

Chalmers University of Technology  
Department of Applied Physics  
Aleksandar Matic/Johan Sjöström

**Exam in Soft Matter Physics TIF015/FIM110**

**Time and place:** Saturday October 24, 14.00-18.00 2009.

**Examiners:** Aleksandar Matic (0730-346294), Johan Sjöström (0737279624)

**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 or Johan Sjöström after 2/10 2009

**Exam results:** Exam results are displayed 2/10 outside office S2046.

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

1) 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). (2p)

2) 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.

a) Estimate the critical micellar concentration (CMC). (3p)

b) Assuming that the critical chain length is given by  $l_c \approx (0.154 + 0.1265n)$  nm and that hydrocarbon volume is given by  $v \approx (27.4 + 26.9n) \times 10^{-3} \text{ nm}^3$  show that these micelles can not be spherical and calculate what the maximum aggregation number for spherical micelles for SDS would be? (4p)

**2. a)** Estimate the instantaneous shear modulus,  $G_0$ , for a glass forming liquid at the glass transition. (3p)

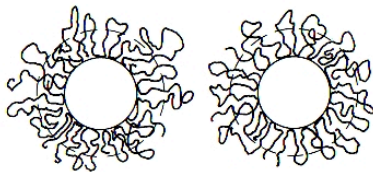
**b)** You have a piece of solid material. How can you determine if this material is a glass? (2p)

**c)** There is an urban myth saying that glasses are actually liquids flowing very slowly. The apparent proof of this is that old church windows are thicker in the bottom. Prove this urban myth wrong using physical arguments. You can assume that the glass in the windows has the VFT-parameters  $\eta_0=1.1 \cdot 10^{-10}$  Pas,  $B=41359$  and  $T_0=0$  K. (6p)

**3. a)** What is characterizing nematic and smectic liquid crystal phases respectively? (2p)

**b)** Explain the three fundamental deformations of liquid crystals: splay, twist and bend. (3p)

**4.** Gelatine and epoxy raisins are both gel systems. To what class of gels do these two systems belong to? Motivate your answer! (2p)



**5.** A colloidal system can be stabilized by adsorbing a polymer layer onto the surface. Discuss three mechanisms for destabilizing this system. (3p)

6. If you stretch a rubber band and touch it with your lips, what will you feel? What is the microscopic explanations to this sensation? What is the qualitative change in free energy, enthalpy and entropy? Motivate your answer! (5p)

7) Consider a dilute solution of a polymer. The expression for the free energy, according to Flory-Huggins theory, is:

$$F = k_B T \left[ \frac{3}{2} \frac{r^2}{Na^2} + \nu(1-2\chi) \frac{N^2}{2r^3} \right]$$

a) Explain the physical origin of the terms in the expression. You don't have to derive, just explain the physical mechanisms involved and discuss if the mechanism is expanding or contracting the polymer coil. (6p)

What is the  $N$ -dependence of the mean end-to-end distance if the interaction parameter is:

b)  $\chi=1/4$

c)  $\chi=1/2$

d)  $\chi=1$  (3p)

8. The free energy of mixing for two liquids is the free energy of the completely mixed state minus the free energy when the liquids are totally separated. With the assumptions of the regular solution model the free energy of mixing (in units of energy) is:

$$F_{mix} = -TS_{mix} + U_{mix},$$

where  $S_{mix}$  is the entropy of mixing and  $U_{mix}$  is the change in internal energy between the mixed and the separated state.  $U_{mix}$  depends on the bond strengths and the number of nearest neighbours in the lattice.

We can measure the free energy of mixing, for example by measuring the heat released or absorbed when mixing thoroughly. For two given liquids at 25° C,  $F_{mix} = 2.00 \times 10^{-20}$  J per molecule when mixing them in equal proportion by stirring.

a) What will happen to the solution if the regular solution model is valid? (2p)

b) If we measure the free energy of mixing at a much higher temperature. What would you qualitatively expect to be the effect on  $F_{mix}$ ? Would it increase or decrease? Motivate your answer! (2p)

c) For water and oil (n-butane), with  $F_{mix} = 2.00 \times 10^{-20}$  J per molecule at 25° C, the free energy of mixing at 75 ° C is  $2.28 \times 10^{-20}$  J per molecule. At first thought this appears strange to a physicist. Why? Explain what goes on and what we call this effect with a general term! (6p)

9. The figure shows the phase diagram of a polymer solution. When phase separation occurs the phase with a high concentration forms a gel. Below you see three characteristic structures of phase separated systems formed by rapidly cooling the solution from a temperature above 83 °C.

a) What is the difference between the two dispersed phases 1 and 3? (3p)

b) Obviously there is a difference in the characteristic length scale of the heterogeneities in the bicontinuous network (2) compared to the other dispersed phases (1 and 3). What are the mechanisms behind these different length scales? (3p)

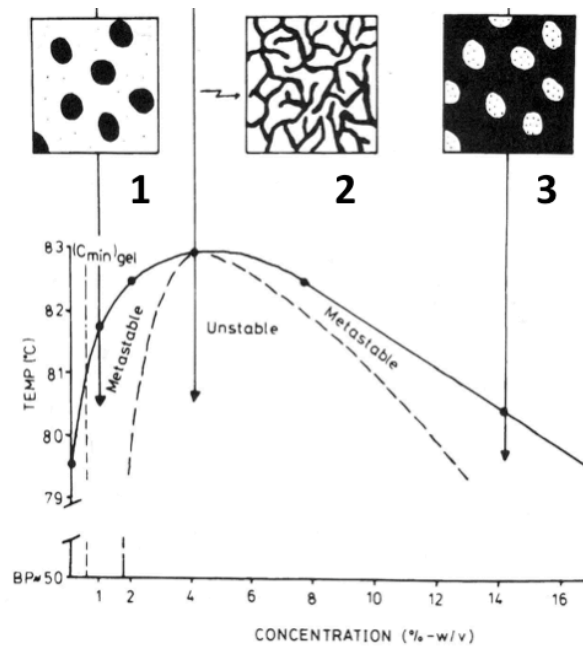


Fig. 86. Detail of Upper Critical Temperature phase diagram of aPS ( $\bar{M}_w = 2750 \text{ kg/mol}$ ) in cyclohexanol, including expected variation in (gel) morphology with concentration. Reproduced from Makromol Chem [Ref. 276] by the courtesy of the authors and of Hüthig & Wepf Verlag Publishers, Zug, Switzerland