equation constants are valid when other proteins are present.

(a) Determine the maximum percentage recovery of protein 4 that can be obtained if it is desired to obtain a precipitate containing 100% protein 4.

(b) Determine the maximum percentage recovery of protein 3 that can be obtained if it is desired to obtain a mother liquor containing 99% protein 3.

8.4 **Mixer Power to Achieve Complete Mixing** It is desired to precipitate a protein in a solution with a density of 1.02 g/cm^3 and kinematic viscosity of 0.012 cm^2/s. The diffusion coefficient of the protein has been estimated to be 1.2×10^{-7} cm^2/s. You need to select a mixer for this precipitation. To aid in this selection, plot as a straight line the dependence of the mixer power per solution volume (kW/liter) as a function of the time (s) to completely mix the solution for mixing times up to 100 s.

8.5 **Kinetics of Precipitation of a Protein** The data in Table P8.5 for particle number concentration N were obtained for the precipitation of a protein. Nucleation started at time zero.

You also know the following information:
Protein concentration = 3.0 g/liter
Power input = 1.5 kW (2.0 hp)
Liquid volume = 1000 liters
Liquid density = 1.05 g/cm^3
Liquid viscosity = 0.012 g cm^{-1} s^{-1}
Molecular weight of protein = 200,000
Density of protein particles = 1.3 g/cm^3
The flow is turbulent.

From this information, determine:

(a) The time and particle diameter at which particle growth started to be governed by particles colliding and sticking together,

(b) The constant K_A in the equation by Smoluchowski describing particle growth by diffusion,

(c) The collision effectiveness factor α for particle growth by fluid motion

TABLE P8.5

t (min)	N (particles/cm^3)	t (min)	N (particles/cm^3)
0.5	3.72×10^9	3.5	4.51×10^8
1.0	1.86×10^9	4.0	2.29×10^8
1.5	1.24×10^9	4.5	8.49×10^7
2.0	9.28×10^8	5.0	3.14×10^7
2.5	7.42×10^8	5.5	1.16×10^7
3.0	6.19×10^8	6.0	4.31×10^6

8.6 **Protein Precipitation in a CSTR** For a protein precipitation in a CSTR, determine the functional dependence of the mass-averaged particle size $\bar{L}_m$ (for particles above the critical aggregate diameter L_0) on the residence time τ, parameter K_0, and L_0. Assume that particle breakage is negligible. For a value of K_0 of 0.02 min^{-1} (determined for soy protein precipitating in a CSTR by A. M. Petenate and C. E. Glatz, "Isoelectric precipitation of soy protein. II. Kinetics of protein aggregate growth and breakage," *Biotech. Bioeng.*, vol. 25, p. 3059, 1983) and L_0 of 1.0 μm, plot the dependence of $\bar{L}_m$ on τ.

8.7 **Scaleup with Constant Power/Volume or Maximum Shear Rate** A protein precipitation reactor with a mechanical agitator is being scaled up from volume V_1 to volume V_2 by two different methods: keeping power per unit volume (P/V) constant, or keeping the maximum shear rate (γ_{max}) constant.

(a) For the scaleup keeping P/V constant, determine the ratio of γ_{max} at volume V_2 to γ_{max} at volume V_1 as a function of V_1 and V_2:

$$\frac{(\gamma_{max})_2}{(\gamma_{max})_1} = f(V_1, V_2)$$

(b) If constant γ_{max} is being used for scaleup, determine the ratio of P/V at volume V_2 to P/V at volume V_1 as a function of V_1 and V_2:

$$\frac{(P/V)_2}{(P/V)_1} = g(V_1, V_2)$$

8.8 **Design of a Tubular Reactor to Precipitate a Protein** A protein at a concentration of 2.0 g/liter is to be precipitated in a tubular reactor at 20°C and a rate of 1.0 kg/h. It is desired that the protein precipitate particles leaving the reactor have a diameter of 10 μm. The properties of the protein are as follows: molecular weight of 480,000, diffusion coefficient of 3.5×10^{-7} cm^2/s at 20°C, and precipitate particle density of 1.29 g/cm^3. Design a tubular reactor (i.e., specify diameter and length) to carry out the precipitation in turbulent flow at a Reynolds number of 10,000. It can be assumed that the particle collision effectiveness factor (α) is 0.05 for particle growth governed by fluid motion.