Exam in Soft Matter Physics TIF015/FIM110

Time: Monday October 27 2014, 8.30-12.30.

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Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator approved by Chalmers (Chalmersgodkänd räknare).

Grading: Maximum 60 points, 24 points required to pass.

Note: All answers must be in English. Motivate all answers carefully.

Question 1

The free energy of mixing for a binary liquid mixture is given by:

$$\Delta F_{\text{mix}} = k_B T\left[\Phi_A \log(\Phi_A) + 3\Phi_B \log(\Phi_B) + 3\Phi_A \Phi_B \chi\right]$$

A (6p)

Is the mixture stable, unstable or metastable for $\chi = 5/3$ and $\Phi_A = 0.2$? (Motivate your answer by a calculation.)

B (4p)

Estimate what values of χ that always result in stable mixtures (for any volume fractions)!

Question 2

A (3p)

When a liquid is cooled below the melting point (T_m) thermodynamics tells us that it should crystallize. However, from experience we know that most liquids will not crystallize directly at T_m but need to be cooled further. But we also know that if a liquid is rapidly cooled to a very low temperature, well below, T_m and close to the glass transition temperature (T_g), we can also avoid crystallization. Thus there is a "sweet spot" for crystallization somewhere between T_m and Tg where the tendency for crystallization is high. Discuss why this behaviour is observed, i.e. that there is a certain temperature range where the probability of crystallization is high.

B (2p)

Estimate the structural relaxation time in liquid water at the melting point! Motivate your estimation carefully. You might be helped by knowing that the viscosity of water in the temperature range 273-643 K is rather accurately given by the equation:

$$\eta(T) = 2.414 \cdot 10^{-5} \cdot 10^{247.8/(T-140)}$$

C (5p)

A glass is formed by cooling a liquid at a certain cooling rate ΔT_1. Using the same cooling rate in a calorimetric experiment the glass transition temperature is found to be T_g=353 K. For this liquid the structural relaxation time is found to be well described by the VFT-equation with the parameters D=710 K and T_0=323 K. Do you expect that the density of the glass formed by cooling with the cooling rate ΔT_1 will change noticeably if you anneal it at a temperature of T=345 K? Carefully motivate your answer.

Question 3

(10p)

A colloidal dispersion is formed by adding silica particles, radius=10 nm, to water. Make an estimation if this will be a stable suspension or if you expect to have sedimentation. In the estimation take into account the influence of Brownian motion and don't forget to carefully motivate different assumptions.

Some useful relations:

Stokes-Einstein relation:

$$D_{SE} = \frac{k_B T}{6\pi\eta a}$$

Stokes law:

$$F_f = 6\pi\eta a$$

Question 4

A (2p)

A rubber band is taken into a sauna. Assume the density remains the same. Will it be easier or harder to pull the band? (You need to give a brief motivation, but you do not have to refer to any equation.)

B (4p)

Silly Putty or "bouncing clay" is viscoelastic: It bounces when dropped on the floor, but it also behaves as a highly viscous liquid which settles down by gravity. If the degree of polymerization is increased, will Silly Putty bounce higher, lower or the same? Will it take shorter, longer or about the same time for it to settle as a liquid? Motivate your answers briefly.

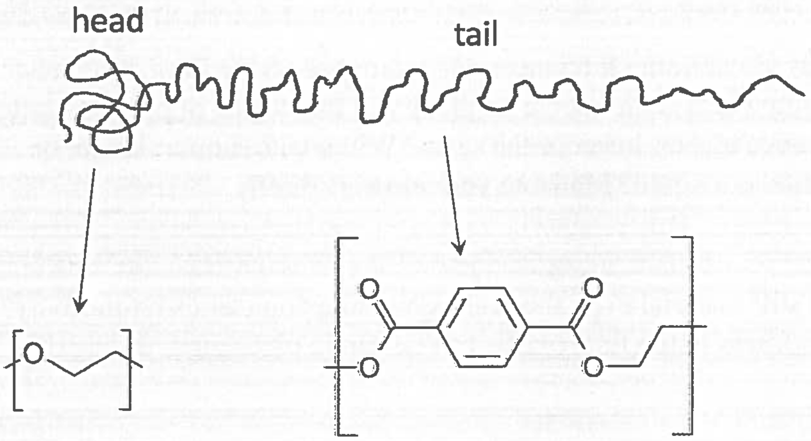
C (4p)

Polyethylene can be a hard and stiff material even above the glass transition temperature. Why? Give one example of how the stiffness of the final plastic can be varied by changes during the synthesis of the polymer!

Question 5

A (3p)

Various aggregates can be formed in water with block copolymers that have a hydrophilic and a hydrophobic part. Assume we have a small but flexible head consisting of poly(ethylene glycol) (PEG) with $M = 2$ kDa connected to a hydrophobic poly(ethylene terephthalate) (PET) "tail":



Estimate the "optimal head area" by assuming it is simply the square of the end to end distance of the PEG in water (ignore the PET). PEG has a monomer (CH_2-CH_2-O) of size 0.28 nm and Kuhn length 0.72 nm in water.

B (3p)

Assume the characteristic size of the PET monomer is 2.0 nm. Show that the block copolymer should form spherical micelles!

Hint: You may use the combination parameter from self assembly principles.

C (4p)

The interior of the micelle can be thought of as a homogenous melt of PET, where the PET part of each molecule starts at the surface and ends somewhere in the interior. However, some molecules might have to stretch so that the whole interior is properly "filled up" with PET. If $N = 50$ for the PET block, what is the free energy cost in $k_B T$ for a molecule to stretch out in order to reach the center of the micelle? You may use a Kuhn length of 4 nm.

Hint: The configurational entropy contribution to the free energy of a coil is given by:

$$G(r) = \frac{3k_B T r^2}{2Na^2} + \text{constant}$$

Question 6

A (5p)

Describe the basic structure of a liquid crystal display panel, i.e, from the backlight unit to the viewer!

B (2p)

What are thermotropic and lyotropic liquid crystals, respectively?

C (3p)

Describe the order and structure of the nematic, the smectic A, and the smectic C liquid crystal phase.