# Biophysical Chemistry for Life Scientists

**Biotechnology Research Center, National Taiwan University**
**Fall 2000**
**Instructor: Sunney I. Chan**
**Vice President & Distinguished Research Fellow**
**Institute of Chemistry, Academia Sinica**
**Telephone: 2-2789-9402**
**E-mail: chans@chem.sinica.edu.tw**

**Problem Set 7**
**Due Monday, December 18, 2000**

1) Estimate the charge density across a biological membrane of thickness 100 Å when the transmembrane potential is 100 mV. You may assume that the membrane is made up of neutral or uncharged lipids only, and that the transmembrane potential arises from asymmetric distribution of ions across the membrane. The dielectric constant of the membrane ($\varepsilon$) may be taken as $\approx 4$. Express your result in number of charges per square micron.

2) A membrane permeable only to $Zn^{++}$ ions separates $ZnSO_4$ solutions of $10^{-5}$ $\underline{m}$ (left) and $10^{-4}$ $\underline{m}$ (right). Calculate the transmembrane potential at equilibrium of this concentration cell.

3) The potassium ion concentration inside a nerve cell at 25°C is measured and found to be 20 times higher than the concentration outside the cell. In contrast, the sodium ion concentration is 20 times higher outside the cell than inside. The potential difference across the cell membrane is 77 millivolts, with the inside negative relative to the outside. Identify the component that must be transported actively and calculate the minimum free energy required to operate the ion pump to maintain steady state. You may assume ideal solutions in this analysis.

4) Consider a solution of DNA molecules at a concentration of 1 mg/ml, at 25°C, dialyzed to equilibrium against 0.001 M NaCl, pH 7. Calculate the ratio of $Na^+$ and $Cl^-$ across the dialysis membrane and the transmembrane potential at equilibrium. You may assume 1 negative charge per nucleotide of molecular

weight 340 gram/mole.

5) Calculate the frictional coefficient of ribonuclease, which has a diffusion constant of $1.1 \times 10^{-6}$ $cm^2$/sec at 20°C.

6) (a) Calculate the average time required for a protein molecule of diffusion coefficient $10^{-6}$ $cm^2$/sec to move the length ($10^{-4}$ cm) of a bacterial cell by diffusion.

(b) Suppose the diffusion constant for a molecule moving across a lipid bilayer is $10^{-8}$ $cm^2$/sec. How long would be required to traverse the 100 Å= $10^{-6}$ cm width?

7) The equation of motion for a particle that is diffusing in a viscous medium could be described by

$$m\,(dv/dt) = F_d - f\,v,$$

where m is the mass of the particle, v is its instantaneous velocity, f is the frictional coefficient, and $F_d$ is the driving force. The solution to this differential equation is

$$v(t) = (F_d / f)\,[\,1 - \exp(-f\,t/m)].$$

(a) Verify by differentiation that the above solution satisfies the differential equation.
(b) The solution describes the behavior of the particle from the initiation of the flow to its asymptotic limit when it reaches the limiting terminal velocity. Study the limit at long times and show that the terminal velocity is given by $v_{limiting} = F_d/ f$.

(c) From the result obtained in Problem 5 above, calculate m/f for ribonuclease (M = 13,683) and estimate the time constant for decay of the acceleration terms during the diffusion process.