Tfy-0.3252 Soft Matter Physics / Pehmeän aineen fysiikka
Exam 19.12.2007 (5 problems / 2 pages).

Since the language of the course was English, the exam problems are in English as well. You can write your answers either in English or Finnish.

Problem 1. (4 points)
Define *soft matter*: What are the characteristic features of soft matter systems? What distinguishes soft matter from other types of condensed matter, for example crystalline solids and standard liquids? Give three every-day examples of soft matter and explain why your examples classify as soft matter.

vastefunktiot suuret pienet muutokset
heikot sidokset vdW / Hydro k_BT

neste-kide-näyttö
kananmunan proteiinit
hyytelö

Problem 2. (5 points)
Consider a semi-infinite flat wall that fills the space $x \leq 0$. The surface charge density of this wall is σ_{surf}. The space $x > 0$ is filled with an aqueous solution. The solution contains ions of different types i, each with an ionic valence z_i and a concentration c_i^0 very far from the surface (that is, in the bulk solution).

Starting from the Poisson-Boltzmann equation, derive the contact value theorem that relates the wall surface charge density σ_{surf} and the ionic bulk concentrations c_i^0 to the ionic concentrations c_i^{surf} at the wall surface. (Hint: remember the requirement for electroneutrality in the total system.)

$x \to \infty \quad c \to 0$
$x \to 0 \quad c \to 1$

Problem 3. (10 points)
Give a short explanation of the following concepts and terms. Use illustrations if possible.

a) Hydrogen bond $D^- - H^+ \cdots A^-$
b) Critical micelle concentration
c) Aerosol neste→kaasu tai kiinteä→kaasu
d) Spinodal curve 2. Derivaatta metastabiilin ja epästabiilin raja
e) Molecular dynamics simulation method

molekyylien väliset yleiset vuorovaikutukset => mikä hylkii mitäkin

Problem 4. (5 points)
Answer either to part **(a)** or **(b)**.

a) Outline the fundamental molecular interactions that give rise to the hydrophobic effect with small solute particles (linear size $R < 1$ nm). From a thermodynamic point of view, what is the driving force for the hydrophobic effect in this case? How does this differ from the case of a large solute particles ($R \gg 1$ nm)? Finally, give two examples of how the hydrophobic effect manifests in the functioning of biological soft matter systems. lipidikalvot lipidikalvoissa
proteiinit

b) Describe the most typical liquid crystal phases and the general types of molecules forming them. What are the positional and orientational symmetries related to each phase? Describe the general relation between temperature and liquid crystal phases formed at a fixed mesogen concentration.

N & N* Nematic *=chiral
SmA SmC SmC*
smectic
discotic

Problem 5. (6 points)
The DNA of the bacterium *Escherichia Coli* (or simply *E. Coli*) is 4.64 $\times 10^6$ basepairs long. Along the double helix form of the DNA, each basepair contributes 0.34 nm to the total contour length of the DNA. The persistence length of the DNA is $l_p = 50$ nm.

a) The mean-square end-to-end distance of a freely rotating polymer chain is

$$\langle R^2 \rangle = Na^2 \left(\frac{1+\cos\theta}{1-\cos\theta} \right),$$

where N and a are the number and length of bond vectors along the polymer, respectively, and θ is the angle between two consecutive bond vectors. The persistence segment for the same model is

$$s_p = -\frac{1}{\ln\cos\theta}.$$

Interpret the cosine term in parentheses in the expression of $\langle R^2 \rangle$. Explain what is the physical meaning of the persistence segment and how it is related to the persistence length l_p.

b) Conformations of double-stranded DNA are often described with the *worm-like chain model.* Derive approximate expressions for $\langle R^2 \rangle$ and s_p in this model. Then, construct an equivalent freely joint chain model for the DNA of *E. Coli*. That is, determine the the Kuhn length b and the number of coarse-grained bonds $\tilde{N}$ in this particular case.

c) Using your equivalent freely joint model, calculate the root-mean-square end-to-end distance, $R_{rms} \equiv \sqrt{\langle R^2 \rangle}$, of the DNA of *E. Coli*. Compare your result to the length of an *E. Coli* bacterium, 2 μm.

The linear charge density of a double-stranded DNA is extremely high, $\approx -e/0.17$ nm. This means that different parts of the DNA repel each other very strongly electrostatically. Based on what you have learned at the course, suggest a way how, in principle, the DNA could fit inside *E. Coli.*

Remember that you got 1 exam point by filling in and returning the course feedback form. If you have not returned the form, please contact the lecturer as soon as possible.