Chapter 1

1. Name one separation process that requires energy input to the system.

   Ans: Distillation

2. Name one separation process that requires a matter as input to the system.

   Ans: Coagulation

3. Define separation factor.

   Ans: $\alpha_{ij} = \frac{(x_{i1}/x_{j1})}{(x_{i2}/x_{j2})}$

   i,j are two components and 1,2 are two streams.

4. What is the driving force of mass transfer?

   Ans: Gradient of chemical potential.

5. For no separation, what is the value of separation factor?

   Ans: $\alpha_{ij} = 1$

Chapter 2

1. Name two equilibrium governing separation processes.

   Ans: Distillation, absorption.

2. Name two rate governed separation processes.

   Ans: Reverse osmosis, ultrafiltration.

3. What is the difference between absorption and adsorption?

   Ans: Absorption is a bulk phenomena and adsorption is a surface phenomena.

4. What is the difference between osmosis and reverse osmosis?

   Ans: In osmosis, water moves from solvent to salt side. In reverse osmosis, water is forced out of solute side by applying pressure.

5. What is driving force of dialysis?

Ans: Concentration gradient.

Chapter 3

1. What is the difference between symmetric and asymmetric membrane?

Ans: In symmetric membrane, the material is same with uniform porosity. In asymmetric membrane, a thin skin of lower porosity over a symmetric support acts as a membrane.

2. What is the relationship of osmotic pressure with concentration and molecular weights?

Ans: Osmotic pressure decreases with molecular weight and increases with concentration.

3. What is the relationship between observed and real retention?

Ans: Real retention > observed retention.

4. Consider filtration of 5 kg/m^3 concentration of ultrafiltration is gel layer controlled with gel concentration of 150 kg/m^3. Filtration occurs in a tube of diameter 25 mm and length 1m. The flow rate is 150 L/h, protein diffusivity is 3x10^{-11} m^2/s. Find the permeate flux?

Ans: J= Permeate flux = $k \ln \frac{c_g}{c_0}$

$$= k \ln \frac{150}{5} \quad = \quad 3.4k$$

Estimation of k:

For tubes, $Sh = \frac{kd}{D} = 1.62 \left(\mathrm{Re}\, Sc \frac{d}{L} \right)^{\frac{1}{3}}$

$$k = 1.62\left(\frac{D^3}{d^3}.\frac{u_0 d}{r}.\frac{r}{D}.\frac{d}{L}\right)^{\frac{1}{3}}$$

$$= 1.62\left(\frac{u_0 D^2}{dL}\right)^{\frac{1}{3}}$$

Q = 150L/h = $\frac{150X10^{-3}}{3600}$ m^3/s= 4.17X10^{-5} m^3/s

$$u_0 = \frac{Q}{A} = \frac{4.17\times10^{-5}}{\pi(25X10^{-3})^2/4} = 0.085\,\text{m/s}$$

$$k = 1.62\left(\frac{0.085\times9\times10^{-22}}{25\times10^{-3}\times1}\right)^{\frac{1}{3}} = 2.35\times10^{-7}\ m/s$$

J= 2.35x10^{-7}x3.4 =8x10^{-7} $m^3/m^2.s$

5. Consider reverse osmosis of salt solution at a concentration of 10 kg/m^3, in a thin channel of length 2 m and equivalent diameter of 2 mm. The membrane permeability is 2x10^{-12} m^3/(N-s). The real retention is 0.95. $\Delta P = 2500$ kPa and u_0=1.0 m/s. The osmotic pressure of salt is π(pa)=85000c (c is in kg/m^3) and salt diffusivity is 1.5x10^{-9} m^2/s. Find the permeate flux and concentration assuming a film theory?

Ans: C0=10kg/m^3; Lp= 2X10^{-12} m^3/N.s; L=2m; d_e=2mm; R_r= 0.95;

Π=85000C; D=1.5X10^{-9} m^2/s; u_0=1m/s

Mass transfer coefficient:

$$Sh = \frac{kd_e}{D} = 1.85\left(\mathrm{Re}\, Sc \frac{d_e}{L} \right)^{\frac{1}{3}}$$

$$\mathrm{Re} = \frac{\rho u_0 d_e}{\mu} = 10^6 \times 1 \times 2 \times 10^{-3} = 2000$$

So laminar flow

$$k = 1.85\left(\frac{u_0 D^2}{d_e L} \right)^{\frac{1}{3}}$$

$$= \quad 1.85\left(\frac{1 \times 1.25 \times 10^{-18}}{2 \times 10^{-3} \times 2} \right)^{\frac{1}{3}}$$

$$= \quad 1.53 X 10^{-5} \ m / s$$

Film Theory:

$$j = k \ln\left(\frac{c_m - c_p}{c_0 - c_p} \right)$$

$$C_P = C_0 (1 - R_r) = 0.05 X 10 = 0.5 kg / m^3$$

$$J = .53 X 10^{-5} \ln\left(\frac{C_m - 0.5}{9.5} \right)$$

Osmotic Pressure Model

$$J = L_P (\Delta P - \Delta \pi) = L_P (\Delta P - a C_m R_r)$$

$$\therefore J = 2 \times 10^{-12} (2500 \times 10^3 - 85000 \times 0.95 c_m)$$

$$J = 2 \times 10^{-12} (2.5 \times 10^{6} - 8 \times 10^{4} c_m)$$

$$\therefore J = 5 \times 10^{-6} (1 - 0.032 c_m) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

From equations (1) and (2),

$$1.53 \times 10^{-5} \ln\left(\frac{c_m - 0.5}{9.5}\right) = 5 \times 10^{-6} (1 - 0.032 c_m)$$

$$3 \ln\left(\frac{c_m - 0.5}{9.5}\right) = (1 - 0.032 c_m)$$

Cm	12	15	12.5	12.2
LHS	0.573	1.26	0.7	0.62
RHS	0.616	0.52	0.6	0.61

$\therefore$ C_m=12.2 kg/m^3

C_p=0.05x12.2 =0.61 kg/m^3

J= 3.05x10^{-6} m^3/m^2.s