Biophysical Chemistry for Life Scientists

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Problem Set 4
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(1) Two silver blocks, each of heat capacity C_v, are brought into thermal contact so that heat could be transferred from one block to the other. One block is at 75 °C, while the other is at 25 °C. Calculate ΔS for the process. Express the result in terms of C_v.

(2) Suppose that we have two immiscible liquids, such as water and chloroform ($CHCl_3$). They form two separate phases when placed in the same container. Now, let us add solute A that is soluble in both liquids. At equilibrium, some of A will be in the water phase, and some in the organic phase. Our problem is to describe the equilibrium quantitatively.

(a) Write down the chemical equation that would describe the partitioning of A from the aqueous phase into the chloroform.

(b) What equation would you use to describe the free energy of transfer of A from the aqueous phase to the organic phase?

(c) What equation would you use to describe the situation when the system has reached equilibrium?

(d) If the solubility of A in the aqueous phase is 10^{-4} m, and the equilibrium constant for the partitioning of A from the aqueous phase into the organic phase is 10, what is the concentration of A in the organic phase when the aqueous phase is saturated?

(e) What are the units of the equilibrium coefficient and the equilibrium constant (often referred to as the partition coefficient)?

(f) Use the result in (d) to rewrite the chemical equation for the process

when the system is in chemical equilibrium. That is, specify the concentration of A in the two phases.

(g) Repeat (e) for the system when the process is taking place under the standard states of the system.

(h) Does the answer to part (g) differ if the concentrations of A were expressed in terms of mole fractions in the two solvents? In other words, does $\Delta G°(T)$ differ if mole fractions were used to denote the concentrations of A instead of moles/1000 grams of solvent in each phase?

[Note that the above process is akin to partitioning of a solute from the aqueous solution into the phospholipid bilayer of a bio-membrane in a cell.]

(3) Chemical reactions take place at 37 °C in most biological systems. On the other hand, standard heats and entropies of formation of most substances are only tabulated at 25 °C. Obtain a general expression for (a) $\Delta G°(T)$ and (b) the equilibrium constant for a biological reaction at 37 °C. Express your result in terms of $\Delta H°$, $\Delta C°_p$ and $\Delta S°$ for the biological reaction.