Chalmers University of Technology
Department of Applied Physics
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Exam in Soft Matter Physics TIF015/FIM110

Time and place: Tuesday October 21 14.00-18.00 2008, Väg och Vatten.
Examiners: Aleksandar Matic (0730-346294), Johan Sjöström (0737279624)
Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator
Grading: 26 points, is required for a passed.
Exam results: Exam results are displayed 30/10 outside office S2046.
Review of the exam: Contact Aleksandar Matic or Johan Sjöström after 30/10
Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. a) Discuss why glasses both can be considered to belong to and not to belong to soft matter materials. (4p)

b) For a glass former the temperature dependence of the relaxation time is given by the Vogel-Fulcher-Tamman equation

$$\tau = \tau_0 \exp\left(\frac{D}{T - T_0}\right)$$

with the material dependent parameters D=710 K and T_0=323 K.

Using a certain cooling rate, ΔT_1, in a calorimetric experiment we obtain a glass transition temperature T_g=348 K. Is this to be considered a rapid or a slow quench? Carefully motivate your answer! (6p)

2. a) Sketch the potential energy curve (potential energy vs distance) for a charge stabilized and an ideal hard sphere system respectively. Discuss the different contributions. (2p)

b) How can you in practice obtain a system that behaves as a hard sphere system? (2p)

c) For an ideal hard sphere colloidal suspension the transition between a fluid phase and an ordered phase takes place at a volume fraction of ϕ_c=0.494.

A colloidal suspension, of particles with a radius 100 nm, is charge stabilized in an aqueous electrolyte solution with salt concentration 10^{-4} mol/dm^3. The salt in the solution is KCl and the system is held at room temperature. Calculate the volume fraction for the transition to an ordered phase in this case. (6p)

You may assume the charge stabilized colloidal suspension still behaves as a hard sphere system and that the Debye screening length, κ^{-1}, is given by:

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

3. a) Discuss the different contributions to the free energy of the head group of an ionic surfactant. Propose a way to control/change the optimum head group area. (3p)

b) Sodium dodecyl sulphate (SDS) is a common surfactant in detergents. The chemical formula is $C_{12}H_{25} - OSO_3Na$. What kind of surfactant is this? (2p)

c) Experimentally it is found that the aggregation number of SDS in water is M≈74. Discuss the shape of these micelles. (5p)

You can assume that the critical length is given by $l_c \approx (0.154+0.1265n)$ nm and that hydrocarbon volume is given by $v \approx (27.4+26.9n)\times 10^{-3}$ nm^3.

4. a) If we study the dynamics of a polymeric melt of high molecular weight over many orders of magnitude in time we can observe three different dynamical regimes

a. The glassy regime
b. The rubbery regime
c. The viscous regime

Discuss the nature of the dynamics in these three regimes (6p)

b) The zero shear viscosity η_0 for an entangled melt of linear polystyrene depends on the degree of polymerisation (N) and the temperature (in Kelvin) (T) according to:

$$\eta_0 = 3.68 \times 10^{-3} \exp\left(\frac{1404}{T-128}\right) N^{3.4} \text{ Pa s.}$$

Why does the viscosity have this functional form? (2p)

c) For this linear polystyrene ***estimate*** the self-diffusion coefficient, D_{self}, at T=298 K of the polymer if the relative molecular weight is 100000 g mol^{-1}. Given that:

- The statistical step length is a=0.65 nm.
- The plateau value of the shear modulus 1.15×10^6 Pa.
- The relative molecular weight of the monomer unit is 54 g mol^{-1}.

(6p)

d) Suppose that

- The same polymer was branched and not linear.
- The average molecular weight between branching is much larger than the average molecular weight between entanglements.

What would qualitatively be the effect on the viscosity and the plateau value compared to the situation with linear chains? (4p)

5 The mixing of two molecular liquids (A and B) can be described by the regular solution model.

a) The liquids are mixed and thoroughly stirred in a proportion ϕ_a that corresponds to a <u>metastable</u> composition. Discuss what might happen after we stop mixing. Please give a qualitative answer! (3p)

b) The temperature is thereafter decreased which results in an increase of the interaction parameter. What is the qualitative effect on the phase/phases in the binary mixture? (2p)

6

a) A liquid is supercooled 100 K below melting point. The change in free energy if crystallisation of the whole sample occurs at this temperature is 22 J/g. If the sample crystallises via homogeneous nucleation, what is the critical radius of a nucleus given that the crystal/liquid interfacial tension is 0.29 J/m^2 and the density of the liquid is 1g/cm^3. (3p)

b) Given that the melting point of the liquid is 473 K. Comment on the probability that the liquid will crystallise. (4p)