Combined Heat and Mass Transfer Operations

Introduction

Content

General Separation Techniques

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Content

- Introduction
- Separation techniques

Introduction

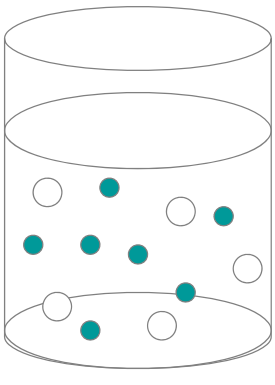
- Heat and mass transfer operations considered in this course are examples of many separation processes.
- What are separation processes?

  Separation processes are defined as those operations which transform a mixture of substances into two or more products which differ from each other in composition.

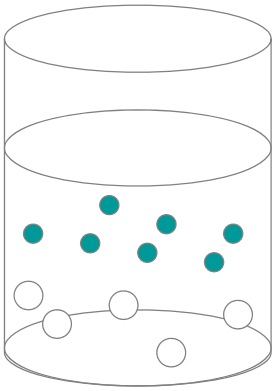
- The main goal of separation process is to purify solution

  To do this we must cause different transport of species or convection of species so that the purer mixture can be collected. Most separation processes involve differential transport.

Introduction



mixed



separated

Introduction

➢ Why Separation?

There are many reasons for wanting pure substances. Some of these reasons include:

- Need for pure material in engineering applications.
- Preparation of raw materials into their component.
- Need for pure material for materials processing.
- Need to remove toxins or inactive components from solution (drugs)
- Need for ultra-pure samples for testing.
- Need for analysis of the components of mixture (DNA testing)

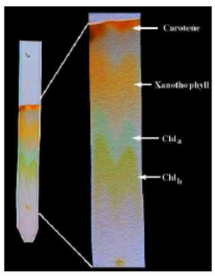
Introduction

Separations includes

– Enrichment
– Purification
– Isolation
- Concentration
- Refining

Separations are important to chemist & chemical engineers

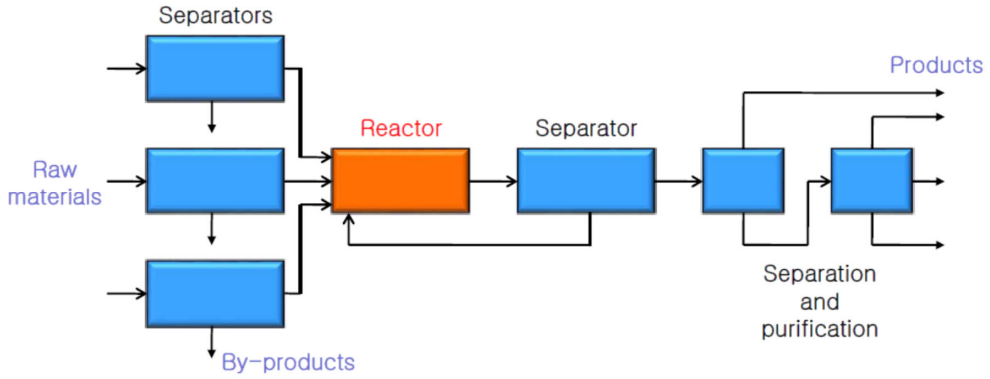
– Chemist: analytical separation methods,small-scale preparative separation techniques
– Chemical engineers: economical, large scale separation methods





Why Separation Processes are Important ?

- Almost every element or compound is found naturally in an impure state such as a mixture of two or more substances. Many times the need to separate it into its individual components arises
- A typical chemical plant is a chemical reactor surrounded by separators.



- Chemical plants commonly have 50-90% of their capital invested in separation equipments.

Why Separation is Difficult to Occur?

Second law of thermodynamics

- Substances are tend to mix together naturally and spontaneously
- All natural processes take place to increase the entropy, or randomness, of the universe
- To separate a mixture of species into products of different composition, we must supply the equivalent of energy (heat or work)

How Separations are Achieved?

- Enhancing the mass transfer rate of certain species
  - ✓ Rate of Separation: how fast ?
    - Governed by mass transfer (Rate-controlled separation)
  - ✓ Extent of Separation: how far ?
    - Limited by thermodynamics (Equilibrium-staged separation)
- Properties of Importance

Molecular Properties	Thermodynamic and Transport Properties
Molecular weight	Vapor pressure
van der Waals volume	Solubility
van der Waals area	Adsorptivity
Molecular shape (Acentric factor)	Diffusivity
Dipole moment	
Polarizability	
Dielectric constant	
Electric charge	
Radius of gyration	

Separation Techniques

- In general, separation techniques are classified as follows:

a. Separation by phase creation.

b. Separation by phase addition.

c. Separation by barrier.

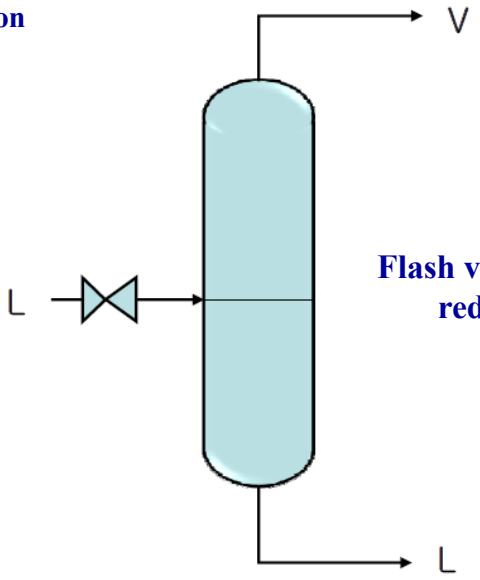
d. Separation by solid agent.

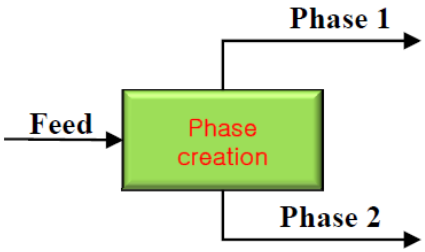
e. Separation by external field or gradient.

a. Separation by phase creation:

Examples:

- **Evaporation**



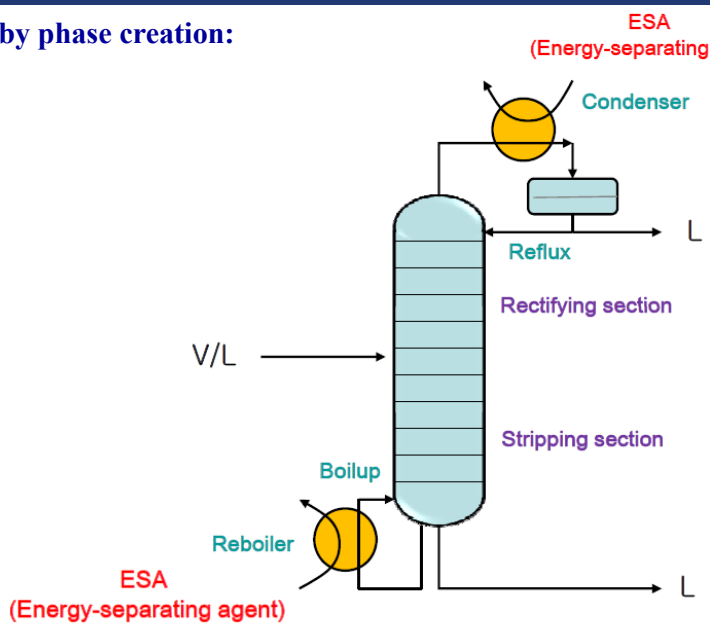


Flash vaporization by pressure reduction e.g. Desalination

a. Separation by phase creation:

Examples:

- **Distillation**



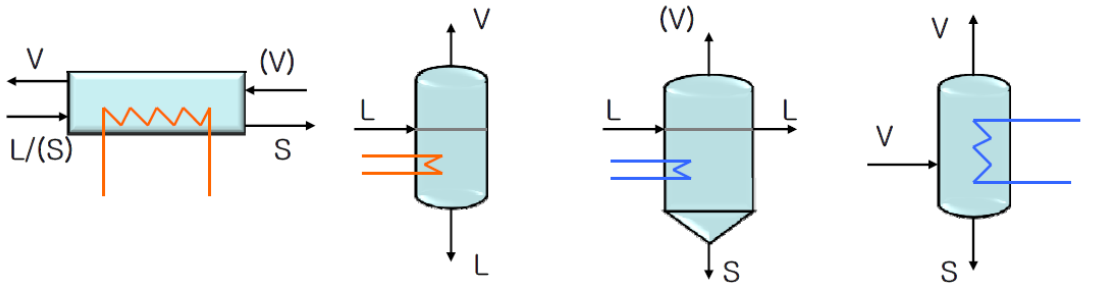
Energy-separating agent:

-Separation involves heat transfer (heating/cooling)

a. Separation by phase creation:

Examples:

• Drying	• Evaporation	• Crystallization	• Desublimation
Heat transfer (ESA)	Heat transfer (ESA)	Heat transfer (ESA)	Heat transfer (ESA)



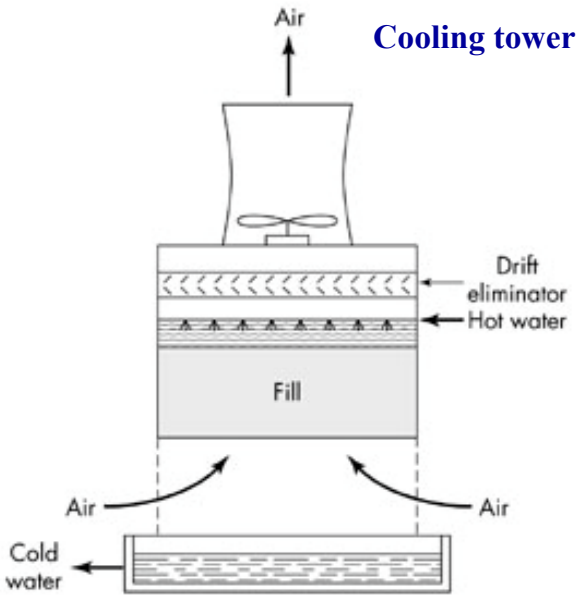
Removal of water from PVC	Evaporation of water from water + urea	Crystallization of high purity silicon for semiconductor	Recovery of phthalic anhydride from non-condensible gas

a. Separation by phase creation:

Examples:

- **Humidification**

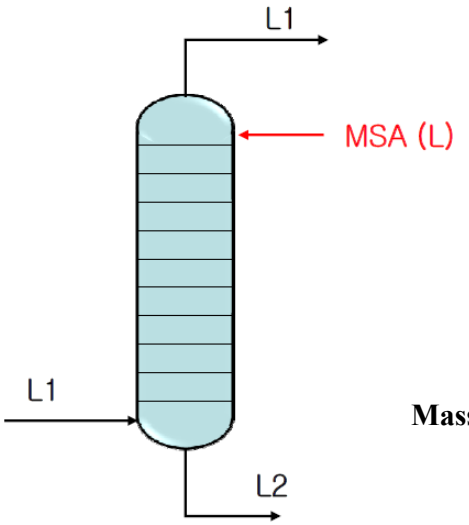
Cooling tower

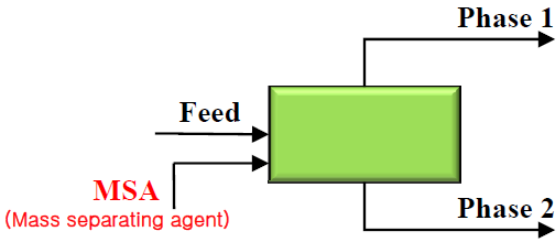


b. Separation by phase addition:

Examples:

- **Liquid-liquid extraction:**





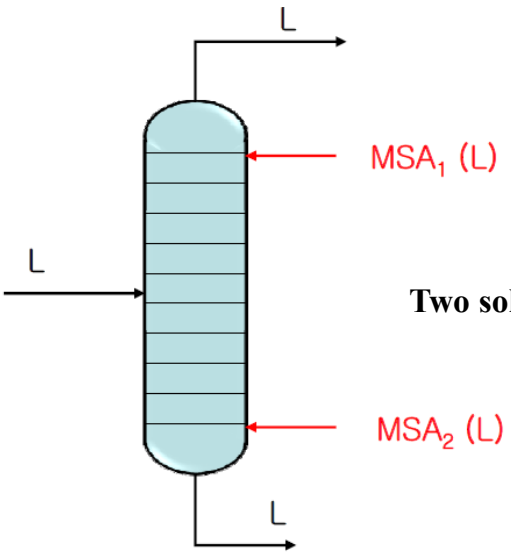
Mass-separating agent:

-Separation involves mass transfer

b. Separation by phase addition:

Examples:

- **Liquid-liquid extraction:**



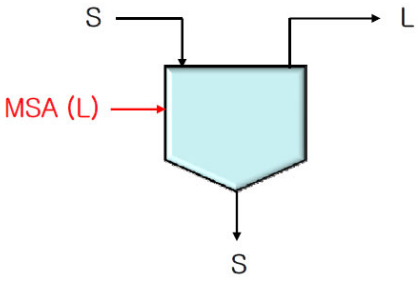
Two solvents: MSA_1 and MSA_2

b. Separation by phase addition:

Examples:

- Leaching (Liquid-solid extraction)

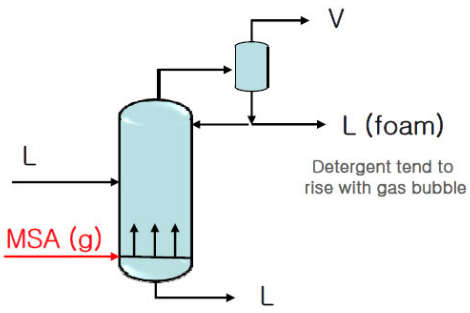
Liquid solvent



Extraction of sugar using hot water

- Foam fractionation

Gas bubbles (MSA)



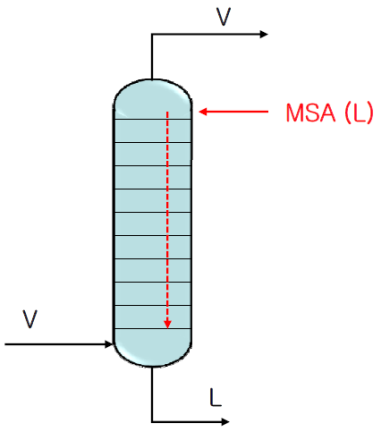
Recovery of detergent from waste solutions

b. Separation by phase addition:

Examples:

- Absorption

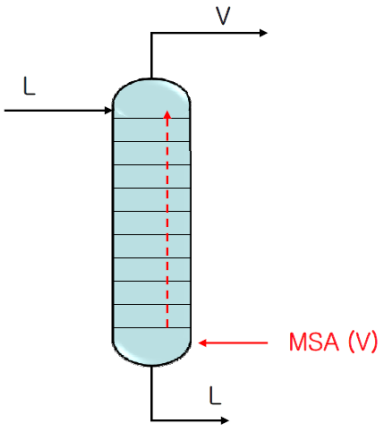
Liquid absorbent (MSA)



Separation of CO_2 from combustion product using ethanolamine

- Stripping

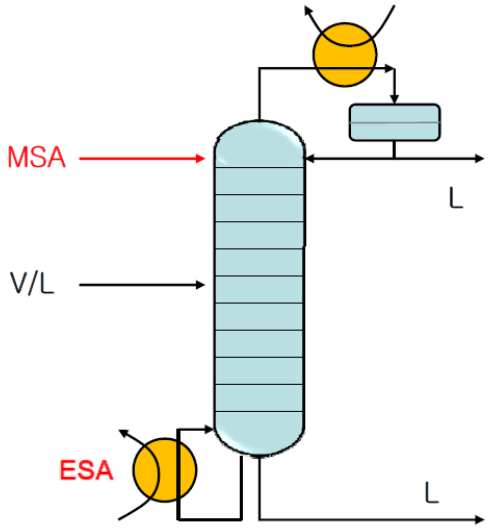
Stripping vapor (MSA)



Removal of light ends from naphtha, kerosene, and gas oil

• Extractive distillation

Liquid solvent (MSA) and Heat transfer (ESA)



- When the volatility difference among species are so small (more than 100 trays are required)
- MSA is used to increase volatility difference (reducing the number of trays)
- Minimize MSA loss (recycling)
- Separation of acetone (b.p. 56.5℃) and ethanol (b.p. 78.4℃)

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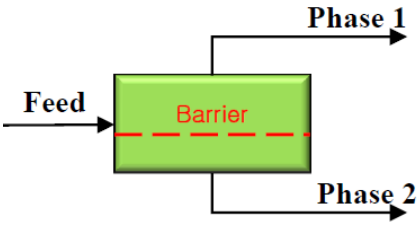
c. Separation by barrier:

Examples:



• Reverse osmosis

Nonporous membrane

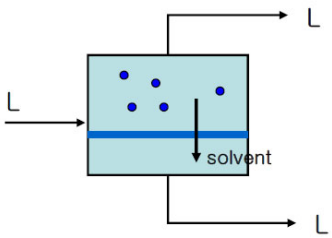
Pressure gradient

• Dialysis

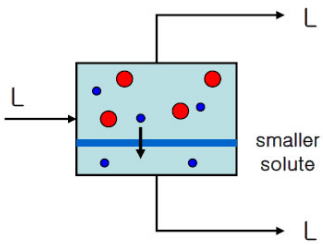
Porous membrane

Concentration gradient,

Pressure gradient



Desalination of sea water



Recovery of caustic from hemicellulose

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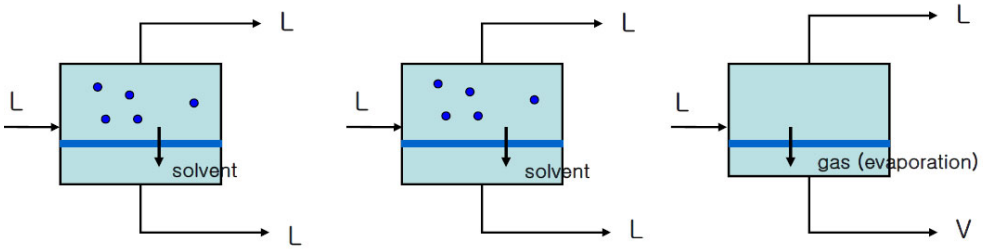
c. Separation by barrier:

Examples:

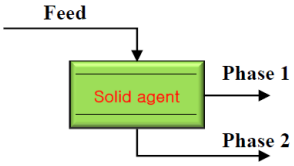
• Microfiltration	• Ultrafilration	• Pervaporation
Microporous membrane	Microporous membrane	Nonporous membrane
Pressure gradient	Pressure gradient	Pressure gradient



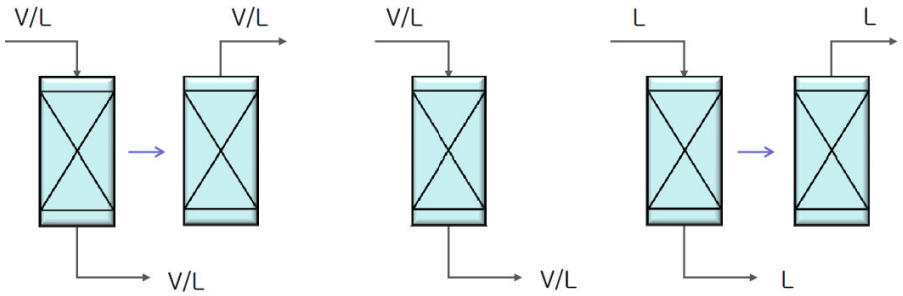
Removal of bacterial from drinking water	Separation of whey from cheese	Separation of azeotropic mixtures
(retention of molecules : 0.02 – 10 μm)	(retention of molecules : 1 – 20 nm)	

d. Separation by solid agent :

Examples:



• Adsorption	• Chromatography	• Ion exchange
Solid adsorbent	Solid adsorbent or liquid adsorbent on solid support	Resin with ion-active sites

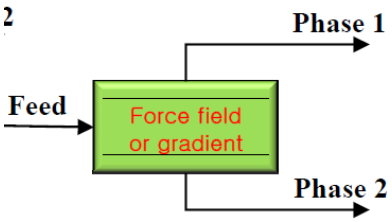


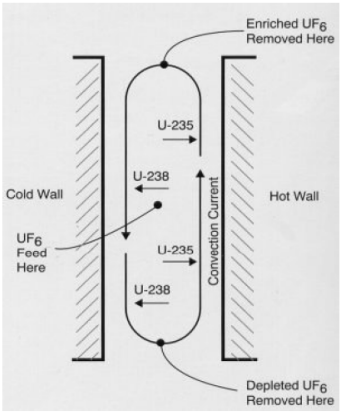
Purification of p–xylene	Separation of xylene isomers and ethylbenzene	Demineralization of water (removing calcium ions)

e. Separation by external field or gradient :

Examples:

- Thermal diffusion
  - Force field or gradient: Thermal gradient
  - Example: Separation of uranium isotopes

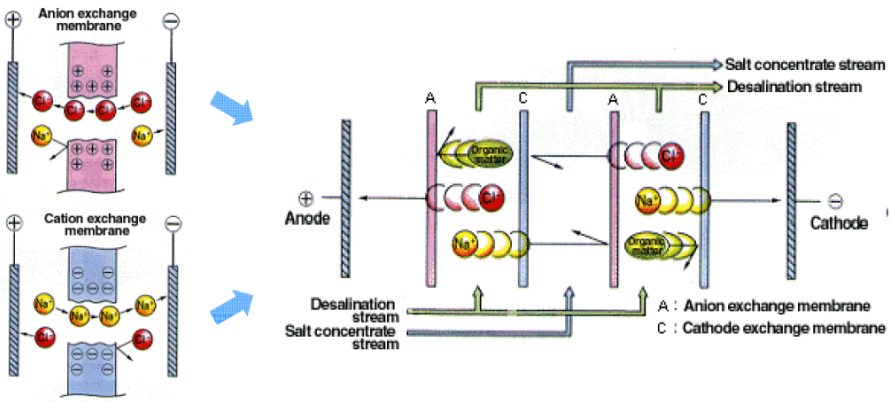




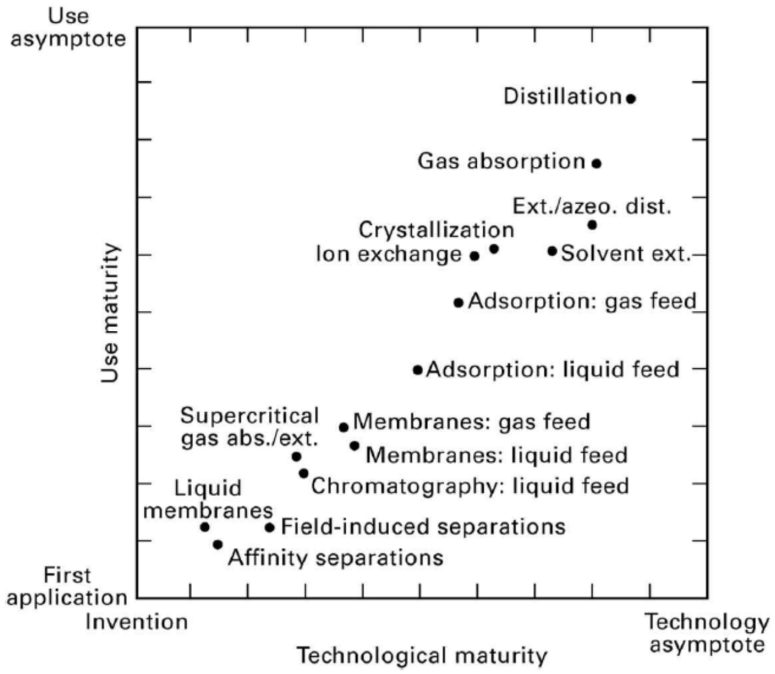
e. Separation by external field or gradient :

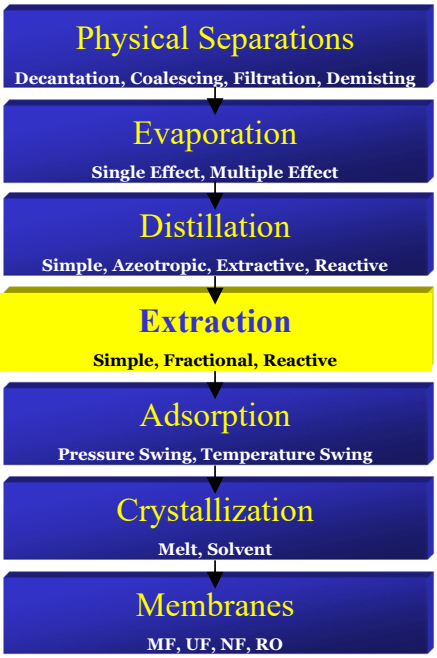
Examples:

- Electrodialysis
  - Force field or gradient: Electrical force field and membrane
  - Transport salt ions from one solution through ion-exchange membranes to another solution under the influence of an applied electric potential difference
  - Example: Desalinization of sea water



Technological and Use Maturities of Separation Processes





Easy

Difficulty Of Separation

Difficult

Choice of separation process

Factors to be considered:

- Feasibility
- Product value
- Cost
- Product quality
- selectivity