Department of Biochemical Engineering & Biotechnology

BBL 445: Membrane Applications in Biotechnology

Minor II

March 26, 2018 **M.M.: 20** **Time: 1 hour**

1. (a) A dilute solution of protein is ultrafiltered at room temperature of 25^0C through two modules, namely, hollow fibers and tubular. The protein concentration C_B is 2.5% (w/v), protein diffusivity at 25^0C is 7×10^{-7} cm^2/sec and C_G value is estimated to be 30% (w/v). The density and viscosity of dilute protein solution is estimated to be 1.05g/cc and 1.05mPa.s respectively. The modules specifications and the protein solution volumetric flow rate data is given in the following table:

Module/ Specification	Diameter (d_h), cm	Length (L), cm	No. of fibers/tubes	Cross flow rate m^3/h
Hollow Fibers	0.10	65	600	2.7
Tubular	1.5	250	20	16.2

Estimate the maximum flux (in LMH) one can expect in the above two modules based on the concentration polarization model. **(8)**

(The correlations for calculating mass transfer coefficients k for laminar and turbulent flow regime are: For turbulent flow, when Re > 4000, $Sh = 0.023 (Re)^{0.8} (Sc)^{0.33}$ and for laminar flow, when Re < 1800, $Sh = 1.86 (Re)^{0.33} (Sc)^{0.33} (d_h/L)^{0.33}$ where Sh ($=kd_h/D$) is Sherwood number, Re ($= d_h V \rho/\mu$) is Reynold number and Sc ($= \mu/\rho D$) is Schmidt number. All symbols are same as followed in the book.)

(b) What will be the resistance of concentration polarization layer in hollow fiber module, given that the limiting flux appears for 450 kPa and membrane permeability is 0.20 l/m^2 h kPa. **(1)**

(c) What will be the most likely osmotic pressure in hollow fiber module when limiting flux occurs at 450 kPa? (Hint: Use Osmotic model to explain the limiting flux) **(1)**

2. (a) Make few representative sketches of spiral wound module to briefly explain its functioning by the way of cross section area, feed fluid trajectory and collection of permeate. **(2)**

(b) For a low flux UF membrane using a high cross flow velocity of 5 m/s, a protein transmission was measured and found to first decrease and then increase with increasing volumetric flux. If reflection coefficient (σ) for this UF membrane-protein system was 0.87 and minimum transmission occurred at 50 LMH flux calculate solute permeability through UF membrane. Mass transfer coefficient at 5 m/s cross flow velocity was estimated to be 3×10^{-5} m/s. **(2)**

3. (a) The concentration polarization changes the observed rejection coefficient due to build-up of solute at the membrane surface which affects MWCO of the membrane. Briefly explain this effect. Make suggestions to minimize this effect. **(2)**

(ii) A very dilute solution of a protein is ultrafiltered through a partially retentive UF membrane in a tubular module. The volumetric flux and transmission coefficient through UF membrane was measured as a function of pressure for a constant cross flow velocity. The following data was obtained:

TMP (bar)/Flux (LMH)	0.2/ 36	0.4/ 72	0.6/ 108	0.8/ 144	1.0/ 180
Transmission coefficient	0.28	0.40	0.50	0.60	0.72

Calculate the mass transfer coefficient (k) & true transmission coefficient (τ). State your assumptions. **(4)**

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