

Assignment 13

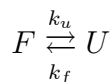
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Physics G731

Fall 2007

Due Monday, Dec. 10.

Protein folding. When a certain protein is dissolved in water at 320 K, 70% of the proteins are folded in equilibrium. After a rapid 10 K temperature increase to 330 K, the fraction that are folded decreases to 20% with a time constant of 400 μ s. Consider the reaction

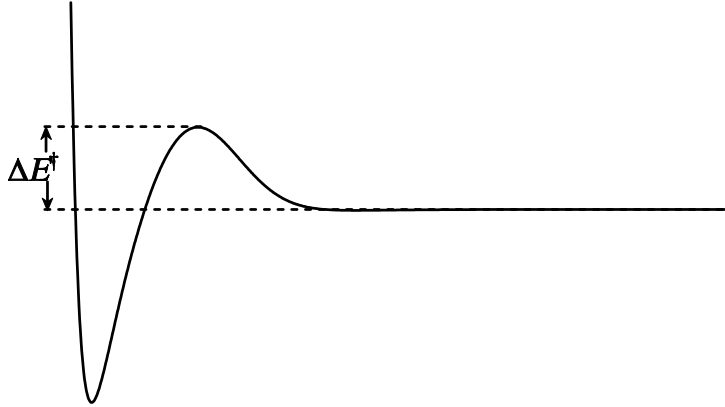


connecting the folded and unfolded states, F and U .

- (a) Determine the free energy difference Δg between folded and unfolded states at 330 K. ($\Delta g > 0$ means that the unfolded state is more stable.)
- (b) Determine the rate constants k_f and k_u for folding and unfolding, respectively.
- (c) Determine the enthalpy and entropy changes, Δh and Δs , between folded and unfolded states at 330 K.
- (d) The experiment is repeated in a sucrose/water solution with a viscosity $\eta = 15$ mPa·s, 15 times larger than the original water solution. Assuming that the sucrose does not interact directly with the protein, predict how each of the rate constants k_f and k_u will change.

Kramers theory: high friction limit. In the high friction limit, diffusion on a one-dimensional energy surface models the viscosity and temperature

dependence of many activated reactions. Recall that molecular drift at an average velocity v_d produces a net flux $J = cv_d$ in addition to the constant diffusive flux $J = -D\partial c/\partial Q$. Assume that the drift velocity $v_d = F/\zeta$ is proportional to an applied force $F = -\partial V/\partial Q$ determined by the molecular potential energy $V(Q)$ as a function of the reaction coordinate Q .



- (a) Use the Einstein-Smoluchowski relation to demonstrate that the total flux (drift + diffusion) takes the form

$$J(Q) = -De^{-V/k_B T} \frac{\partial}{\partial Q} (ce^{V/k_B T})$$

for diffusion on the potential surface $V(Q)$.

- (b) Take the minimum of the product well as $Q = 0$ and expand the potential

$$V = \Delta E^\ddagger - \frac{1}{2}\omega^\ddagger{}^2 (Q - Q^\ddagger)^2 + \dots$$

about the transition state position Q^\ddagger . Show that

$$\int_0^\infty J e^{V/k_B T} dQ = J e^{\Delta E^\ddagger/k_B T} \left(\frac{2\pi k_B T}{\omega^\ddagger{}^2} \right)^{1/2}$$

using this lowest order approximation for V , assuming steady state conditions where $J = \text{const.}$ State the conditions under which this is a good approximation.

- (c) Take as boundary conditions an empty product well [$c(0) = 0$] and a fixed concentration at large distances [$c(Q \rightarrow \infty) = c_0$]. Use equations to demonstrate how the reaction rate

$$J = \left(\frac{\omega^\ddagger^2}{2\pi k_B T} \right)^{1/2} D e^{-\Delta E^\ddagger / k_B T} c_0$$

depends on concentration and temperature. Explain how the rate depends on the viscosity of the solvent.