Phys 450
Homework set 4 due Wednesday May 1, 2002

Problem 1

Plot the time dependence of the depletion of the species A in the following reactions:

(a) $A \xrightarrow{k_{uni}} B$

(b) $A + A \xrightarrow{k_{bi}} P$

Pick rate constants and initial concentrations such that $k_{uni} = [A]_0 k_{bi}$ where $[A]_0$ is the initial concentration of A.

Plot the time dependence of the two reactions on the same graph.

Choose two different representations for the axes:
(i) linear in x-axis & logarithmic in y-axis
(ii) logarithmic in both x-axis and y-axis

Problem 2

Plot the time dependence of the depletion of the species A for the following bimolecular reaction with $[A]_0 < [B]_0$. Pick either representation (from Problem 1) for your axes.

$$A + B \xrightarrow{k_{bi}} P$$

Pick four different concentrations for $[B]_0$ ranging from slightly larger than $[A]_0$ to much larger than $[A]_0$.

How do the kinetics change as you increase $[B]_0$?

Problem 3

An enzyme M has four binding sites for its substrate X. The binding affinity for each site is given by the *microscopic* association constant $K_a = k_{on}/k_{off}$ where k_{on} is a bimolecular rate constant for the binding of X to each site, and k_{off} is the unimolecular rate constant for the dissocation of X from a bound site. Write down the *macroscopic* rate constants for association and disocciation, and the *macroscopic* equilibrium association constant for each of the steps in the following reaction, taking into account the statistical factors that arise as a consequence of multiple binding sites in M

$$[M_0] + X \Leftrightarrow [M_1]$$

$$[M_1] + X \Leftrightarrow [M_2]$$

$$[M_2] + X \Leftrightarrow [M_3]$$

$$[M_3] + X \Leftrightarrow [M_4]$$

Problem 4

Consider a microtubule which is 100 microns long, and has a bending modulus of B = 1.5×10^{-23} J.m (microtubules of this length can be grown on a microscopic slide)

(a) Find the Young's modulus, approximating the microtubule to have a uniform and circular cross-section of radius 12 nm. (Ignore the fact that microtubules are hollow).

(b) Now, suppose that one end of the microtubule is clamped down, leaving the other end free to wobble. Estimate the work that must be done to displace the free end of the microtubule by an amount x in a direction perpendicular to the microtubule itself.

(c) Thermal fluctuations will bend the microtubule spontaneously. What is the mean-squared amplitude $< x^2 >$ that we should expect?