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Department of Applied Physics  
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**Exam in Soft Matter Physics TIF015/FIM110**

**Time:** Tuesday August 28, 2012, 14-18.00.

**Examiner:** Aleksandar Matic (0730-346294)

**Allowed material:** Physics Handbook or equivalent, dictionary and pocket calculator

**Grading:** 24 points, is required for a passed.

**Review of the exam:** Contact Aleksandar Matic after September 11

**Note:** All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. a) Given the free energy as a function of concentration of one of the species of a binary mixture, how can you graphically determine the stable compositions of the mixture? (4p)

b) The graphical method mentioned above can be derived from requiring that a certain thermodynamic property must be equal in the coexisting phases. Which quantity? (3p)

c) More generally, all so called intensive quantities must be equal in all coexisting phases. Name two other intensive quantities (different from the one in b). (3p)

2. a) Sketch the general behaviour of a radial distribution function  $g(r)$  for a glass and a crystal respectively. (4 p)

b) How can you experimentally determine the radial distribution function,  $g(r)$ , for a glass? (2 p)

3. For an ideal polymer chain the mean square end-to-end distance can be described simply by a random walk:

$$\langle r^2 \rangle_0 = nl^2$$

where  $n$  is the number of monomers and  $l$  is the length of each monomer. In the valence angle model a fixed valence angle  $\theta$  between successive bonds is introduced.

$$\langle r^2 \rangle_0 = nl^2 \left( \frac{1 - \cos\theta}{1 + \cos\theta} \right)$$

In the next level of approximation also the restriction on bond angle rotation  $\phi$  (i.e. trans, gauche+ or gauche-) is taken into account. The steric hindrance is difficult to work out theoretically so instead  $\sigma$ , an experimentally extracted factor is introduced in the rotational isomeric state model:

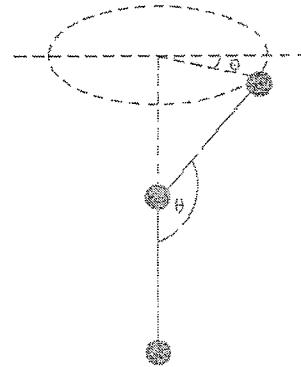
$$\langle r^2 \rangle_0 = \sigma^2 nl^2 \left( \frac{1 - \cos\theta}{1 + \cos\theta} \right)$$

For a linear molecule of polyethylene of molar mass 150 000 g/mol (the monomer is CH<sub>2</sub>) calculate

- the contour length of the polymer chain. (1p)
- The root-mean-square end-to-end distance according to the valence angle model. (1p)
- The root-mean-square end-to-end distance according to the rotational isomeric state model. (1p)

For polyethylene the steric factor  $\sigma$  is 1,73. The C-C bonds are of length 0.154 nm and  $\theta$  is 109,5°

- Give an expression for the number of conformations the polyethylene chain in question one can adopt in the rotational isomeric state model. (2p)

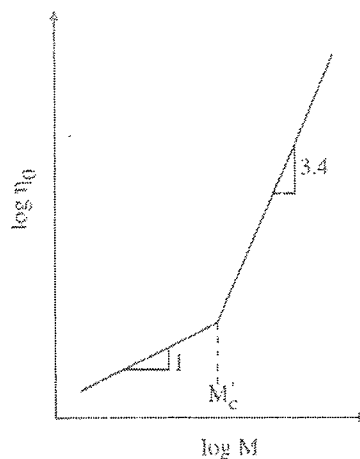


4. Measurements of the plateau modulus of polystyrene indicate a value of  $G_e = 2 \times 10^5 \text{ Pa}$  at  $T = 433 \text{ K}$ . Using a density  $\rho = 1,05 \text{ g cm}^{-3}$ , the entanglement molar mass  $M_e = \rho RT / G_e$  can be determined.

- Determine  $M_e$  (1p)

For two pairs of samples with the following molar masses determine the ratios of the viscosities  $\eta$ :

- 14 kg/mol; 7 kg/mol (2p)
- 100 kg/mol; 50 kg/mol (2p)



5. a) Derive the limits for formation of cylindrical micelles and bilayers of amphiphilic molecules in terms of characteristics of the amphiphilic molecule (headgroup area, hydro carbon volume and critical chain length). (4p)

b) In a solution of the amphiphilic molecule Sodium dodecyl sulphate (SDS, chemical formula  $C_{12}H_{25} - OSO_3Na$ ) in water, at room temperature, the amphiphilic molecules are either present as monomers or in micelles of aggregation number  $M$ . The volume fraction of amphiphilic molecules in the micelles,  $X_M$ , is given in terms of the volume fraction of monomers,  $X_1$ , by

$$X_M = M \left[ X_1 \exp\left(\frac{\epsilon_1 - \epsilon_M}{k_B T}\right) \right]^M$$

Experimentally the aggregation number is found to be  $M=74$  and the energy difference between a molecule as a monomer in the solution and a molecule belonging to a micell is determined to 21.25 kJ/mol.

Estimate the critical micellar concentration (CMC). (6 p)

6. a) Estimate the instantaneous shear modulus,  $G_0$ , for a glass forming liquid at the glass transition. (4 p)

b) Explain the behavior of entropy as a function of temperature around the glass transition. What physical property that can be experimentally determined is measure related to the entropy of the system? (4 p)

7. a) What is the difference between a physical and a chemical gel? Give also one example each of a chemical and a physical gel. (4 p)

b) Discuss the mechanism controlling the swelling properties of a superabsorber (4 p).

8. A colloidal suspension is formed by polystyrene spheres (radius 150 nm) covered with an adsorbed polymer layer dispersed in an aqueous electrolyte solution of concentration  $10^{-3}$  mol/dm<sup>3</sup> (the salt is NaCl).

a) Estimate the thickness of the polymer layer in order for this system to be regarded as a suspension of hard sphere. (4 p)

b) In a rheological experiment, at room temperature, the suspension is exposed to a strain rate  $\dot{\gamma}=500$  s<sup>-1</sup>. Is this shear rate high enough to restructure the suspension (assuming the thickness of the polymer layer is as determined in a))?  
(4 p)

Two useful relations that might be of use are

• the Stokes-Einstein equation  $D_{SE} = \frac{k_B T}{6\pi\eta a}$

• the Debye screening length  $\kappa^{-1} = \left( \frac{\epsilon\epsilon_0 k_B T}{2e^2 n_0 z^2} \right)^{1/2}$