Homework #8 Due: November 17, 2006
Name _________________________ Chemistry 331

1. The molar mass of a protein is determined from a measurement of the osmotic pressure. If 0.01 grams of the protein is dissolved in 1 ml. and osmotic pressure of 5×10^{-6} atm develops at a temperature of 310 K, what is the molar mass of the protein?
   Solution: $\Pi = cRT = (m/M/V)RT$ where m is mass and M is molar mass.
   Therefore, $M = mRT/\Pi V$ = (0.01 gm) (0.08206 L-atm/mol-K)(310 K)/(5×10^{-6} atm) (0.001 L) = 5×10^{7} grams/mol
   This is some kind of aggregate or a large virus.

   Molar mass = ____.

2. Trehalose acts as a cryoprotectant in fungal cells. Assuming that the major effect of trehalose is to act as a solute to the lower freezing point (freezing point depression), calculate the mole fraction of trehalose that would be needed to lower than the freezing point in cell to 260 K. The enthalpy of fusion of water is ΔH_{fus} = 6 kJ/mol.
   Solution:
   $\ln(a_{H2O}) = \Delta H/R(1/T_1 - 1/T_2)$, where a_{H2O} is the mole fraction of the solvent
   $a_{H2O} = \exp\{\Delta H/R(1/T_1 - 1/T_2)\}$
   $= \exp\{6000$ J/mol/8.31 J/mol-K)(1/273K–1/260K)$\}$
   $= 0.876$
   Therefore, the mole fraction of trehalose is $1 - a_{H2O} = 0.124$

   Mole fraction of trehalose needed = ________________________________.

3. Calculate the surface tension of a liquid if the capillary rise in a tube of radius of 100 μ is 0.1 m and the density is 0.8 gm/cm^3.

Solution: $\rho gh = 2\gamma/R \rightarrow \gamma = \rho ghR/2$ = (800 kg/m^3)(9.8 m/s^2)(0.1 m)(10^{-4} m)/2 = 0.039 J/m^2.

4. Myoglobin is a skeletal protein that binds oxygen. The standard free energy for the reaction

$$Mb + O_2 \rightarrow MbO_2$$

Given that ΔG^o = -30.0 kJ/mol at 298 K and pH 7. The standard state of O_2 is the dilute solution molarity scale; therefore the concentration of O_2 must by in units of molarity (M). What is the ratio (oxymyoglobin)/(total myoglobin) in an aqueous solution at equilibrium with a partial pressure of oxygen $P(O_2)$ = 100 Torr? Assume ideal behavior of O_2 gas and that Henry's law holds for O_2 dissolved in water ($K(O_2)$ = 43×10^3 atm).

Solution: The concentration of O2 in solution is given by Henry's law.
$P(O_2) = K(O_2)\ x(O_2)$ or
$x(O_2) = P(O_2)/K(O_2) = 100$ Torr/43000 atm(760 Torr/atm) $= 3 \times 10^{-6}$
Since the molarity of water is 55.5 molar the molarity of oxygen is approximately
$[O_2] = 3 \times 10^{-6}(55.6\ M) \sim 1.7 \times 10^{-4}$ M.
$K = \exp\{-\Delta G^o/RT\} = \exp\{30000/8.31/310\} = 1.14 \times 10^5$
$\theta = K[O_2]/\{1 + K[O_2]\} = (1.14 \times 10^5)(1.7 \times 10^{-4})/\{1 + (1.14 \times 10^5)(1.7 \times 10^{-4})\} = 0.95$