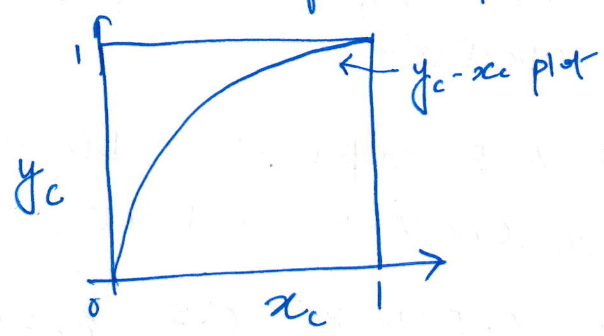
Liquid-liquid extraction: Ternary Diagrams

In LLE, three components are involved. To represent their concentrations, ternary diagrams are often used.

- A : Carrier liquid
- B : Solvent
- C : Solute

Depending on the miscibility of components A, B & C, diff ternary diagrams / concentration-distribution can be observed.

(i) Case 1: A & B are completely immiscible: This case is similar to what was observed in absorption (air/gas & liqui were completely immiscible). Concentration of solute C in feed (with carrier liquid) & solvent can be expressed on y-x plot as was done in the case of absorption.

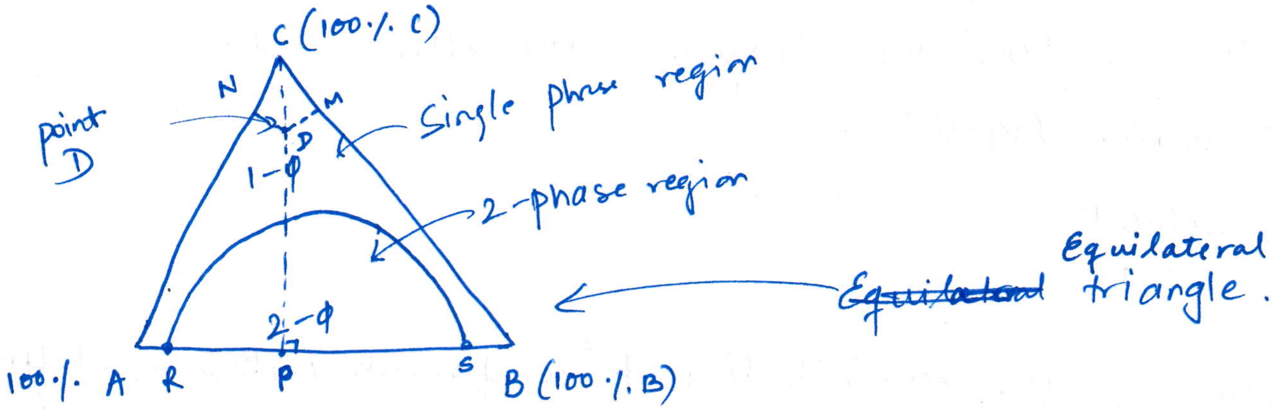


y_c : Conc. of solute in solvent at equilibrium

x_c : Conc. of solute in the feed (carrier liquid) at equilibrium

(ii) Case 2: A & B are partially miscible. However, C is completely miscible with A. Similarly, C is completely miscible with B. [A-C & B-C are miscible in all proportions]. In this case, type-I ternary diagram is observed.

Type I ternary diagram :



Type-I Ternary diagram

Let us discuss ternary diagram, in general, first. Note, on the ternary diagram, the concentrations of solute, solvent & carrier liquid are specified.

* 100% A, 100% B & 100% C represent concentrations of pure A, B & C, respectively.

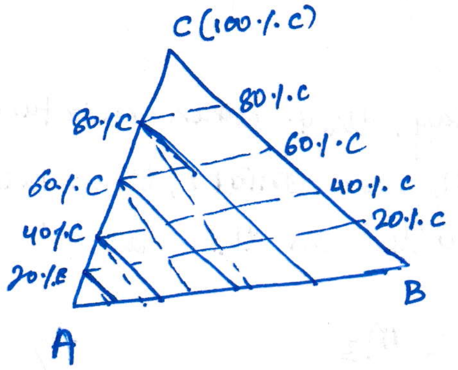
* Any point on line A-B represent a binary mixture of A & B. Say, on line A-B, a point at 50% A represent $z_A = 0.5$ & $z_B = 0.5$, $z_c = 0$.

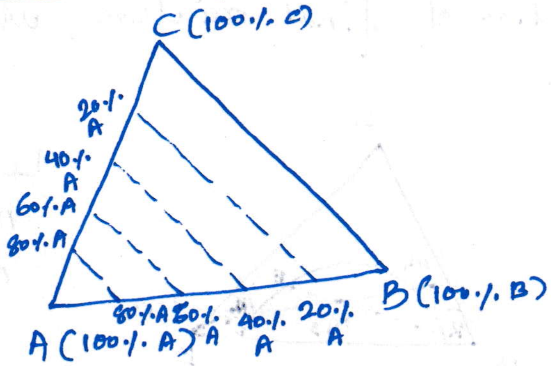
  Similarly, any point on line A-C & B-C represent binary mixtures of A & C and B & C, respectively.

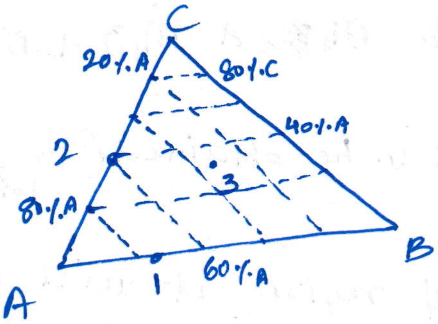
* Any point within the ternary diagram (other than lines A-B, A-C, B-C & vertices A, B & C) represent a ternary mixture. For example, consider point D,

$$\left.\begin{array}{l} \text{length } DM = \text{Concentration of } A \\ \quad " \quad DN = \text{Concentration of } B \\ \quad " \quad DP = \text{Concentration of } C \end{array}\right\} \begin{array}{l} \text{For any point } D, \\ DM + DN + DP = CP \\ \text{for an Equilateral traingle.} \end{array}$$

For example, consider the following example:







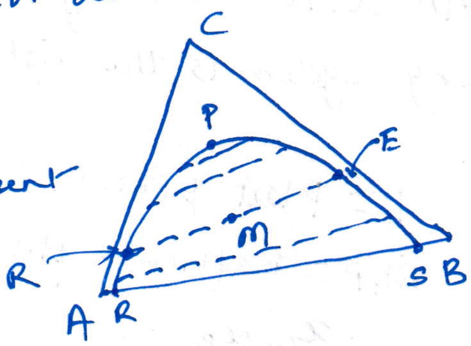
Point 1 ≈ 75% A, 25% B

Point 2 ≈ 60% A, 40% C

Point 3 ≈ 30% A, 30% C, 40% B

Now, in the case of type I ternary diagram, any mixture in the 2-φ mixture separates into raffinate & extract phases when allowed ~~to~~ to stay undisturbed.

Dotted lines represent tie lines.



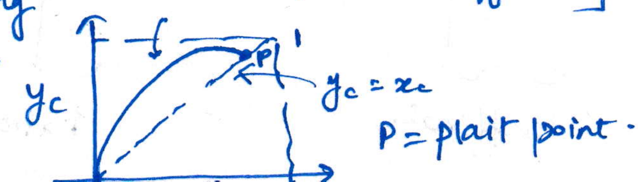
Note: Here R = solubility of B in pure A

Similarly, S = solubility of A in pure B.

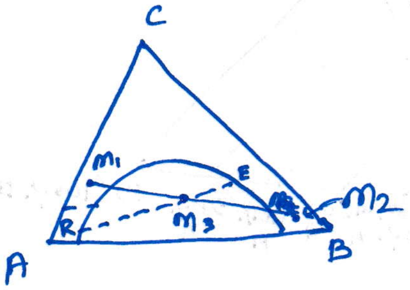
- Any point m in the 2-φ region separates into an extract phase (point E) & a raffinate phase (point R).

Note: E is extract as one can see that the concentration of C (solute) at point E is higher that that for point R (raffinate).

- Point P = plait point. At P: $y_c = x_c$ [conc. of solute in extract = conc. of solute in raffinate]
- One can plot y_c vs x_c, by noting their conc. from various tie-lines.



- Concentration of final mixture, when mixing two separate mixture.



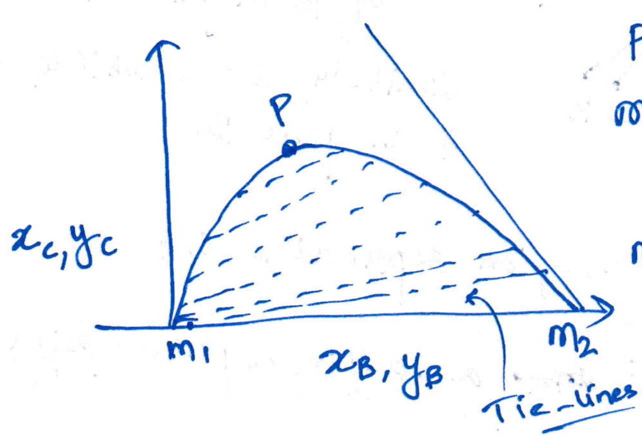
Let us say, that when mixtures M_1 & M_2 are mixed, then point M_3 results. In this case:

$$\left.\begin{aligned} M_1 + M_2 &= M_3 \\ \& \quad M_1 z_1 + M_2 z_2 &= M_3 z_3 \end{aligned}\right\}$$

$\Rightarrow$ z_c can be obtained (z_c lies on the line joining M_1 & M_2)

- Note, since z_3 is in 2-ϕ region, it will separate into extract & raffinate depending on the tie line on which it lies.

- Right Angle coordinate: An alternate way to represent the concentration of ternary system is the right-angle coordinate.



P = Plait point.

M_1P = Raffinate plot, that is, x_c, x_B

M_2P = Extract plot, that is, y_c vs y_B

Data:

x_B	x_C

Raffinate

y_B	y_C

Extract

mole or mass fraction

$x_B = \dfrac{b}{a+b+c}$ in raffinate.

$x_c = \dfrac{c}{a+b+c}$ in raffinate.

Similarly:

$y_B = \dfrac{b}{a+b+c}$ in extract

$y_c = \dfrac{c}{a+b+c}$ in extract

At plait point: $y_c = x_c$