Principles of Chemical Engineering

Mass Transfer

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Syllabus Contents

Liquid - Liquid Extraction - Distribution coefficient. Selection of solvent

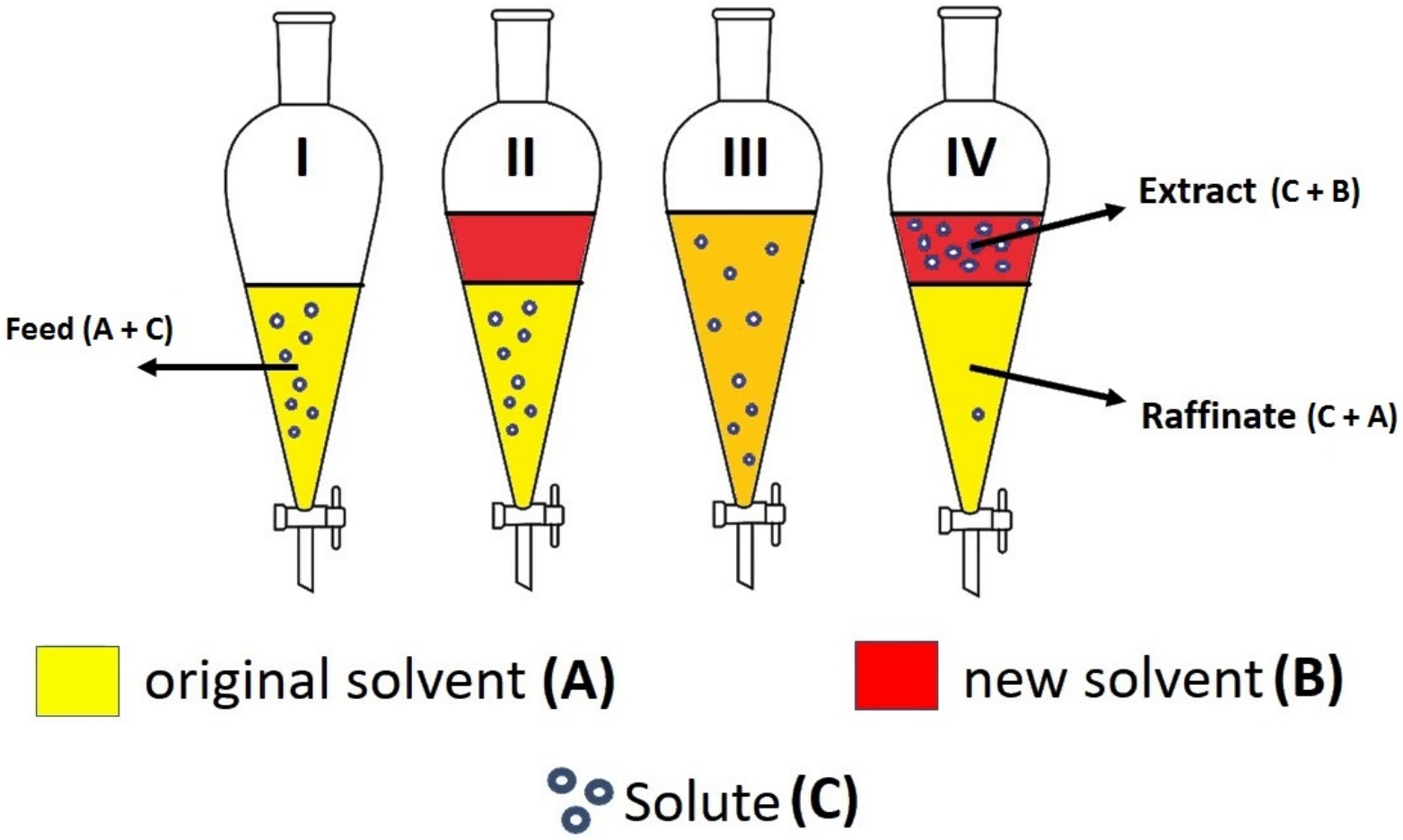
Objectives

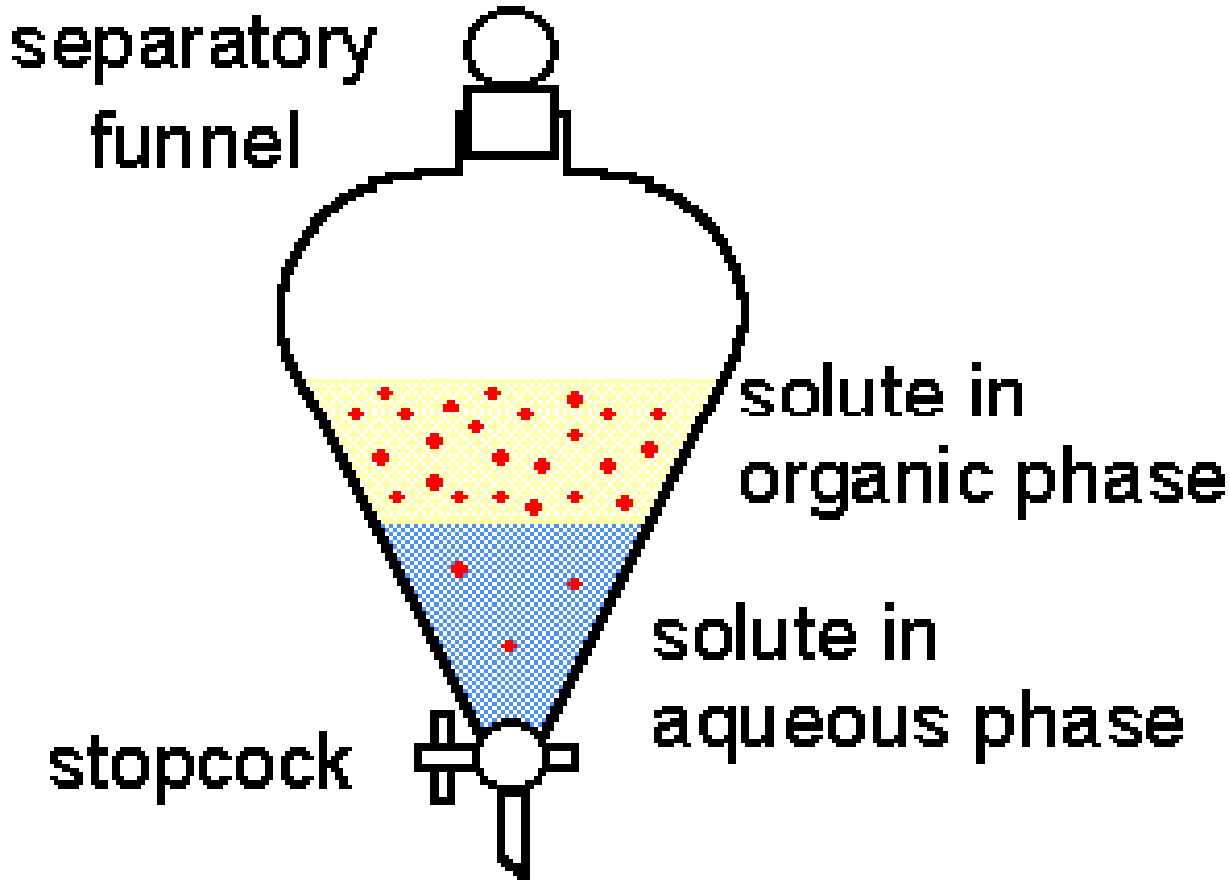
- To give an overview of extraction as a mass transfer operation.

Extraction

- Extraction treats a feed with a liquid solvent to remove and concentrate a valuable solute. When the feed is a liquid, the process is called "liquid-liquid extraction," or "solvent extraction" or "partitioning" or more commonly just "extraction." e.g.: various solvents such as n-butanol, iso butanol, amyl alcohol and ethyl acetate are used for separation of acetic acid from water.
- When the feed is a solid, the process is called "solid-liquid extraction," or more commonly "leaching." e.g.: caffeine from coffee-beans using water as the solvent — decoction.
- In either case, the original solution is commonly called the feed; after the extraction, this stream is called the raffinate. Similarly, the second solvent is called the extract once it contains solute.

Liquid-Liquid Extraction




separatory
funnel
solute in
organic phase
solute in
aqueous phase
stopcock

Extraction as a Choice of Mass Transfer Operation

- Extraction is almost never the first choice as a separation process.
  - If the solute of interest is a gas, then we will first try gas absorption or stripping.
  - If the solute of interest is volatile under convenient conditions, then we will attempt distillation.
  - We will normally try extraction only after we fail at absorption and distillation.
- Extraction is an important process, central to some petrochemical, pharmaceutical, and metallurgical processes.

Extraction as a Choice of Mass Transfer Operation (contd..)

- Extraction is a common separation process used where distillation and gas absorption fail.
- Most obviously, extraction can be used for nonvolatile components like metal ions.
- It is effective for valuable solutes like flavors, which can be unstable at distillation temperatures.
- Extraction is useful for volatile solutes that have nearly equal boiling points, as they are tough to separate them with distillation. Near boiling points imply nearly same vapor pressures, and hence the relative volatility is closer to 1.

Distribution Coefficient

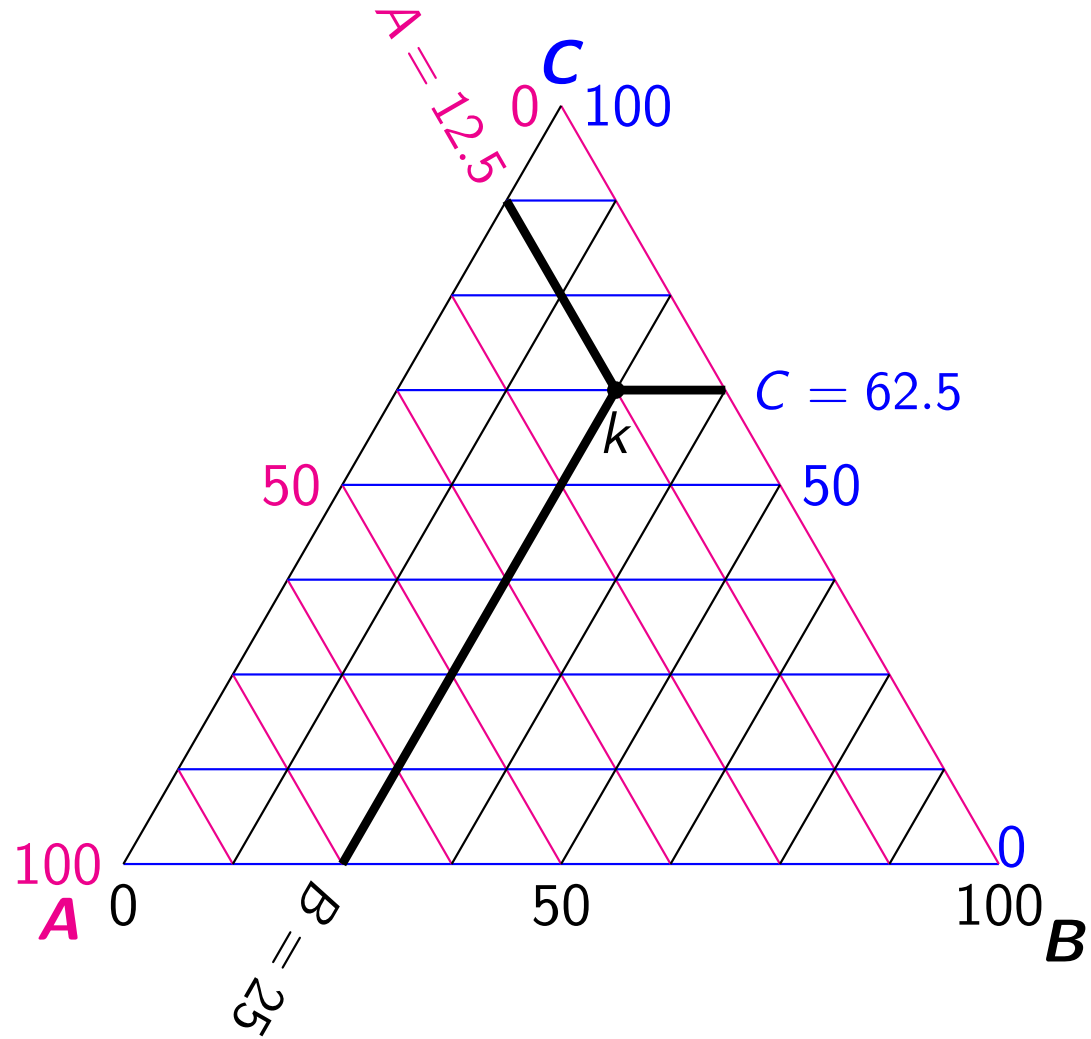
When a aqueous solution (aqueous solvent containing a solute of importance) is brought in contact with an organic solvent, the solute distributes itself in both the solvents but differently, according to its solubility. The aqueous and organic solvents are relatively immiscible. When equilibrium is reached, the ratio of concentration of solute in each solvent is constant, and can be represented by a coefficient (K) called distribution coefficient (or partition coefficient).

$$K = \frac{\text{concentration of solute in organic phase (the extract)}}{\text{concentration of solute in aqueous phase (the raffinate)}} = \frac{y}{x}$$

Higher the K lesser would be the solvent requirement for the extraction.

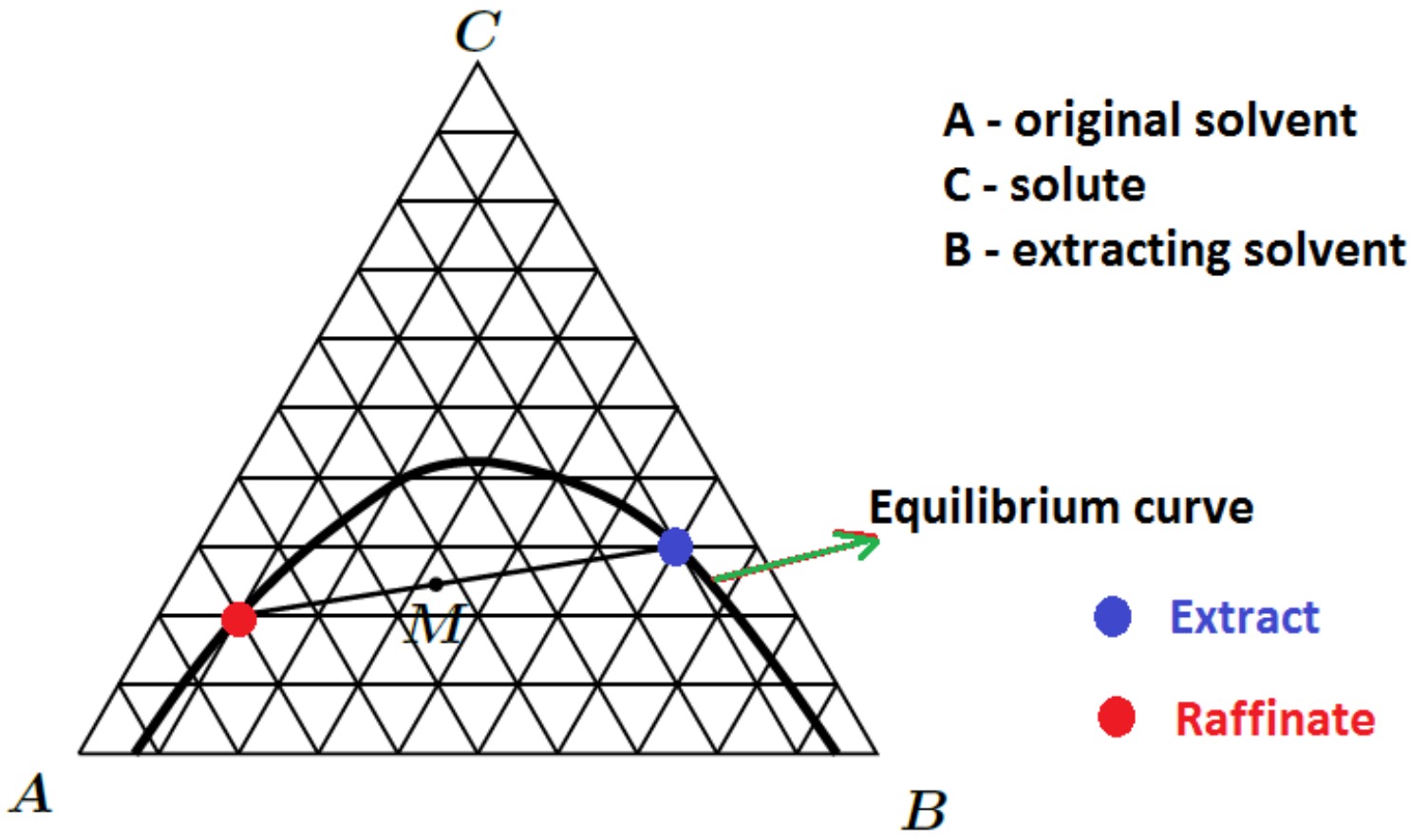
Extraction Equilibrium

Representation in Triangular Chart



Extraction Equilibrium (contd..)

Representation in Triangular Chart



The liquids inside the bell-shaped curve are immiscible; outside the curve they are miscible.

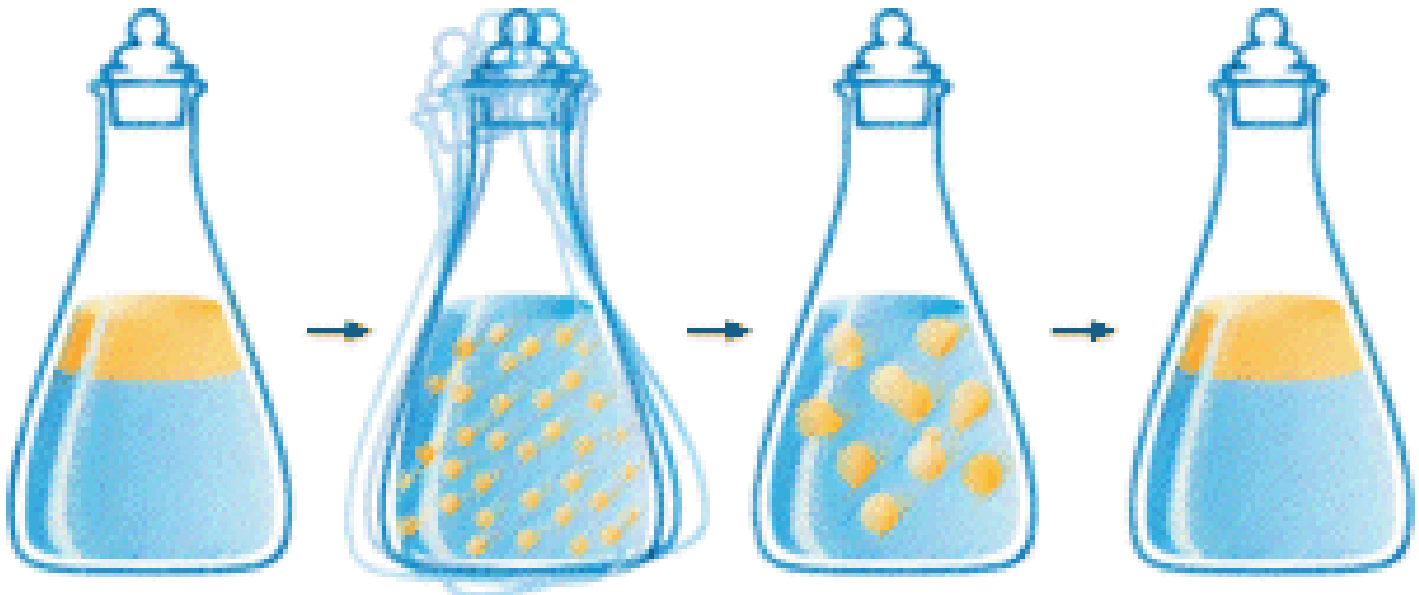
Selection of Solvent

The following are the requirements for the good solvent:

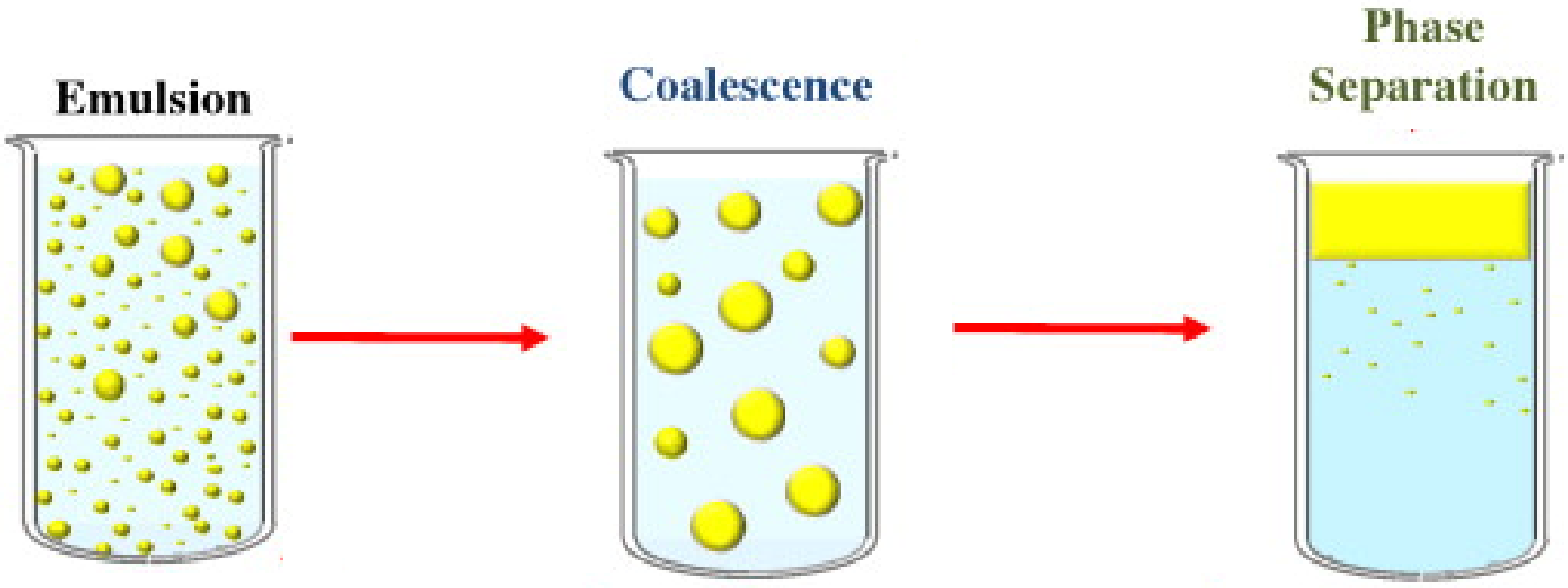
- The distribution coefficient offered by the solvent should be higher.
- The chosen solvent should be immiscible with the original solvent in which solute is present.
- Densities of both the phases — the extract and raffinate should be different. Larger the difference easier will be the separation of extract and raffinate phases.

Selection of Solvent (contd..)

- The interfacial tension between the solvent and the solution should be high. Higher the interfacial tension tougher will be the mixing of two liquids; i.e., creating smaller droplets, and hence bringing uniformity by mixing will be tougher. But higher interfacial tension leads to easy coalescence of liquid droplets thus making the separation of liquids easier.



Selection of Solvent (contd..)



Selection of Solvent (contd..)

- The solvent should not react with any of chemicals involved.
- The solvent should be easily recoverable from the solute, by distillation.
- Viscosity, vapor pressure, freezing point of the solvent should be low for ease of handling.
- The solvent should be non-toxic, non-flammable, and of low cost.

Quiz

1. Define the terminologies ‘extract’ and ‘raffinate’ in extraction.
2. What is the need for difference in density of solvents in extraction?
3. Give example for extraction operations.
4. Define the term ‘distribution coefficient’ in extraction.
5. Represent the liquid-liquid equilibrium in triangular chart.
6. What are the desirable properties of a good solvent for use in extraction?