Separation Processes
BKC3492

Membrane Separation Process

by

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Objective

At the end of this chapter student must be able to;

- Classify a type and membrane characteristic
- Calculate the membrane diffusion
- Estimate liquid film resistances
- Calculate the flux dialysis process

Membrane Processes

➢ A membrane is a **selective/semipermeable barrier** to permits the separation of gaseous or liquid streams.

➢ The mechanics involved are **sieving** and **sorption diffusion**.

Membrane processes

MEMBRANES

FEED

PERMEATE
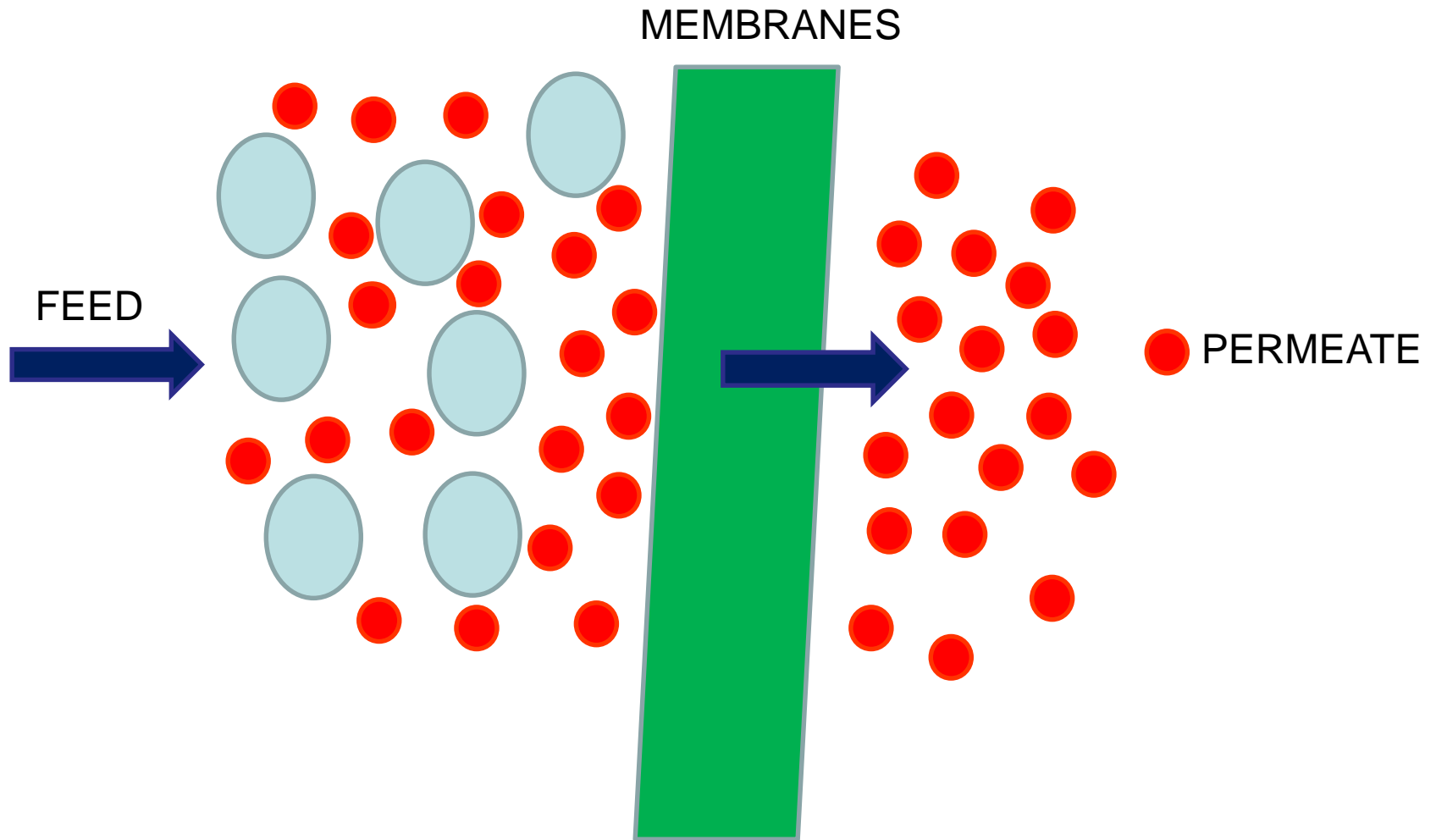
Type of membranes

- Membranes can separate a wide range of particles size and molecular weight
- FOUR common types of membrane
  - ✓Microfiltration
  - ✓Ultrafiltration
  - ✓Nanofiltration
  - ✓Reverse osmosis

Type of membranes

| Membranes Type	Pore sizes (μm)	Water	Mono Valent ions	Multi Valents ions	Viruses	bacteria	Suspended Solids
Microfiltration (MF)	1.0-0.01	√	√	√	√	X	X
Ultrafiltration (UF)	0.01-0.001	√	√	√	X	X	X
Nanofiltration (NF)	0.001-0.0001	√	√	X	X	X	X
Reverse Osmosis (RO)	<0.0001	√	X	X	X	X	X

Industrial application of membrane

| Type of membrane	Applications
Reverse Osmosis	Desalinization of brackish water Treatment of water and wastewater Concentration of foodstuffs Removal of alcohol from beer and wine
Dialysis	Separation of nickel sulphate from sulphuric acid Hemodialysis (removal of waste metabolism)
Microfiltration	Sterilization of drugs Clarification and biological stabilization of beverages Purification of antibiotics
ultrafiltration	Preconcentration of milk before making cheese Clarification of fruit juice Recovery of vaccines and antibiotics from fermentation Colour removal from Kraft black liquor from paper making

Industrial application of membrane

Type of membrane	Applications
Pervaporation	Dehydration of ethanol-water azeotrope Removal of water from organic solvents Removal of organics from water
Gas permeation	Separation of CO_2 and H_2 from methane and other hydrocarbon Adjustment of H_2/CO ratio in synthesis gas Recovery of helium Recovery of methane from biogas
Liquid membranes	Recovery of zinc from wastewater in viscose fiber industry Recovery of nickel from electroplating solutions

Industrial Example

Hydrogen

Toluena

reactor

Flash

Flash Vapor

Flash liquid
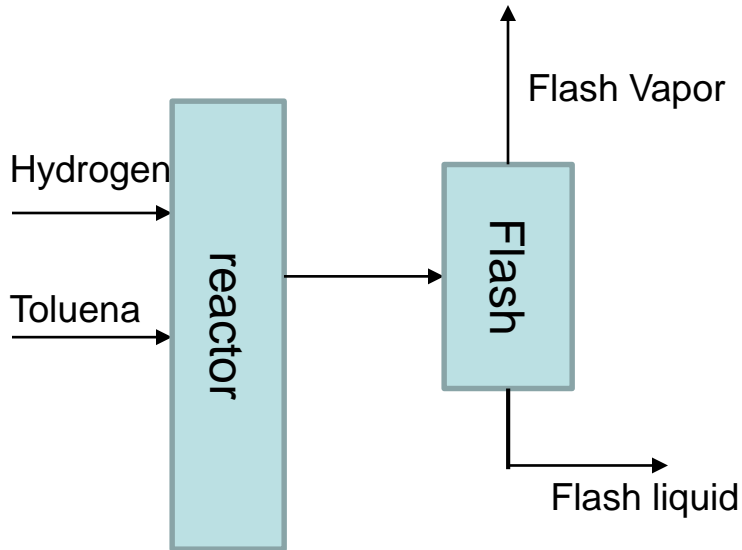
- Production of benzene from toluene

- Benzene, xylenes (BTX), and ethylbenzene are the aromatic hydrocarbons with a widespread use as petrochemicals

Production of benzene

Methane

Recycle Hydrogen

Flash Vapor

Hydrogen

Toluena

reactor

Flash

Flash liquid
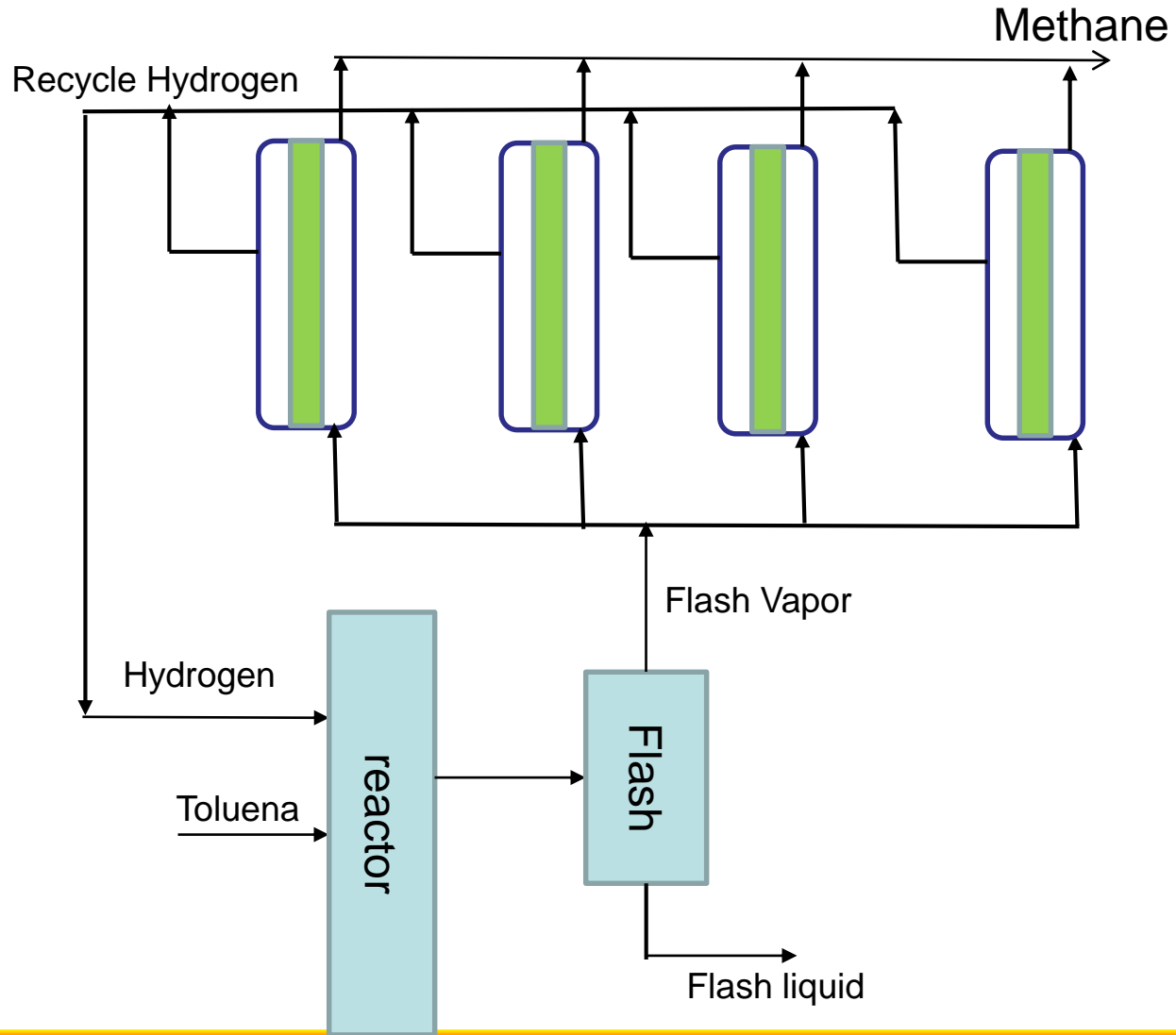
Important Parameters in Membrane Processes

The key properties determining membrane performance are:
- ✓ High selectivity,
- ✓ High permeability/fluxes,
- ✓ Good mechanical, chemical and thermal stability under operating conditions,
- ✓ Low fouling tendencies,
- ✓ Good compatibility with the operating environment,
- ✓ Cost effective,
- ✓ Defect-free production

Liquid permeation membranes
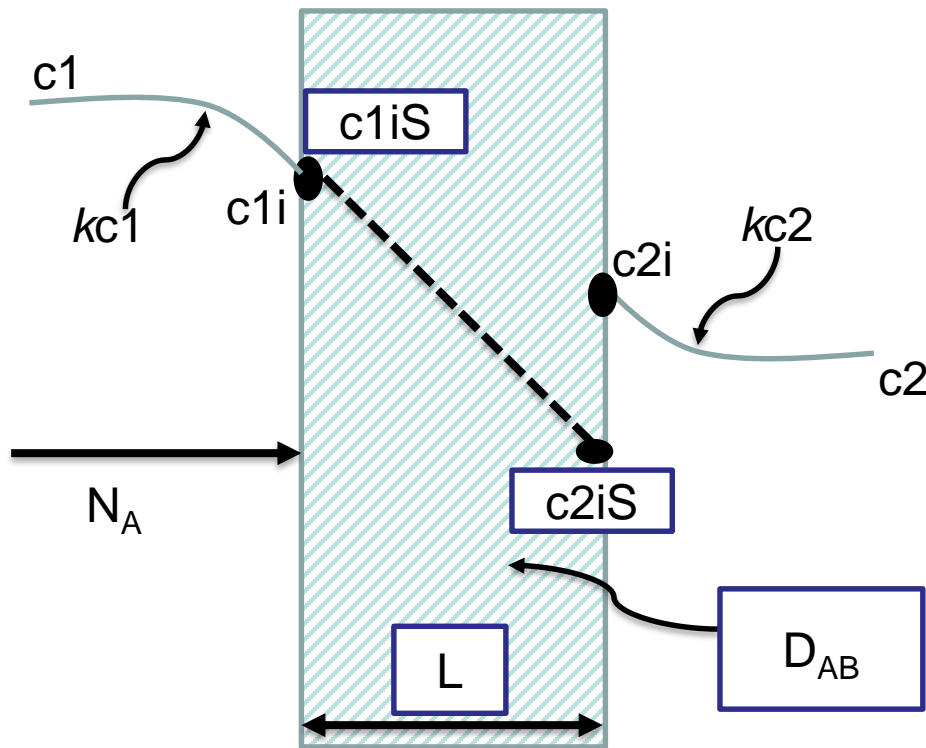
- The equilibrium distribution coefficient

$$K' = \frac{c_S}{c_L} = \frac{c_{1iS}}{c_{1i}} = \frac{c_{2iS}}{c_{2i}}$$

Liquid permeation membranes

- At steady state, the flux equations at each phase are all equal to each other

$$N_A = k_{c1}(c_1 - c_{1i}) = \frac{D_{AB}}{L}(c_{1iS} - c_{2iS}) = k_{c2}(c_{2i} - c_2)$$

- Subs $c_{1is} = K' c_{1i}$ and $c_{2is} = K' c_{2i}$

$$N_A = k_{c1}(c_1 - c_{1i}) = \frac{D_{AB}K'}{L}(c_{1i} - c_{2i}) = p_M(c_{1i} - c_{2i}) = k_{c2}(c_{2i} - c_2)$$

$$p_M = \frac{D_{AB}K'}{L}$$

- p_M = the permeance in the solid (m/s)
- L = thickness (m)
- D_{AB} = the diffusivity of A in the solid (m^2/s)

Liquid permeation membranes

- Final flux equations after solving each part of concentration difference

$$N_A = \frac{c_1 - c_2}{1/k_{c1} + 1/p_M + 1/k_{c2}}$$
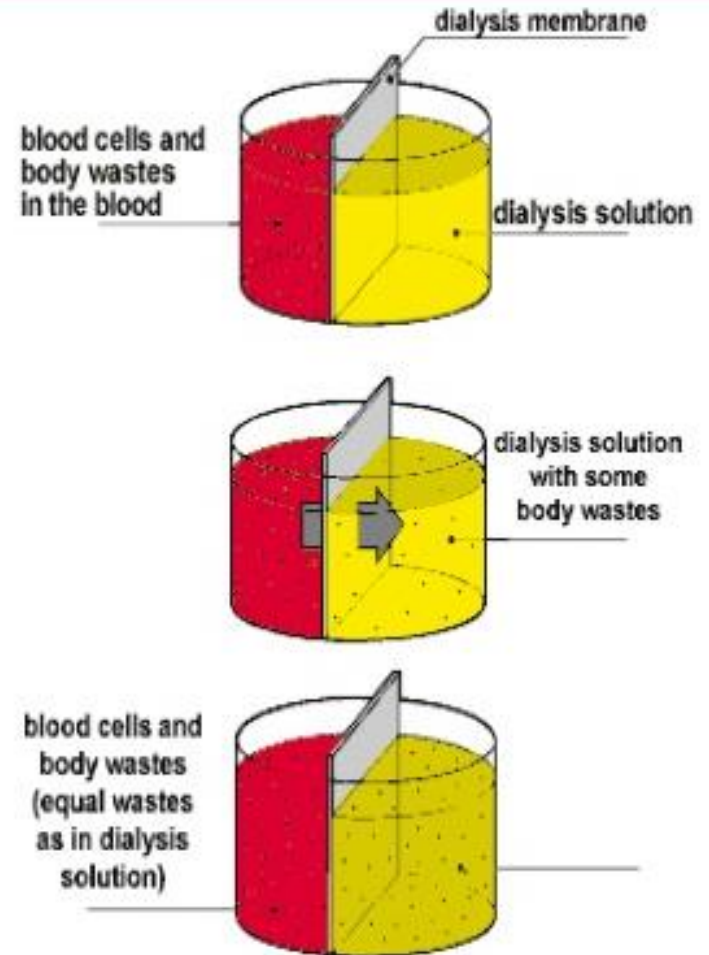
Example of membrane diffusion

- Company ABC has been decided to use a membrane to recover H_2SO_4 from nickel and sulphate in dilute solution with concentration 2.0×10^{-2} kg mol H_2SO_4 /m^3 to a solution with concentration 0.3×10^{-2}. The thickness of the membranes is 1.59×10^{-5} m, the distribution coefficient K' is 0.75 and the diffusivity is 3.5×10^{-11} m^2/s in the membrane. The mass transfer coefficient in the dilute solution is $k_{c1} = 3.5 \times 10^{-5}$ and $k_{c2} = 2.1 \times 10^{-5}$.

1. Determine the P_M
2. Calculate the total resistances
3. Calculate the flux at steady state

Dialysis membranes

- As known as Visking tubing

- A semipermeable membrane to separate a small molecular based on differential diffusion (high concentration to low concentration)

- Application of dialysis
  - ✓Blood treatment
  - ✓Desalting
  - ✓Purification of virus
  - ✓Alcohol reduction in the beer..etc

Hemodialysis

- Treatment for kidney failure for removes waste from the blood

- Typical membranes used is cellophane with 0.025mm thick.

- Hollow fiber type is used

dialysis membrane

blood cells and body wastes in the blood

dialysis solution

dialysis solution with some body wastes

blood cells and body wastes (equal wastes as in dialysis solution)

Example of dialysis

From the lab analysis, cellophane with the thickness 0.025 mm and area is 2.0 m^2 is suitable use in an artificial kidney device. The mass transfer coefficient on the blood side and aqueous side are 1.25 x 10^{-5} m/s and 3.33 x 10^{-5} m/s, respectively. The initial urea concentration in the blood is 0.02 g urea/100 mL and assume as 0 for dialyzing fluid.

- Determine the flux if the P$_M$ value is 8.73 x 10^{-6} m/s.

- Estimate the removal rate of urea from the blood