**Tfy-0.3252 Soft Matter Physics / Pehmeän aineen fysiikka**
**Exam 10.01.2008 (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. (5 points)**
Describe different ways to control the stability of colloidal systems. Briefly explain the physics behind each method. Use illustrations if possible. Give an example of a real-life application where the stability of a colloidal system is desired. Conversely, give an example of an application where a colloidal system needs to be made unstable instead.

**Problem 2. (6 points)**
In the Flory-Huggins theory for polymer solutions and melts free energy of mixing, per monomer, is written as

$$\Delta g = k_B T \left[ \chi x_A x_B + \left( \frac{x_A}{N_A} \right) \ln x_A + \left( \frac{x_B}{N_B} \right) \ln x_B \right],$$

where $x_i$ and $N_i$ are the molar fraction and degree of polymerization, respectively, of species $i$. Explain the meaning of the parameter $\chi$. Determine the critical point for the case of two polymers of the same degree of polymerization, $N_A = N_B = N \gg 1$ and $\chi > 0$.

Demonstrate the difficulty of mixing the two polymer species by determining the molar fraction limits of solubility (*i.e.*, limiting molar fractions of stable solutions) by using some reasonable approximations. Qualitatively speaking, how does the situation change if one has $N_A \gg 1$ and $N_B = 1$ instead?

**Problem 3. (8 points)**
Give a short explanation of the following concepts and terms. Use illustrations if possible.
a) Glass transition
b) Osmotic pressure
c) Dielectrophoresis
d) Smectic liquid crystal

**Problem 4. (5 points)**
Answer <u>either</u> to part (**a**) or (**b**).

**a)** Define the surfactant packing parameter $P$ and explain its importance. What physical factors determine the values of the different quantities in $P$? How could one control the value of $P$ in the case of some given surfactant? Finally, show that surfactants form cylindrical micelle aggregates when $1/3 < P \leq 1/2$.

**b)** Outline the DLVO theory of colloidal stability: its components, assumptions and limitations. Describe the general features of the DLVO energy profile and their significance to colloidal stability. Furthermore, describe the effect of ion concentration of the colloidal suspension on the DLVO energy profile.

**Problem 5. (6 points)**
a) Write the Poisson-Boltzmann equation for the electrostatic potential $\Phi$ of a polyelectrolyte near a charged object. Linearize the Poisson-Boltzmann equation to obtain the so-called Debye-Hückel approximation. Identify the related characteristic length $\kappa^{-1}$ known as the Debye screening length.

b) Consider a spherical colloidal particle of radius $R$ and charge $Q$ in a symmetric monovalent electrolyte. Within the framework of the Debye-Hückel approximation, solve the electrostatic potential $\Phi$ around the spherical particle.

How does your result differ from the usual Coulomb potential of a charged sphere?

Recall: for a spherical symmetric case $\Phi = \Phi(r)$ and so $\nabla^2\Phi = \frac{1}{r^2}\left(\frac{d}{dr}\left(r^2\frac{d\Phi}{dr}\right)\right)$. Assume a functional form $\Phi(r) = u(r)/r$.

**Remember that it was possible to get 1 exam point by filling in and returning the course feedback form by December 18. This point is *not* a bonus point.**