Biophysical Chemistry for Life Scientists

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Problem Set 3
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(1) A collagen fiber, bathed in a salt solution, can be stretched reversibly. The restoring force which the fiber exerts is $F = - k x$, in which x is the distance (from equilibrium), and k is the force constant (10^4 dyne cm^{-1}). Calculate the work performed by the fiber when it contracts isothermally from $x = 10$ to $x = 0$.

(2) Two phospholipids of different acyl chain lengths A and B form a bilayer membrane that is essentially an ideal mixture of the two components at 37 °C. What is the (a) entropy of mixing and (b) free energy of mixing, to form a membrane of composition 30% lipid A and 70% lipid B from the pure bilayers at this temperature? (c) What assumption(s) have you made about the interaction energies between the A lipids, between the B lipids, and between the A and B lipids, in estimating the enthalpy of mixing in (b) above? Recall that in the fluid phase of these bilayer membranes, the lipid molecules are organized in an approximately hexagonal close-packed arrangement.

(3) In the diatomic molecule HCl, the energy separation between the ground and first excited vibrational states/levels is 8.26 kcal mol^{-1}. (a) Calculate the vibrational contribution to the molecular entropy at 298 K. (b) Repeat the calculation for 1000 K. You may assume that the stretching vibration behaves like a harmonic oscillator in this molecule. (c) During the process of bringing the gas from 298 K to 1000 K, it would take different amounts of

heat or thermal energy to excite the translational, rotational, and vibrational degrees of freedom. In addition, the vibrational contribution to the molar heat capacity should be strongly temperature-dependent over such a wide temperature range. Work out an expression that would allow you to predict the temperature dependence of the vibrational contribution to C_p over this temperature range, and sketch out the result in a plot.

(4) Calculate the entropy change for the hypothetical process in which 0.5 gram of ice at 0 °C melts to water at 0 °C and 0.5 gram water at −10°C freezes to ice at −10 °C. Assume $\Delta H_{fusion} = 80$ cal g^{-1}, independent of temperature.