Extraction and Leaching

- Extraction is defined as a separation process, based on differences in solubility. A solvent is used to solubilize and separate a solute from other materials.
- The extraction processes can be classified in two groups as solid- liquid extraction (leaching) and liquid-liquid extraction.

General information about leaching:

- Leaching is a separation process in which the desired component, the solute, in a solid phase is separated by contacting the solid with a liquid, the solvent, in which the desired component is soluble.
- The desired component leaches from the solid into the solvent.
- Then the solid and the liquid phases are separated and the desired component is recovered from the liquid phase.

- Some common examples for leaching in food industry are;
  - extraction of soluble compounds from roasted and ground coffee in the soluble coffee production;
  - extraction of edible oils from oilseeds with organic solvents;
  - extraction of proteins from soybeans in the production of isolated soybean protein.

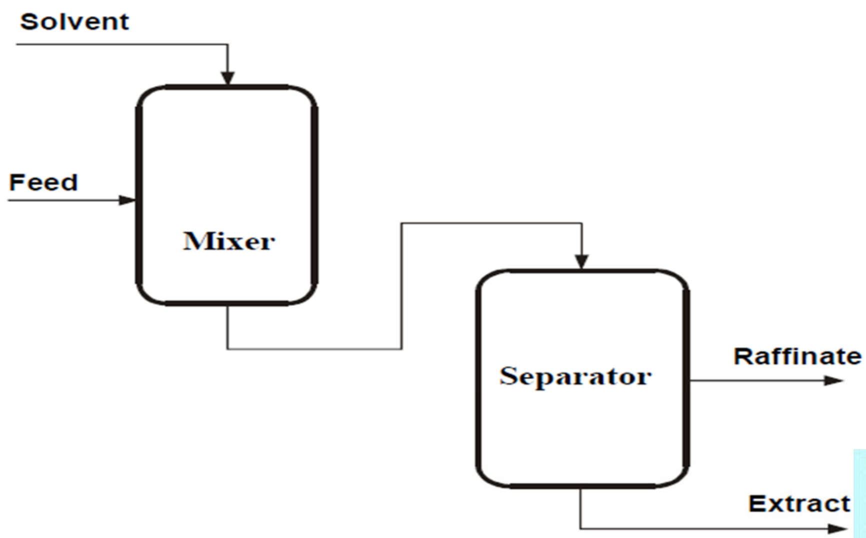
- Solid-liquid extraction can be performed in either single or multiple stages.
- A stage can be defined as an equipment in which the solid and liquid phases are brought into contact, maintained in contact for a period of time and then physically separated from each other.
- During the contact of solid and liquid phases, mass transfer of components takes place and finally they reaches to equilibrium.

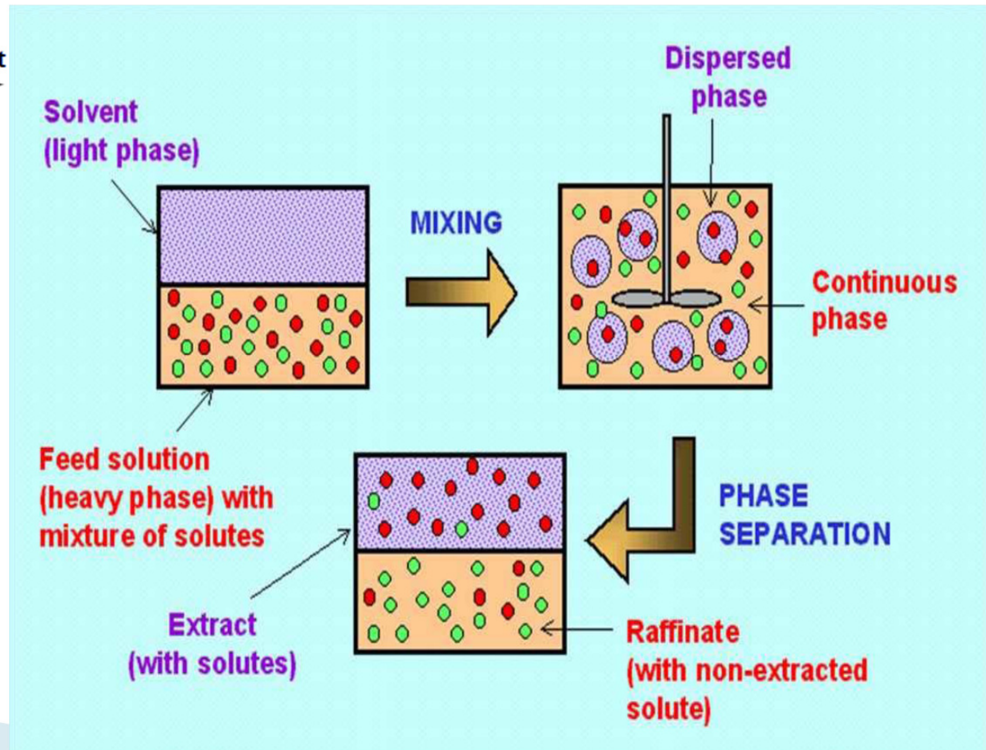
General information about liquid liquid extraction:

- Liquid-liquid extraction is a method for extracting solute from a solution by a solvent. It is also known as partitioning.
- Liquid-liquid extraction is common in the chemical and pharmaceutical industries and in biotechnology, but it is not common in food processing.
- An example to this kind of an extraction can be given as extraction of penicillin from aqueous fermentation broth by butanol.

LIQUID LIQUID EXTRACTION

- Liquid liquid extraction is a separation process consisting of the transfer of a solute from one solvent to another, the two solvents being immiscible or partially miscible with each other. Liquid liquid extraction consists of a step of mixing followed by a step of phase separation.
- The two phase pair which are brought into contact are chemically quite different, which leads to a separation of the components according to physical and chemical properties.

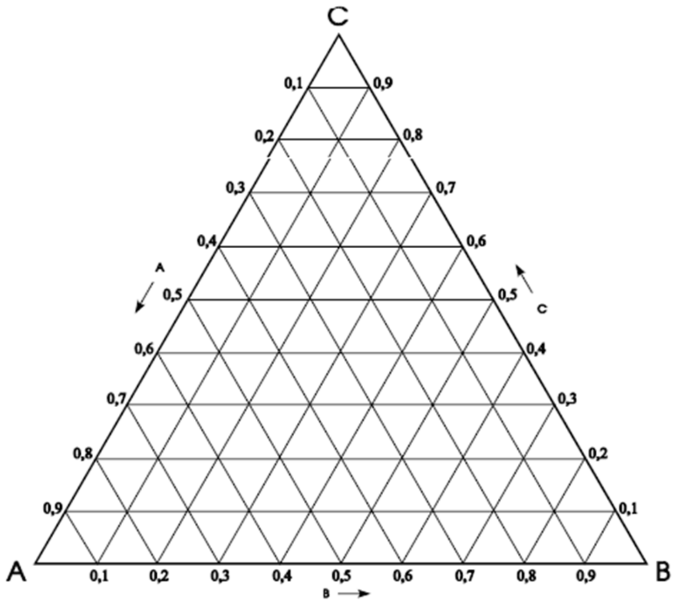

Solvent
Feed
Mixer
Separator
Raffinate
Extract


Solvent
(light phase)
MIXING
Dispersed
phase
Continuous
phase
Feed solution
(heavy phase) with
mixture of solutes
PHASE
SEPARATION
Extract
(with solutes)
Raffinate
(with non-extracted
solute)

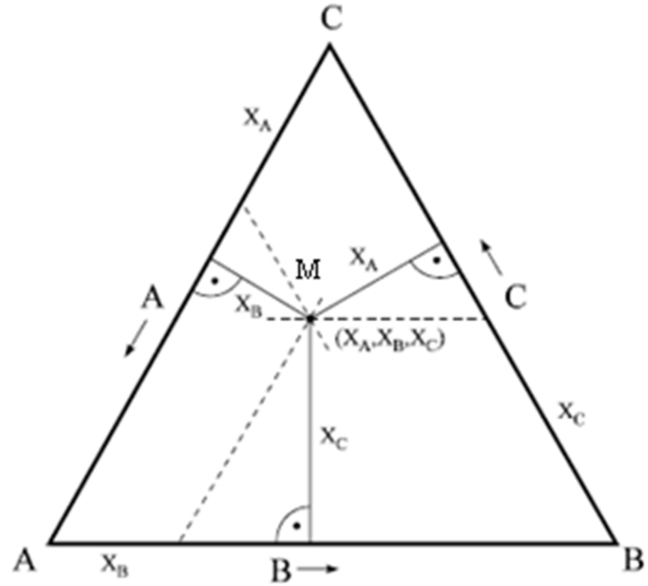
Equilibrium relations

- In a liquid-liquid system there are three components and two phases in equilibrium.
- The degrees of freedom can be calculated as 3.
- The three variables which should be determined to define the process are pressure, temperature and concentrations.
- This means, if the pressure and the temperature of the system are set at equilibrium, it is enough to set one concentration in either phase to fix the system.

- Equilateral triangular coordinates are often used to represent the equilibrium data for a three component system



Triangular diagram,



Coordinates for a triangular diagram

- Each of the three corners represents a pure component, A, B or C. The point M represents a mixture of A, B and C. The perpendicular distance from the point M to the base AB represents the mass fraction of C in the mixture at M (x_c), the distance to base BC the mass fraction of A (x_A) and the distance to base AC the mass fraction of B (x_B).

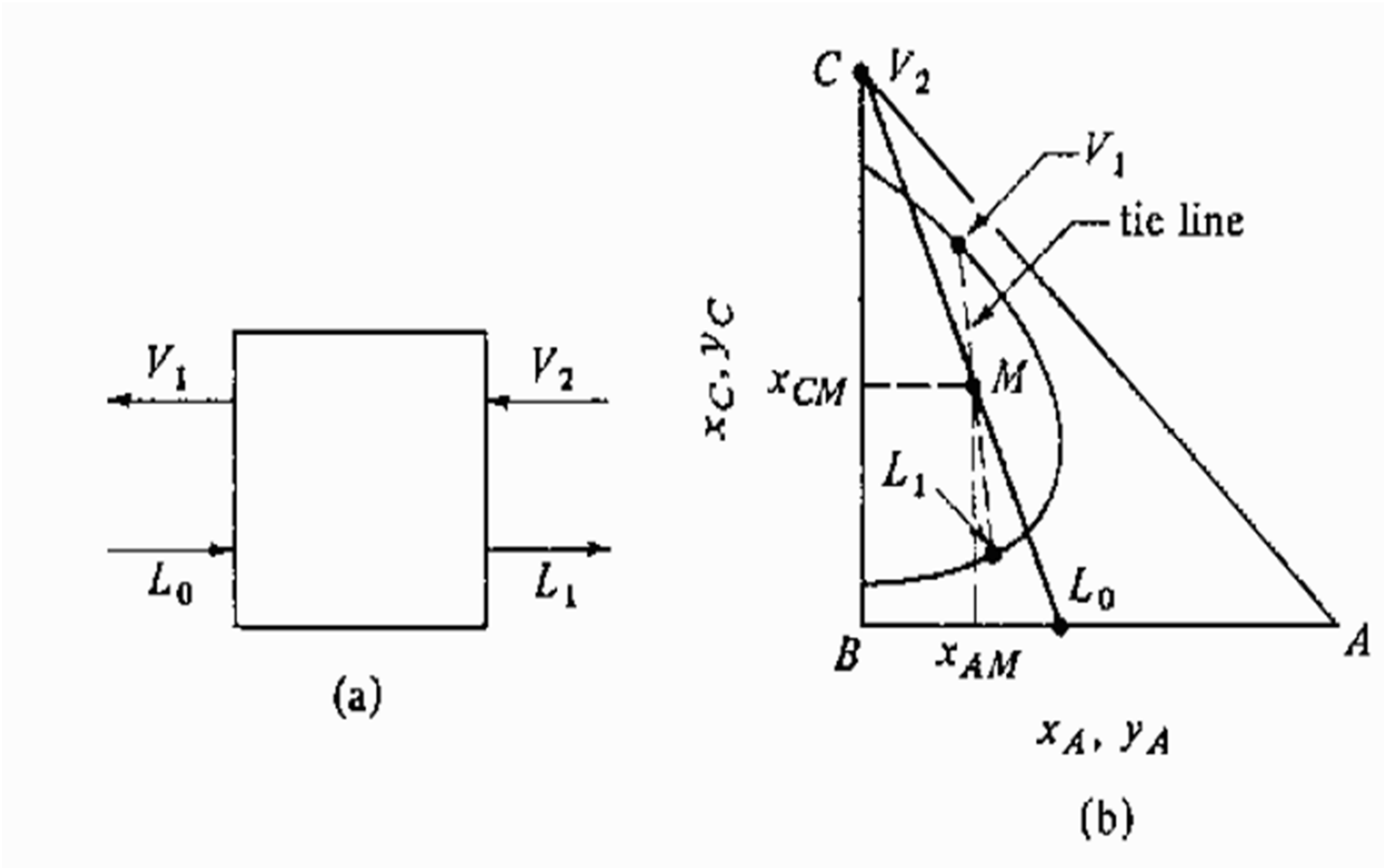
$$x_A + x_B + x_C = 1.0$$

Single stage equilibrium extraction

- In an extraction process there are two input streams (L kg and V kg) which are not in equilibrium.

- The two entering streams (L_0 and V_2) are mixed and equilibrated and then exit as streams L_1 and V_1, which are in equilibrium with each other.

- To find the final product compositions in the two phases, it is required to know the total mass and composition of the mixture (point M).
- In order to calculate the total mass and composition of mixture material balances should be used.
- After the identification of point M, the product composition can be found by the equilibrium tie line.



Single stage equilibrium liquid-liquid extraction (a)process flow diagram (b)phase diagram

- The material balances used for point M identification;
- Overall:

$$L_0 + V_2 = L_1 + V_1 = M$$

- A:

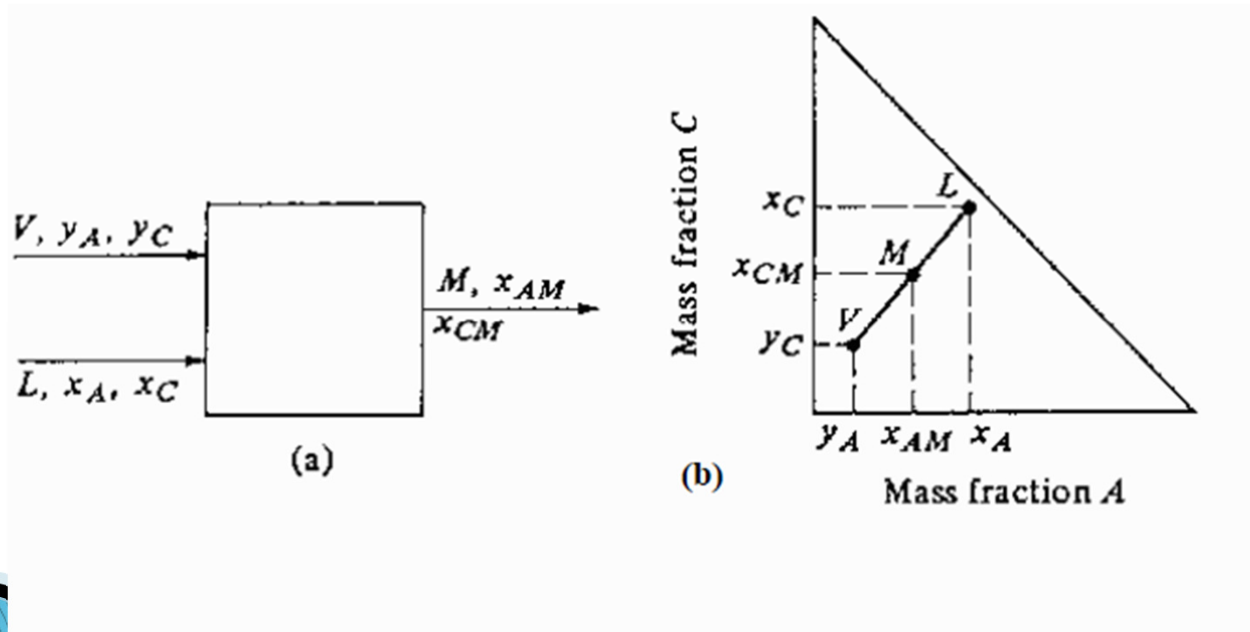
$$L_0 x_{A0} + V_2 y_{A2} = L_1 x_{A1} + V_1 y_{A1} = M x_{AM}$$

- C:

$$L_0 x_{C0} + V_2 y_{C2} = L_1 x_{C1} + V_1 y_{C1} = M x_{CM}$$

- Since it is known that the summation of mass fractions of A, B and C is equal to 1, there is no need to obtain an equation for B.

- To calculate the unknowns by using rectangular extraction phase diagram charts *lever arm rule* should be derived.
- For this derivation the process flow and the graphical addition given in Figure below will be used.



(a) Process flow (b) Graphical addition

- In this system, there are two entering streams (L kg and V kg) containing components A, B and C.
- These streams are mixed to give a resulting stream (M kg).
- The material balances are;
- Overall:

$$L + V = M$$

- (A):

$$Lx_A + Vy_A = Mx_{AM}$$

- (C):

$$Lx_C + Vy_C = Mx_{CM}$$

$$\frac{L}{V} = \frac{y_A - x_{AM}}{x_{AM} - x_A}$$

$$\frac{L}{V} = \frac{y_c - x_{cM}}{x_{cM} - x_c}$$

$$\frac{x_c - x_{cM}}{x_A - x_{AM}} = \frac{x_{cM} - y_c}{x_{AM} - y_A}$$

- The left side of the Equation (29.10)gives the slope of line LM and the right side isthe slope of line MV. Because of this equality, we can say that point L, M and V must lie on a straight line. By using the similarity property of right triangles; the leverarmrule can be derived:

$$\frac{L(kg)}{V(kg)} = \frac{VM}{LM}$$

$$\frac{L(kg)}{V(kg)} = \frac{VM}{LV}$$

- Example

Pure chloroform is used to extract acetone from a feed containing 60 wt% acetone and 40 wt% water. The feed rate is 50 kglh, and the solvent rate is also 50 kglh.Operation is at 298 K and 1 atm. Find the extract and raffinate flow rates and compositions when one equilibrium stage is used for the separation.