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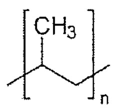
Exam in Soft Matter Physics TIF015/FIM110

Time: Friday January 14, 14.00-18.00 ~~2010~~. 2011
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 25/1 2011
Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. (a) Sketch how the strain rate (time derivative of strain) varies with the shear stress for
   i) a shear thickening liquid
   ii) a shear thinning liquid
   iii) a Newtonian liquid. (3p)

2. Consider a polymer melt of linear atactic polypropylene at room temperature. The chemical structure is



(a) The free energy, F, of a single polymer chain changes as a function of end-to-end distance, R, as $F(R) \propto R^2$.
What is the origin of this R-dependence of the free energy? (3p)

(b) The polymers have N=300 repeating units and a statistical step length of a=7 Å. What is the average end-to-end distance, $R_{End\text{-}to\text{-}end}$, of a single polymer in the melt? (2p)

(c) If the polymers are dispersed in water (to a dilute solution). What is the N-dependence of $R_{End\text{-}to\text{-}end}$ of the dispersed polymers. (4p)
Hint: What do you expect from the solvent quality?

3. The glass transition temperature for isotactic polypropylene is 0 °C. At room temperature it still forms a soft but solid material (plastics).

(a) Describe the structure of plastics and how it forms a soft solid. (4p)

(b) What is the basic unit for a crystalline polymer? (2p)

4. Two liquids, A and B, have a very high surface tension between them. The mixing of the two liquids can be described by the regular solution model. The change in free energy when you mix the liquids is given by:

$$\frac{F_{mix}}{k_B T} = \phi_A \ln \phi_A + \phi_B \ln \phi_B + \frac{750}{T} \phi_A \phi_B ,$$

where ϕ_A and ϕ_B are the volume fractions of the two liquids and T is the temperature in Kelvin. We try to make three mixtures of different concentrations at room temperature

(a) 10 % A-liquid and 90 % B-liquid
(b) 25 % A-liquid and 75 % B-liquid
(c) 40 % A-liquid and 60 % B-liquid.

Which mixtures do you expect will stay mixed? Don't forget to motivate!! (10p)

(d) At what temperature will any possible concentration be miscible? (2p)

5. Consider a colloidal suspension of polystyrene particles, 100 nm radius, dispersed in an aqueous electrolyte solution (the salt is NaCl). To decrease the sensitivity of this system to salt concentration a polymer is grafted on to the surface of the particle. The thickness of the polymer layer is 10 nm.

a) Draw the diagram of the interaction energy as a function of distance from the surface of the colloidal particle when the polymer layer is efficiently stabilizing the system. (2p)

b) Estimate the minimum salt concentration (mol/dm^3) in the solution for polymer layer to efficiently decrease the sensitivity to salt concentration. (5p)

Note: It might be helpful to know that the Debye screening length, κ^{-1}, is given by:

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

To destabilize the system one can either chemically remove the grafted polymers or use depletion.

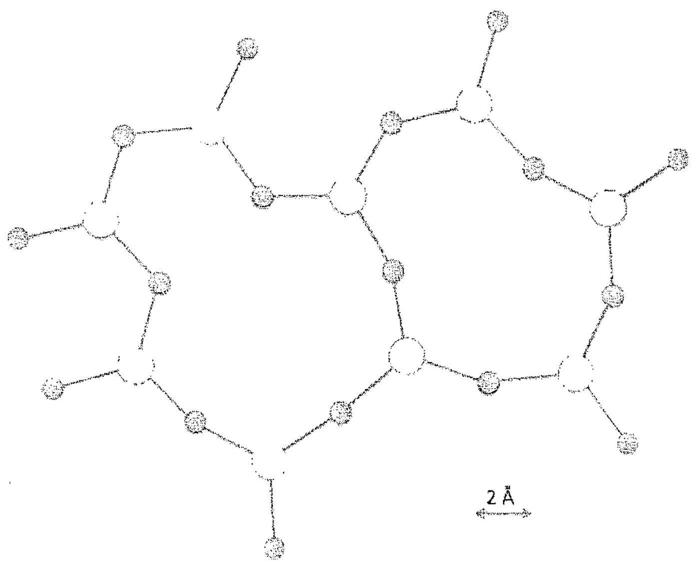
c) Draw the diagram of the interaction energy as a function of distance from the surface of the colloidal particle when the polymer layer is removed. (2p)

d) Explain how the depletion mechanism works and how you could apply it in the case of this particular system. (4p)

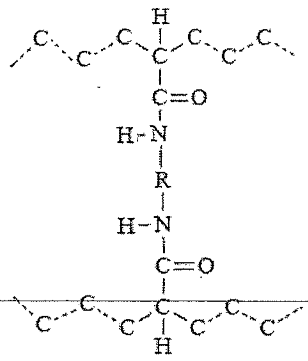
6. a) The viscosity dependence of a certain material in the liquid state follows the Vogel-Fulcher-Tamman equation with the parameters B=12574 K and T_0=470 K. Determine the glass transition temperature for this liquid. (3p)

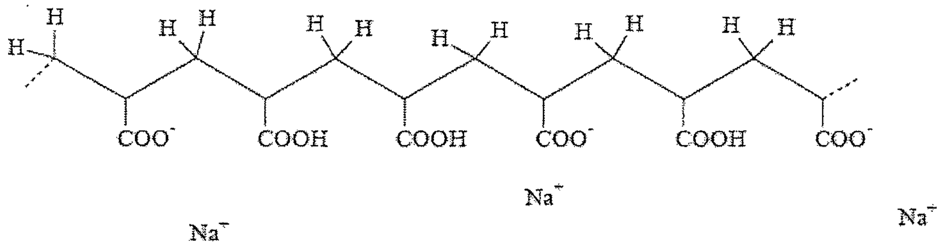
b) How can the microscopic structure of a glass be described? What concepts can be used? How can the structure be determined from experiments? How does it differ from the corresponding crystalline material? (4 p)

c) The figure below shows the atomic structure of a glass. Describe, quantitatively, the short range order in this glass. (3p)



7. a) Super-absorbers are gel materials common in many hygiene products. Below the structure of one super-absorber is sketched. Discuss the mechanism behind the super-absorbing properties and what limits the absorbtion. (4p)





b) Discuss the similarities and differences between the formation of thermoreversible gels and glasses. (3p)