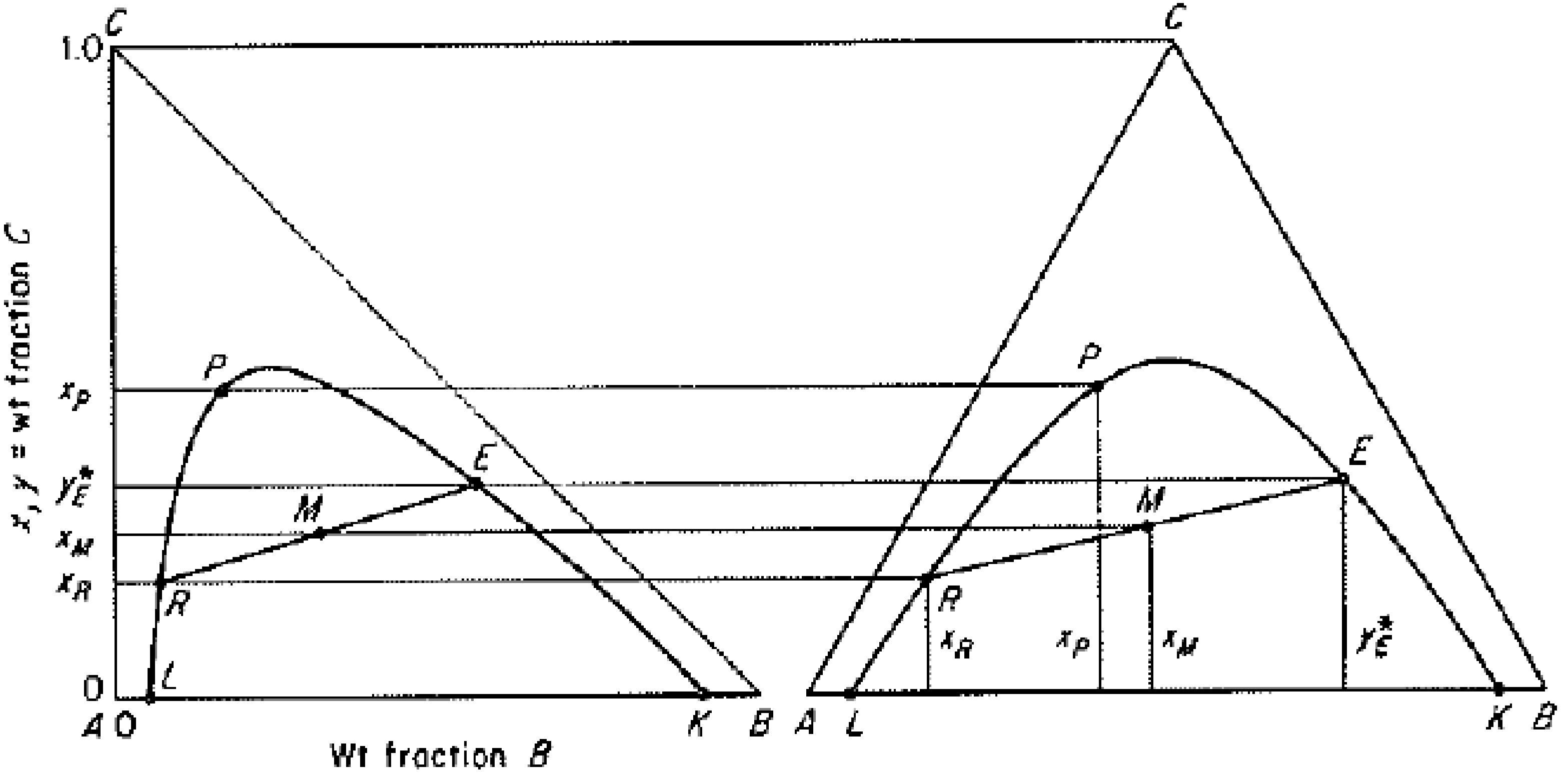


Figure 10.5 System of three liquids, A–B and B–C partially miscible.

Rectangular coordinates



SELECTION OF SOLVENT

1. Selectivity should be more than 1

$$\beta = \frac{Wt\ Frac\ C\ inE / Wt\ Frac\ A\ inE}{Wt\ Frac\ C\ inR / Wt\ Frac\ A\ inR} = \frac{y_E{}^{*}(Wt\ Frac\ A\ inR)}{x_R{}^{*}(Wt\ Frac\ A\ inE)}$$

2. Distribution coefficient : Large value

$$Deistribution\ coeff = \frac{y_E{}^{*}}{x_R{}^{*}}$$

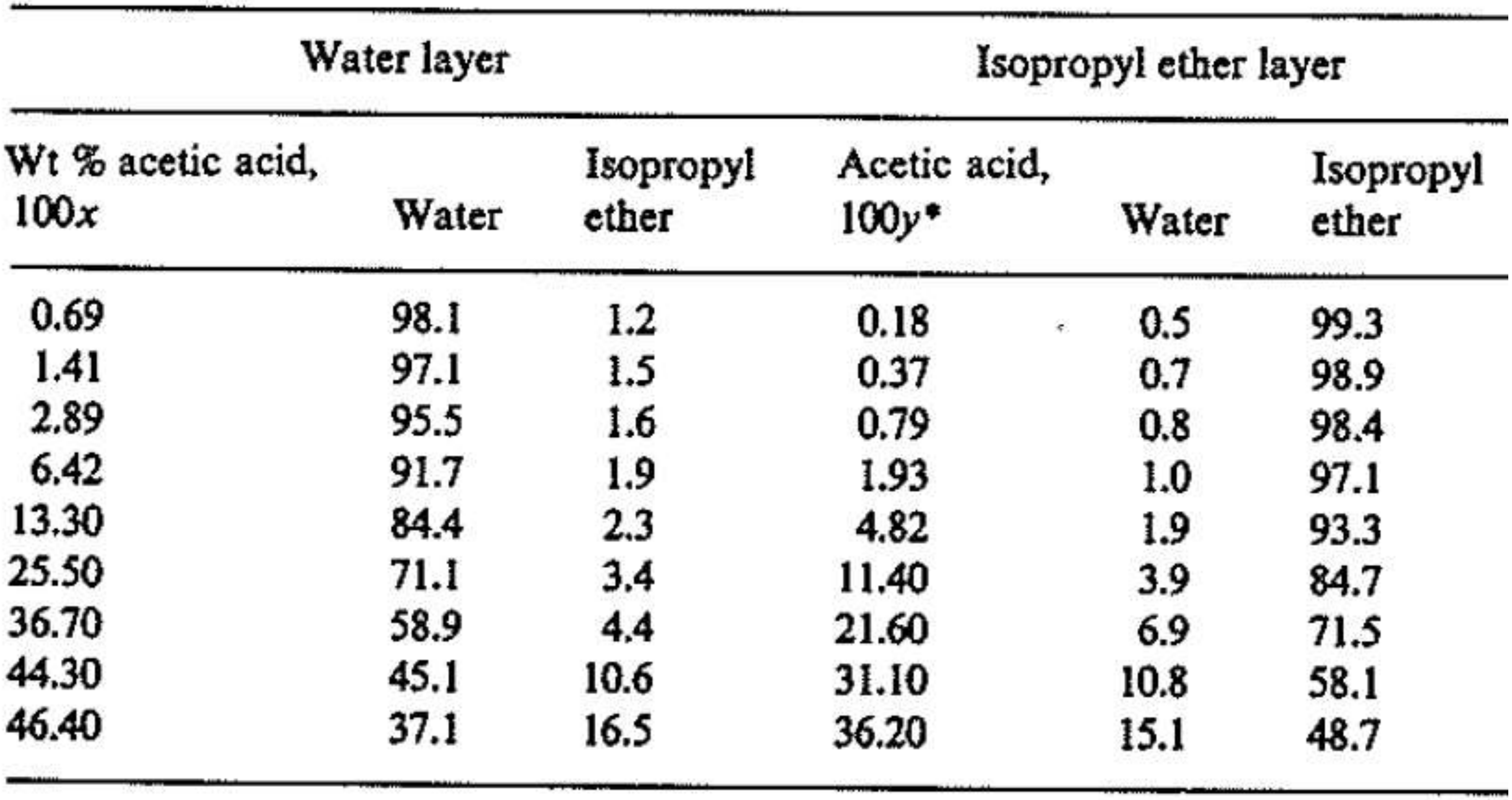
3. Insoluble in solvent
4. Recoverable
5. Density – difference in densities of liquid phases.
6. Interfacial tension high – helps coalescence and separation
7. Chemically stable and inert to components
8. Low Viscosity, vapour press. , and freezing pt. for easy handling and storage
9. Non toxic nonflammable and low cost

Pyridine	Chlorobenzene	Water	Pyridine	Chlorobenzene	Water
0	99.95	0.05	0	0.08	99.92
11.05	88.28	0.67	5.02	0.16	94.82
18.95	79.90	1.15	11.05	0.24	88.71
24.10	74.28	1.62	18.90	0.38	80.72
28.60	69.15	2.25	25.50	0.58	73.92
31.55	65.58	2.87	36.10	1.85	62.05
35.05	61.00	3.95	44.95	4.18	50.87
40.60	53.00	6.40	53.20	8.90	37.90
49.0	37.8	13.2	49.0	37.8	13.2

10.1 Plot the equilibrium data on the following coordinate systems: (*a*) triangular; (*b*) x and y against weight fraction B; (*c*) x against y.

10.2 Compute the selectivity of chlorobenzene for pyridine at each tie line, and plot selectivity against concentration of pyridine in water.

Determine



Water layer			Isopropyl ether layer		
Wt % acetic acid, $100x$	Water	Isopropyl ether	Acetic acid, $100y^*$	Water	Isopropyl ether
0.69	98.1	1.2	0.18	0.5	99.3
1.41	97.1	1.5	0.37	0.7	98.9
2.89	95.5	1.6	0.79	0.8	98.4
6.42	91.7	1.9	1.93	1.0	97.1
13.30	84.4	2.3	4.82	1.9	93.3
25.50	71.1	3.4	11.40	3.9	84.7
36.70	58.9	4.4	21.60	6.9	71.5
44.30	45.1	10.6	31.10	10.8	58.1
46.40	37.1	16.5	36.20	15.1	48.7

Single stage extraction

$$F + S = E_1 + R_1 = M$$

$$Fx_F + Sy_s = E_1y_1 + R_1x_1 = Mx_M$$

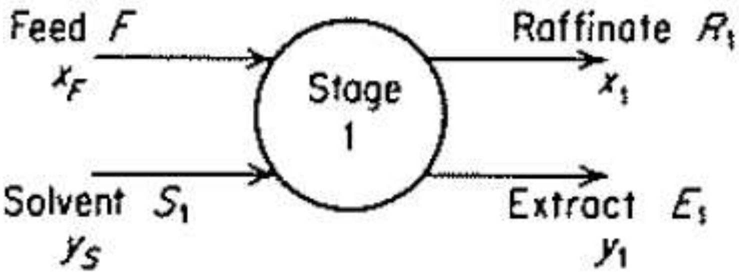
$$x_M = \frac{Fx_F + Sy_S}{M}$$

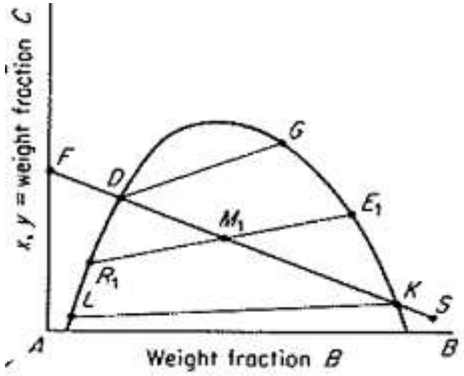
STEPS:

Locate F and S

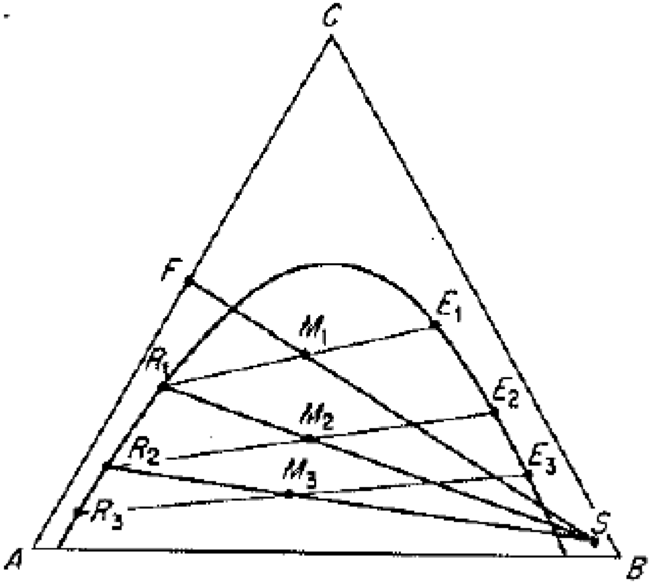
Locate M on line FS at x_M

Draw tie line through M to get E_1 and R_1





Multistage Cross Current Extraction



$F + S_1 = E_1 + R_1 = M_1$

$Fx_F + S_1 y_s = E_1 y_1 + R_1 x_1 = M_1 x_{M_1}$

2nd stage

$R_1 + S_2 = E_2 + R_2 = M_2$

$R_1 x_1 + S_2 y_s = E_2 y_2 + R_2 x_2 = M_2 x_{M_2}$

3rd stage

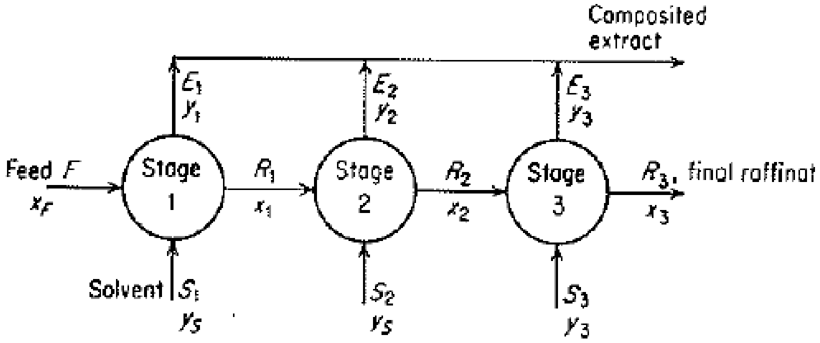
$R_2 + S_3 = E_3 + R_3 = M_3$

$R_2 x_F + S_3 y_s = E_3 y_3 + R_3 x_3 = M_3 x_{M_3}$

Final Extract

$E_1 + E_2 + E_3 = E$

$E y_E = E_1 y_1 + E_2 y_2 + E_3 y_3$

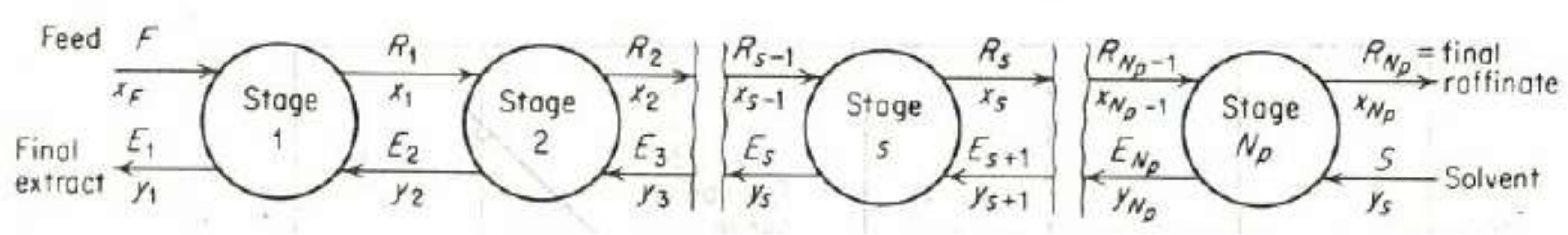


1. Locate F and S
   Locate M_1 on line FS at x_{M1}
   Draw tie line through M1 to locate E_1 and R_1
   Find $y_1 and x_1$

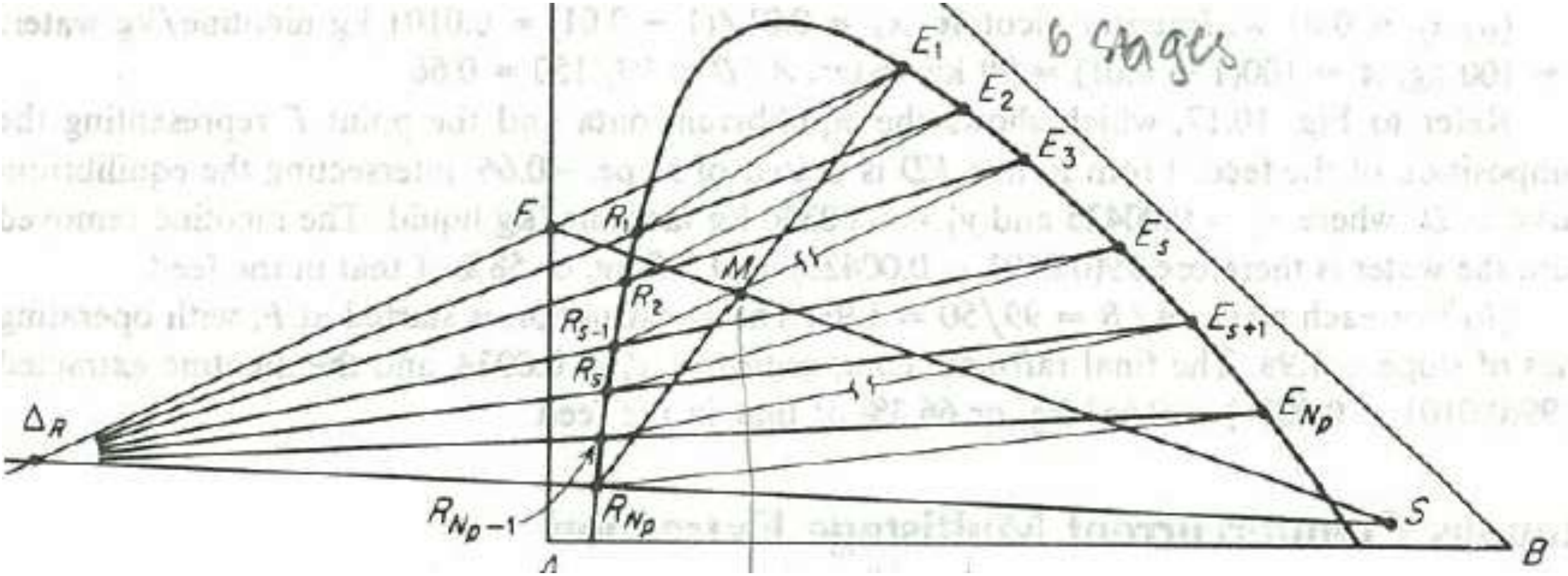
2. Locate R1 and S
   Locate M_2 on line R1S at x_{M2}
   Draw tie line through M2 to Locate E_2 and R_2
   Find $y_2 and x_2$

3. Locate R2 and S
   Locate M_3 on line R2S at x_{M3}
   Draw tie line through M3 to locate E_3 and R_3
   Find $y_3 and x_3$

Multistage Counter current Extraction

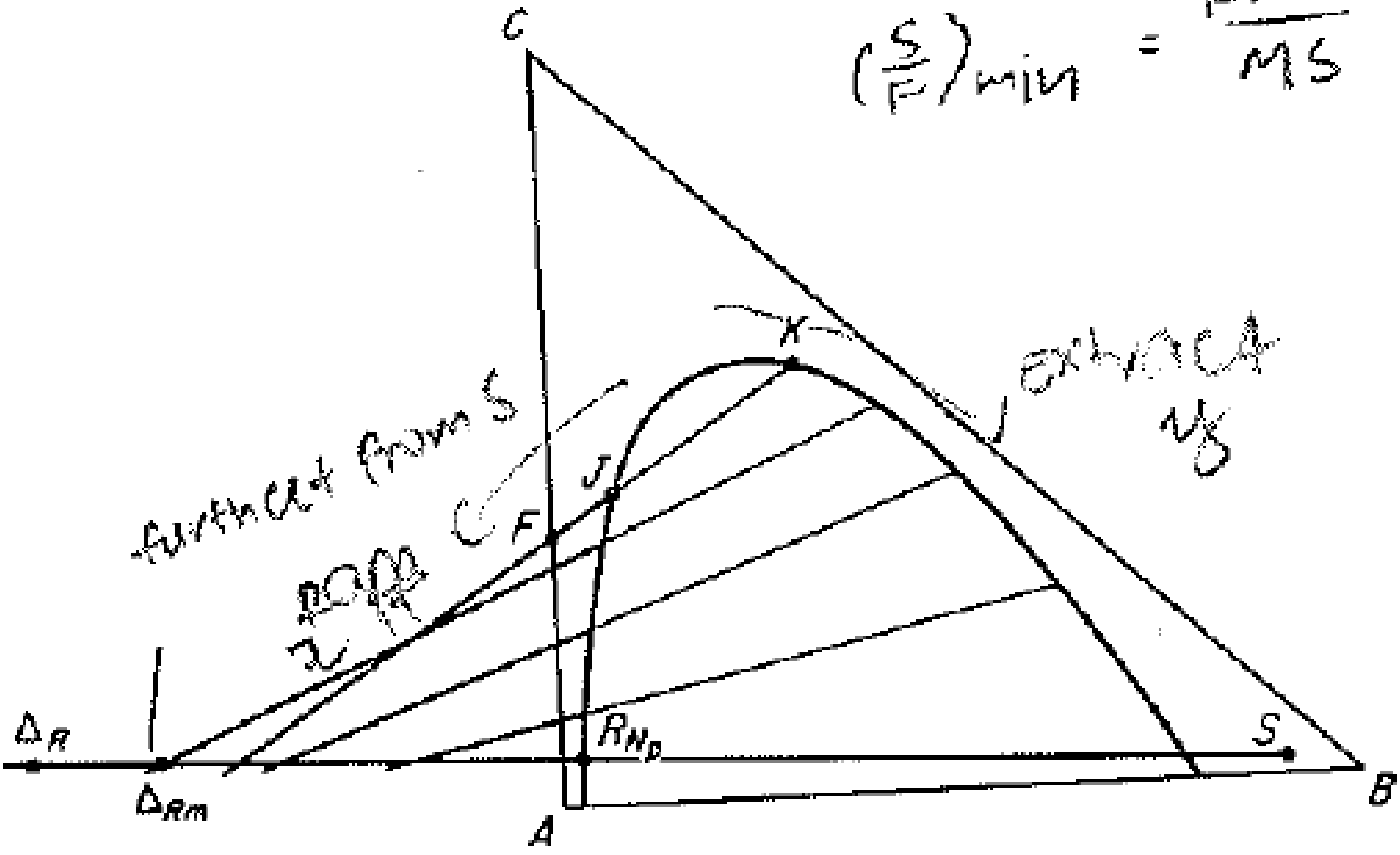


- $F + S = M = R_{Np} + E_1$
- $Fx_F + Sy_s = Mx_M = R_{Np}x_{Np} + E_1y_1$
- $R_{Np} - S = F - E_1 = \Delta R = R_1 - E_2 =$ $..=$Difference point ΔR
- $\Delta R + S = R_{NP}\ \ and\ \Delta R + E_1 = F$



- Locate F,S,M, RNP
- Join RNP and M to get E1
- Join E1, F and extend
- Join S, RNp and extend to get $\Delta Rppoint$
- Draw tie line through E1 to get R1
- Join $\Delta R\ and\ R1\ extend\ toget$ E2
- Draw tie line through E2 to get R2
- Join $\Delta R\ and\ R1\ extend\ toget$ E2
- Repeat above two steps to get number of stages

Minimum solvent requirement



$$\left(\frac{S}{F}\right)_{min} = \frac{FM}{MS}$$

LEACHING

Equilibrium relationship

Single stage leaching

Multistage counter current leaching

Leaching Process

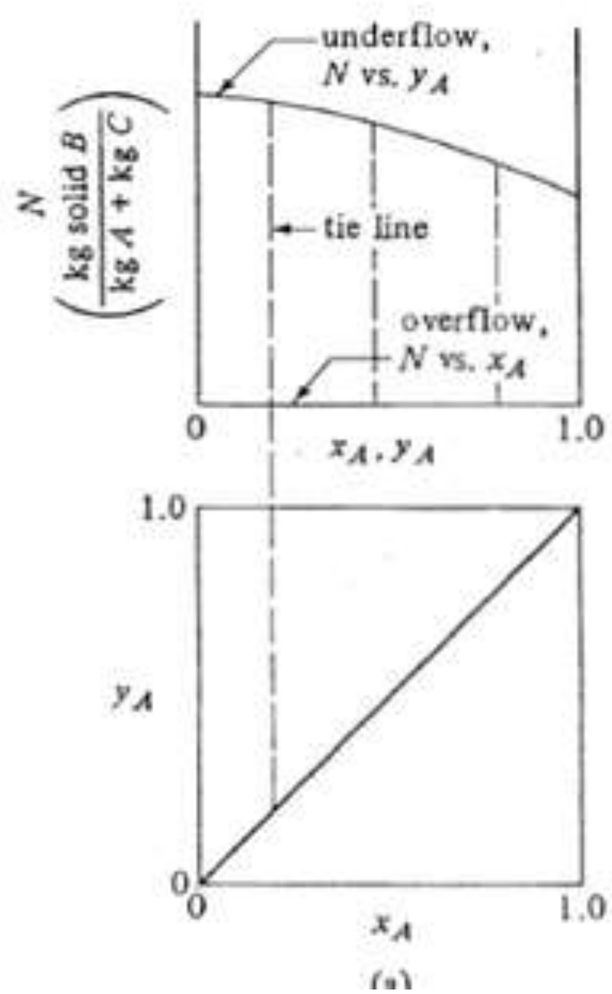
- Step I – solid containing solute and inert mixed with solvent
- Step II – Agitation stopped and separated into solid free overflow and underflow
- Overflow = solvent containing dissolved solute
- Underflow or slurry stream = inert solid and adhering solution [containing solvent and dissolved solute, generally of same concentration as overflow]

Symbols

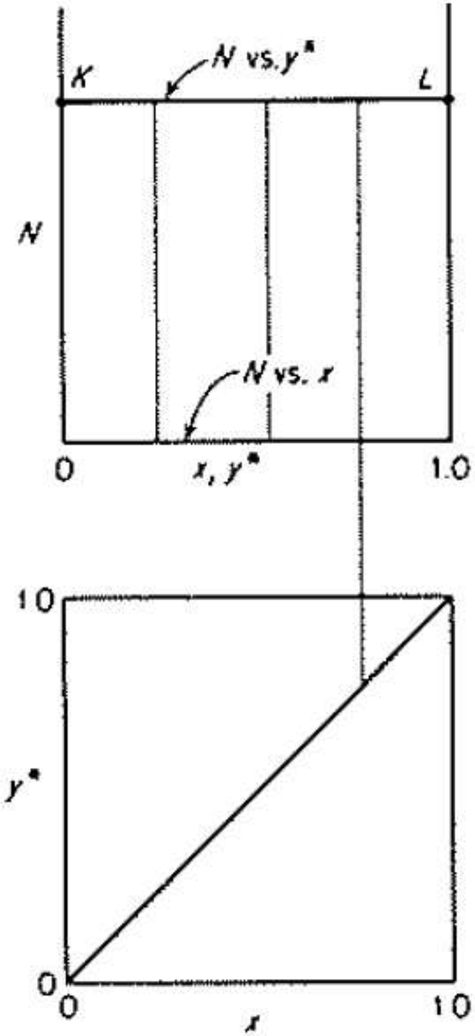
- Solute = A
- Inert solid = B
- Solvent =C
- Concentration of Inert solid:
- $N = \frac{kg\ of\ B}{kg\ of\ A + kg\ of\ C} = \frac{kg\ of\ inert}{kg\ of\ solution}$
- Concentration of solute
- $In\ overflow\ liquid, x_A = \frac{kg\ of\ A}{kg\ of\ A + kg\ of\ C} = \frac{kg\ of\ solute}{kg\ of\ solution}$
- $In\ underflow\ liquid, y_A = \frac{kg\ of\ A}{kg\ of\ A + kg\ of\ C} = \frac{kg\ of\ solute}{kg\ of\ solution}$

Equilibrium diagram for variable underflow and vertical tie line

- Equilibrium Diagram
- No solid in over flow-N=0 for overflow curve
- No adsorption of solute by solid
- concentration of withdrawn solution is same as that of solution associated with solid-tie lines are vertical
- Distribution coefficient =1. and Distribution curve is x=y
- Solution retention changes with concentration – N varies with y



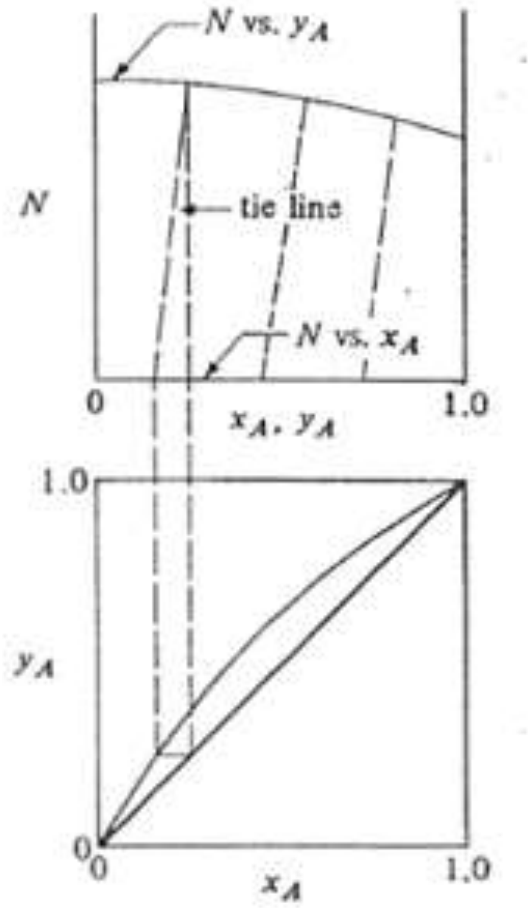
Equilibrium diagram Constant underflow and vertical tie line



- Equilibrium diagram for case Constant underflow:
- Solids settled or drained to same extent at all solute concentration
- Line KL is horizontal

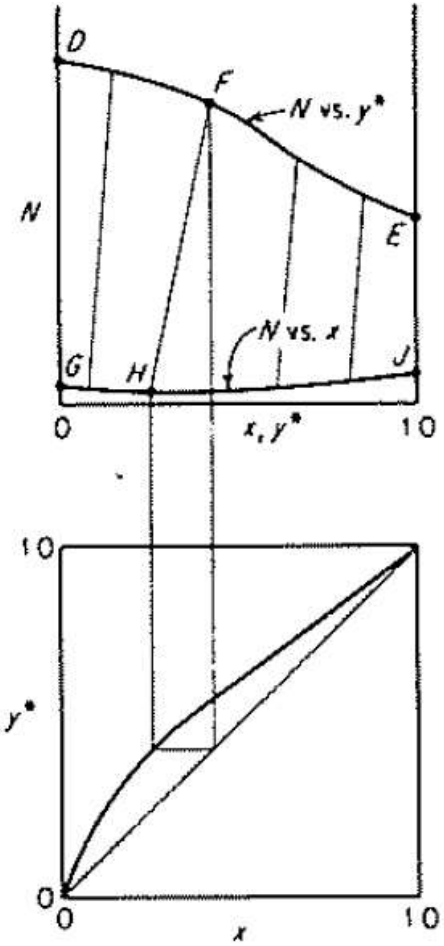
Equilibrium Diagram – non vertical tie line $[y \neq x]$ variable under flow

- Equilibrium diagram for case [tie lines are not vertical]:
- Insufficient contact time, so that all the solute is not dissolved
- Adsorption of solute in the solid.

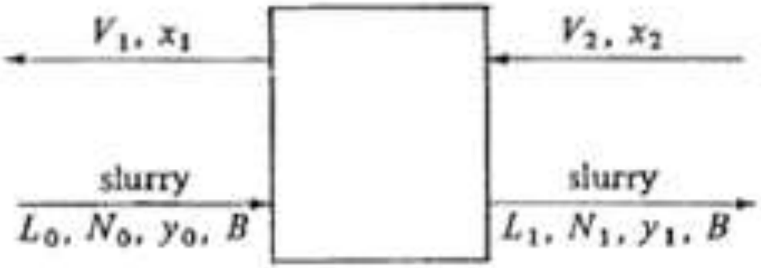


Equilibrium diagram – solids in overflow

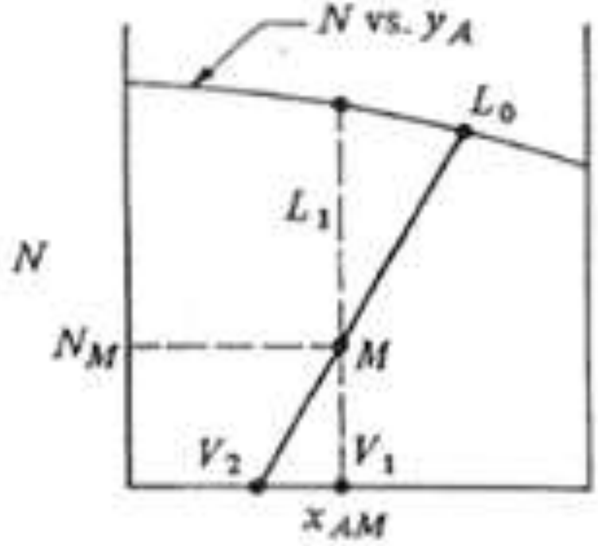
- Equilibrium diagram for case Solids in the overflow
- Solute adsorption on solids



SINGLE STAGE LEACHING



(a)



- **V= kg/h of overflow solution (A+C)with composition x**
- **L= kg/h of liquid (solution) in slurry(A+C) with composition y**
- **B= kg/hr of solute free inert solid flow**
- Total Mass Balance:

$$L_o + V_2 = L_1 + V_1 = M$$

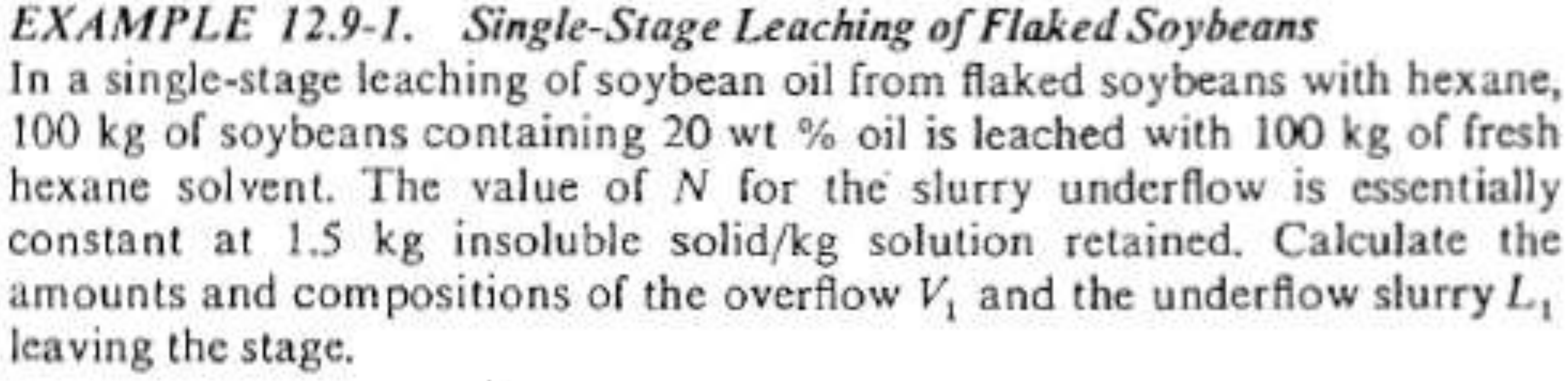
- Solute Balance

$$L_o y_o + V_2 x_2 = L_1 y_1 + V_1 x_1 = M x_M$$

M=Total flow rate kg (A+C)/hr

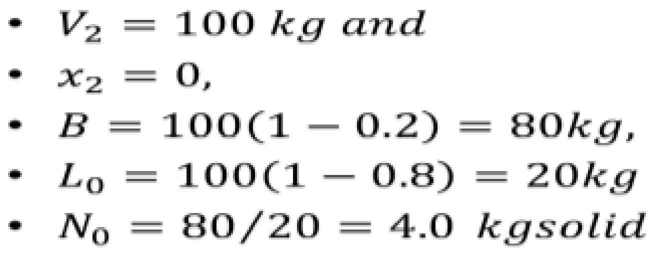
- Inert solid Balance

$$B = N_0 L_0 + 0 = N_1 L_1 + 0 = M N_M$$



EXAMPLE 12.9-1. Single-Stage Leaching of Flaked Soybeans

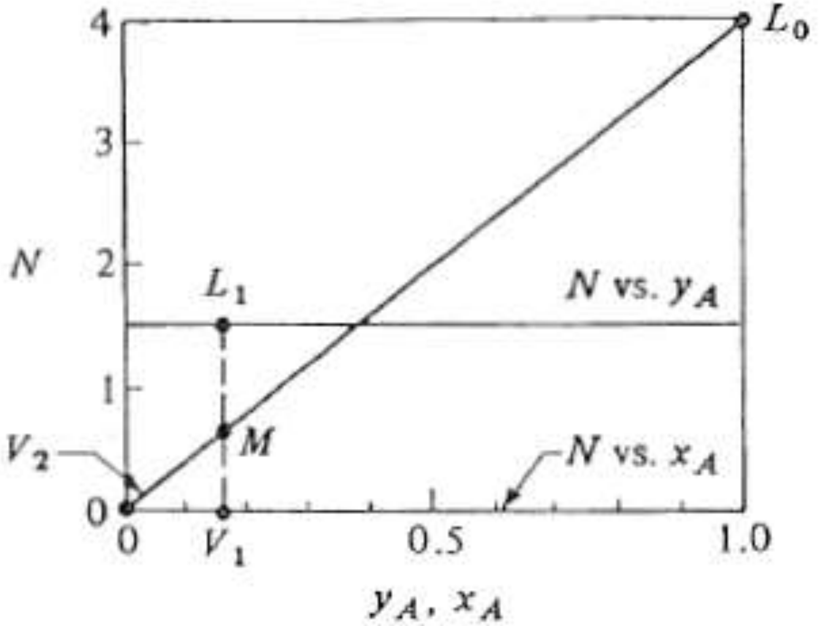
In a single-stage leaching of soybean oil from flaked soybeans with hexane, 100 kg of soybeans containing 20 wt % oil is leached with 100 kg of fresh hexane solvent. The value of N for the slurry underflow is essentially constant at 1.5 kg insoluble solid/kg solution retained. Calculate the amounts and compositions of the overflow V_1 and the underflow slurry L_1 leaving the stage.



- $V_2 = 100\ kg\ and$
- $x_2 = 0,$
- $B = 100(1 - 0.2) = 80kg,$
- $L_0 = 100(1 - 0.8) = 20kg$
- $N_0 = 80/20 = 4.0\ kgsolid$

- **Refer Geankoplis**

- $V_2 = 100\ kg\ and$
- $x_2 = 0,$
- $B = 100(1 - 0.2) = 80kg,$
- $L_0 = 100(1 - 0.8) = 20kg\ and\ y_0 = 1.0$
- $N_0 = 80/20 = 4.0\ \ kgsolid/kgsolution$



$$L_o + V_2 = L_1 + V_1 = M$$

$$L_o + V_2 = 20 + 100 = 120kg = M$$

$$L_o y_o + V_2 x_2 = L_1 y_1 + V_1 x_2 = M x_M$$

$$L_o y_o + V_2 x_2 = 20(1.0) + 100(0)$$

$$= 120 x_M$$

Or $x_M = 0.167$

$$B = N_0 L_0 + 0 = N_1 L_1 + 0 = M N_M$$

- $B = 4\ (20) = 80 = N_M (120)$
- $N_M = 0.667$

Locate M on line noiningV2 and Lo

Draw veritcal line to get L1 and V1.

$$y_1 = x_1 = 0.167\ \ and\ N_1 = 1.5$$

$$L_1 = 53.3\ and\ V_1 = 66.7kg$$

COUNTERCURRENT MULTISTAGE LEACHING

- Total Mass Balance: $L_o + V_{N+1} = L_N + V_1 = M$
- Solute Balance

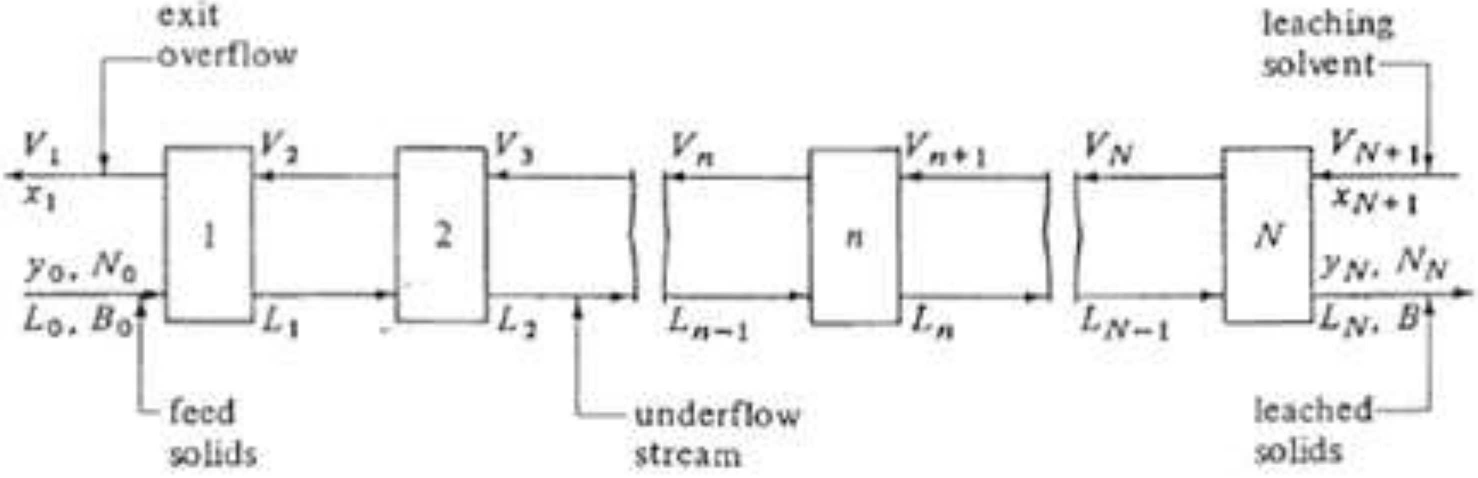
$$L_o y_o + V_{N+1} x_{N+1} = L_N y_N + V_1 x_1 = M x_M$$

Equation of Operating line:

$$x_{N+1} = \frac{L_N}{V_{N+1}} y_N + \frac{V_1 x_1 - L_o y_o}{V_{N+1}}$$

- Inert solid Balance

$$B = N_0 L_0 + 0 = N_1 L_1 + 0 = M N_M$$



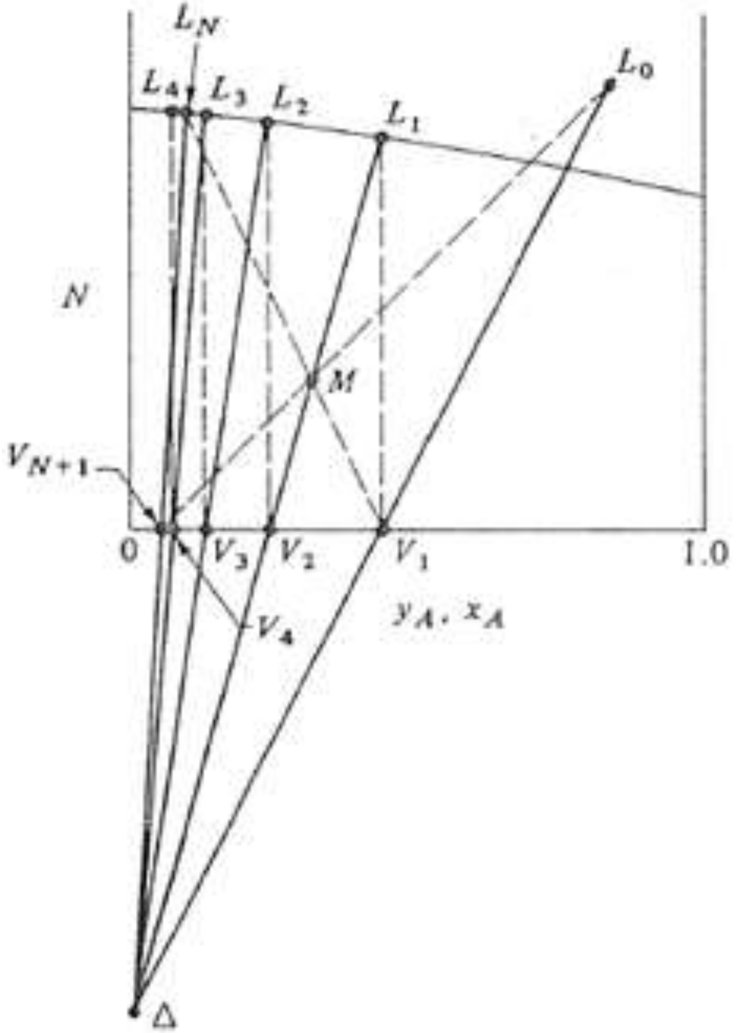
EXAMPLE 12.10-1. Countercurrent Leaching of Oil from Meal

A continuous countercurrent multistage system is to be used to leach oil from meal by benzene solvent (B3). The process is to treat 2000 kg/h of inert solid meal (*B*) containing 800 kg oil (*A*) and also 50 kg benzene (*C*). The inlet flow per hour of fresh solvent mixture contains 1310 kg benzene and 20 kg oil. The leached solids are to contain 120 kg oil. Settling experiments similar to those in the actual extractor show that the solution retained depends upon the concentration of oil in the solution. The data (B3) are tabulated below as N kg inert solid B/kg solution and y_A kg oil A/kg solution.

N	y_A	N	y_A
2.00	0	1.82	0.4
1.98	0.1	1.75	0.5
1.94	0.2	1.68	0.6
1.89	0.3	1.61	0.7

Calculate the amounts and concentrations of the stream leaving the process and the number of stages required.

COUNTERCURRENT MULTISTAGE LEACHING



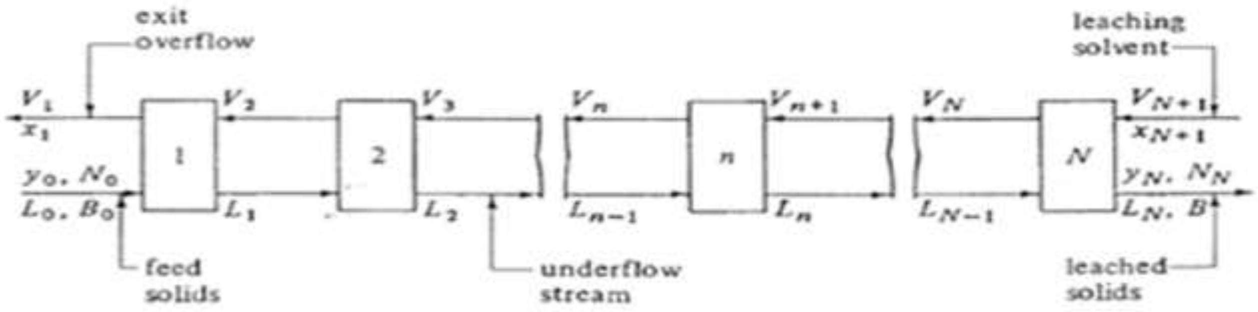
- Material balance around stage 1:

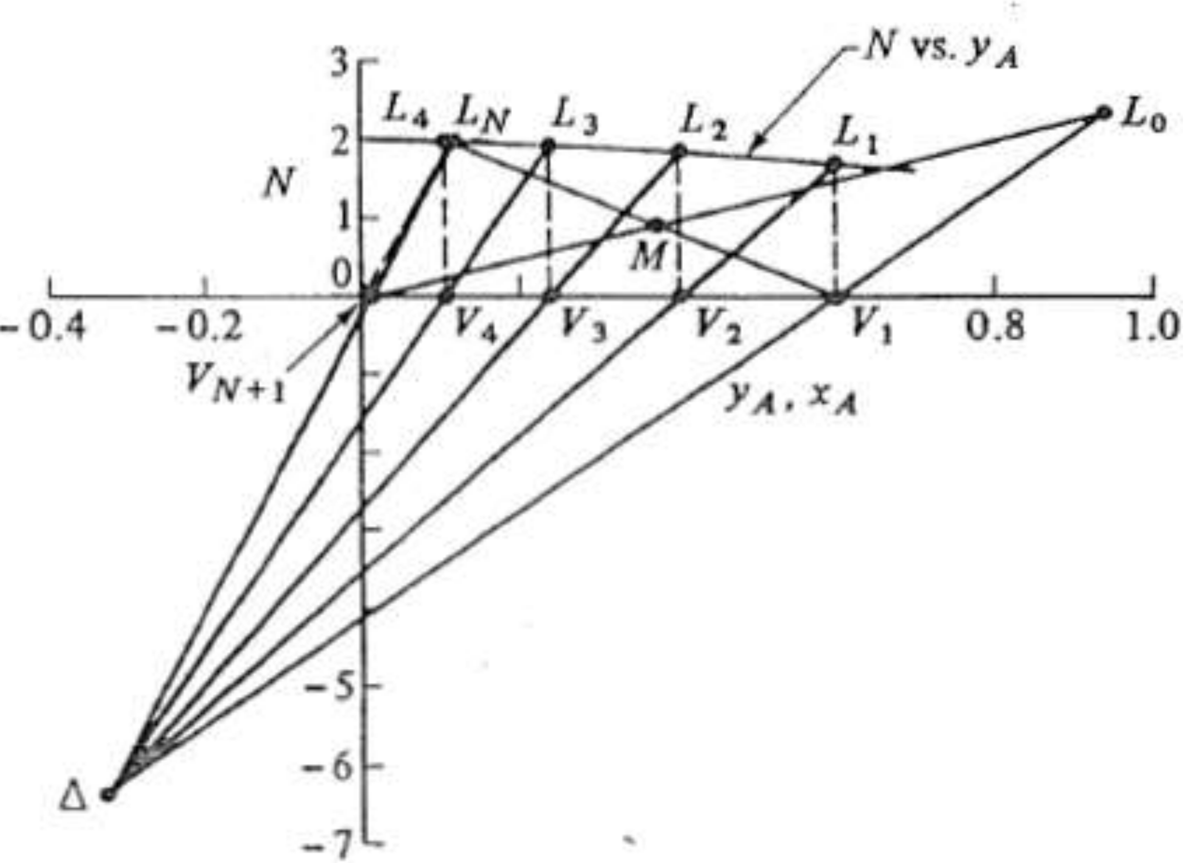
$$L_o + V_2 = L_1 + V_1$$

- Stage n

$$L_{n-1} + V_{n+1} = L_n + V_n$$

- $\Delta = L_0 - V_1 = L_1 - V_2 = L_n - V_{n+1} = \ldots$





- $L_0 = 800 + 50 = 850$
- $y_0 = \frac{800}{850} = 0.941$
- B= 2000
- $N_0 = \frac{2000}{800+50} = 2.36$
- $V_{N+1} = 1310 + 20 = 1330$
- $x_{N+1} = \frac{20}{1330} = 0.015$
- Locate Lo and VN+1
- Locate LN
- $\frac{N_N}{y_N} = \frac{kg\ inert}{kg\ soln} x \frac{kg\ soln}{kg\ solute} = \frac{kg\ inert}{kg\ solute} = \frac{2000}{120} = 16.67$
- Draw line through origin with slope 16.67 and locate LN

$N_N = 1.95\ and\ y_N = 0.118$

- Overall Balance:
- $L_0 + V_{N+1} = 850 + 1330 = M = 2180 kg/h$
- Solute Balance
- 850(0.941)+1330(0.015)= 2180x_M
- $x_M = 0.376$
- Locate M
- Join Lo, M and extend to get V1, $x_1 = 0.6$
- Locate Δ
- Locate L1, V2,L2.
- Determine LN and V1:
- $L_N + V_1 = M = 2180$
- $L_N\, y_N + V_1 x_1 = M x_M$
- $L_N\,(0.118) + V_1(0.6) = 2180\ x\ 0.376$
- LN= 1016kg
- V1=1164kg