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Exam in Soft Matter Physics TIF015/FIM110

Time: Wednesday August 21, 2013, 8.30-12.30.
Examiner: Aleksandar Matic (0730-346294)
Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator approved by Chalmers (Chalmersgodkänd räknare)
Grading: 24 points, is required for a passed.
Note: All answers must be in English. **Motivate all answers carefully. Answers without motivation give no credit.**

1. a) What are thermotropic and lyotropic liquid crystals, respectively? (2p)

b) Sketch the value of the orientational order parameter S as function of temperature around the isotropic to nematic phase transition. (2p)

c) You have a nematic liquid crystal in a cell. The inner faces of the glass plates are prepared to make the director field homogenous in the whole cell, with the director parallel to the plates. You study the cell in your microscope between crossed polarizers. When you rotate the cell it looks black for two cell orientations and green in-between those positions. Why? (6p)

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

b) Explain the behavior of the entropy as a function of temperature around the glass transition. (2p)

c) What physical property that can be experimentally determined is related to the entropy change of the system around the glass transition (motivate how you obtain information on the entropy from this property)? (4 p)

3. a) When a mixture in an unstable state phase separates, it does so via a process of so called uphill diffusion. Describe how uphill diffusion differs from normal diffusion. (3 p)

b) A mixture in a metastable state can also phase separate, but by a different mechanism. What is it called? (1 p)

c) When a metastable mixture phase separates, the free energy will have to overcome a barrier expressed as

$$\Delta F(r) = \frac{4}{3}\pi r^3 \Delta F_v + 4\pi r^2 \gamma$$

Discuss the two competing terms in the right hand side of the equation. (4 p)

d) If the second term in the above equation is too large, the system will not phase separate. What can we do to make it smaller, and hence make the mixture phase separate? (2 p)

4. A colloidal suspension is formed by polystyrene spheres (radius 100 nm) dispersed in an aqueous electrolyte solution with salt concentration 10^{-4} mol/dm^3 (the salt is NaCl). To decrease the influence of salt concentration the particles are covered by a polymer layer. The system is held at room temperature.

a) What is the minimum thickness of the polymer layer required in order for the dispersion to approximately behave as a hard sphere system? (4p)

b) The polymer is polyethylene oxide (PEO), $[-CH_2-O-CH_2-]_n$. Estimate the minimum molecular weight of the polymer needed to obtain the approximate hard sphere system (4p)

c) Describe two ways to destabilize the dispersion. (2p)

You can assume that we are at theta conditions for this particular combination of polymer and solvent at this temperature and a step length of a=0.56 nm for the polymer. A relation that might be of use is:

$$\kappa^{-1} = \left(\frac{\varepsilon\varepsilon_0 k_B T}{2e^2 n_0 z^2}\right)^{1/2}$$

5. A surfactant solution consists of the anionic surfactant sodium tetradecyl sulphate ($NaC_{14}SO_4$) in water. The size of the surfactant can be estimated by the parameters: $l_c=(0.154+0.127\cdot n)$ nm, $v=(0.0274+0.0269\cdot n)$ nm^3, $a_0=0.65$ nm^2

a) Determine the shape of the micelles formed in the solution and the association number. Motivate the answer and the calculations (6 p)

b) Explain what might happen to the shape of the micelles and the association number if you add salt to the solution. Carefully motivate your answer. (4p)

6. Discuss the swelling process in a superabsorbent. What controls and limits the swelling? (4p)

7. The figure below shows the phase diagram for a polymer solution (y-axis: temperature; x-axis: polymer concentration ϕ_{pol}). The solid line is the binodal curve whereas the dashed line is the glass transition curve for the polymer. What happens when the polymer solution is cooled from point A to point B or from point C to point D respectively? Describe the difference of the materials found in the final states B and D. (6p)