Problem set 7
(Discussion on July 9)

Problem 1

Polyethylene glycol (PEG) as a freely-jointed chain. PEG is a polymer that is often used in biophysical and biochemical applications. It consists of N repeating units of the formula $(\mathrm{O{-}CH_2{-}CH_2})_N$. We will assume that it can be modeled as a freely-jointed chain in which we assume the chemical repeat unit to be the segment length with a length $b = 4$ Å .

a) How many repeat units (i.e. what is N) for a 1000 g/mol and for a 100,000 g/mol PEG polymer chain?

b) What is the maximum length (i.e. the contour length) of the chains?

c) What are the root mean squared end-to-end distances?

d) What are the radii of gyration R_g? Hint: For a FJC the relationship between the root-mean-squared end-to-end distance R_{ee} and the radius of gyration R_g is $R_{ee} = \sqrt{\langle \vec{r}_{ee}^2 \rangle} = \sqrt{6} \cdot R_g$.

e) Derive a general formula for the R_g of PEG as a function of molecular weight M_w (in g/mol or Daltons) using the assumptions above.

f) Devanand and Selser (*Macromolecules*, 1991) used light scattering to determine the R_g of different molecular weight PEG chains. They fitted their experimental data with a power law and found an empirical formula given by

$$R_g = 0.215 \; M_w^{0.583 \pm 0.031} \quad \text{Å}$$

Compare your results from the previous part to their formula. How well do they agree? Can you think of a reason for any observed differences?

Problem 2

Michaelis-Menten for survival 1. The antibiotic penicillin can be hydrolyzed (and therefore rendered ineffective) by an enzyme called β-lactamase. This enzyme occurs in several strains of penicillin-resistent bacteria. A β-lactamase from *Staphylococcus aureaus* has a mass of 29.6 kDa. In a series of experiments, we have determined the amount of penicillin hydrolyzed in 1 min by a 10 ml solution containing 1 ng β-lactamase, for different penicillin concentrations (see table below). We assume that the penicillin concentration does not change significantly during the experiment.

[Penicillin] (μM)	Hydrolyzed amount (nmols)
1	0.11
3	0.25
5	0.34
10	0.45
30	0.58
50	0.61

a) Make a plot of the reaction rate vs. penicillin concentration. Does the β-lactamase activity follow Michaelis-Menten kinetics?

b) Determine values for K_M and v_{max} from the data.

c) What is the *turnover frequency* k_{cat} ($= k_2$ in the notation of Lecture 17) for this enzyme (assuming one active site per enzyme molecule)?

Problem 3

Michaelis-Menten for survival 2. Two bacterial strains, A and B, use sucrose (table sugar) as a sole carbon source (i.e. "food"). The first step in the process of sucrose utilization is the passage of sucrose through a sucrose transporter protein in the membrane. The two strains have different transport proteins; both transporters follow Michaelis-Menten kinetics for their transport and both strains have the same (copy) number of transporters. The Michaelis-Menten parameters for the respective transporters have been measured experimentally:

Strain	A	B
K_M	1000 mM	10 mM
V_{max}	1000 mmol/min	100 mmol/min

a) Assuming that the rate of sucrose uptake is the rate limiting step in growth, which strain will grow faster if the concentration of sucrose is: 10 mM? 100 mM? 1000 mM?

b) Schematically draw the transport rate as a function of sucrose concentration for the two strains.

c) One strain was isolated from the soil and the other from the floor of the "Der verrückte Eismacher" ice cream shop. Which was likely to be which? Why?