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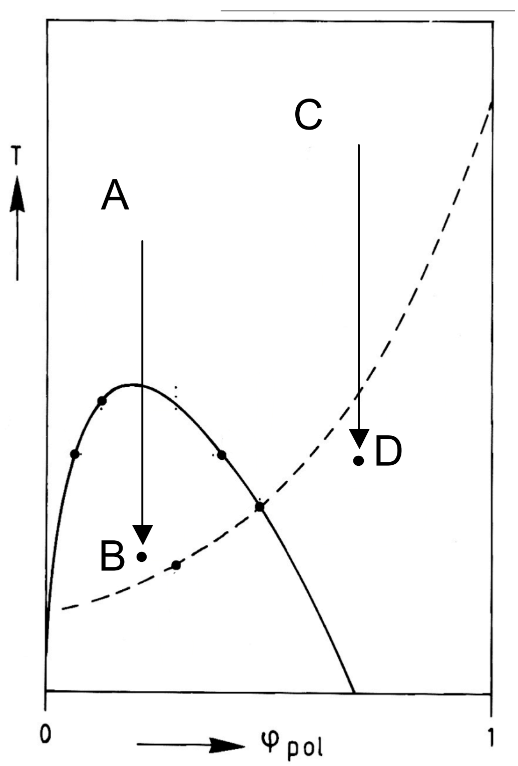
Exam in Soft Matter Physics TIF015/FIM110

Time and place: Monday October 22 2007 14.00-18.00, Väg och Vatten.
Examiners: Aleksandar Matic (0730-346294), Johan Hedström (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 5/11 outside office S2046.
Review of the exam: Delfinen (Soliden) 5/11 12.00-12.15.
Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. a) Glass forming liquids can be classified as strong and fragile. Explain the difference between strong and fragile liquids and give an example of a strong glass forming liquid. (2p)
b) Give a technological example when the fragility of the liquid is of importance (1p)
c) How can we define a glass and how can we experimentally verify that we have obtained a glass when we have prepared a new material? (3p)
d) How does that glass transition temperature depend on cooling rate? Discuss the scenario of forming a glass at infinitely low cooling rate in terms of e.g. entropy? (4p)

2) a) Sketch a typical curve describing the potential energy vs. separation between electrostatically stabilised colloids. Discuss the different contributions to the total potential energy. (3p)
b) Imagine that you would like to instead control the system in a) by sterical stabilization using polymers. How thick (roughly in terms of parameters related to the electrostatic stabilization) should the polymer layer be in order to have a sterically stabilized system? How does the potential energy curve change in this case and? (3p)
c) For colloidal system with attractive interaction describe (and sketch) the typical structures of aggregates in the case of a strong and weak attraction. Why do we get the different structures? (4p)

3) a) Describe the difference between a chemical and a physical gel and give one example of each type of gel? (3)
b) How do you expect the mechanical properties of a gel to change with cross-link density? (2p)
c) The figure below shows the phase diagram for a thermoreversible polymer gel system (x-axis: polymer concentration, y-axis: temperature). The solid line is the binodal curve whereas the dashed line is the glass transition curve for the polymer. What happens when the system is cooled from point A-B and from C-D (in A and C the system is a homogeneous polymer solution)? Describe the difference of the materials in the final states B and D. (5p)



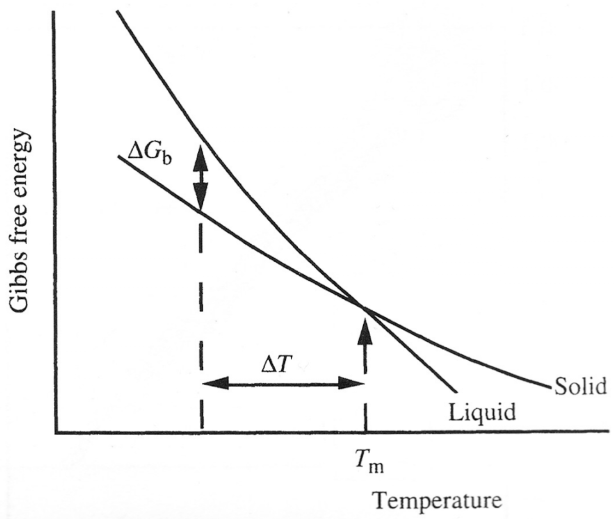
4. The mixing the molecular liquid A with the molecular liquid B can be described by the regular solution model.

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

where the interaction parameter can be written: $\chi = 600\mathrm{K}/T$, and T is the temperature in Kelvin. The two liquids are mixed at T=20°C in the proportions of $\phi_A = 0.25$.

Discuss how the mix behaves when the temperature…

a) is held at 20 °C after being mixed.
b) Slowly decreases to 0 °C and is held constant.
c) Slowly decreases further to -20 °C and is held constant. (4p)



5. The figure above shows a schematic of the free energy for ice and liquid water in the vicinity of the melting point, T_m. If the liquid is supercooled to a temperature ΔT and crystallises the free energy change per unit volume on crystallisation of the bulk material is given by:

$\Delta G_b = -\frac{\Delta H}{T_m}\Delta T$, where ΔH is the enthalpy of fusion (also known as latent heat of fusion) per unit volume and T_m is the melting temperature.

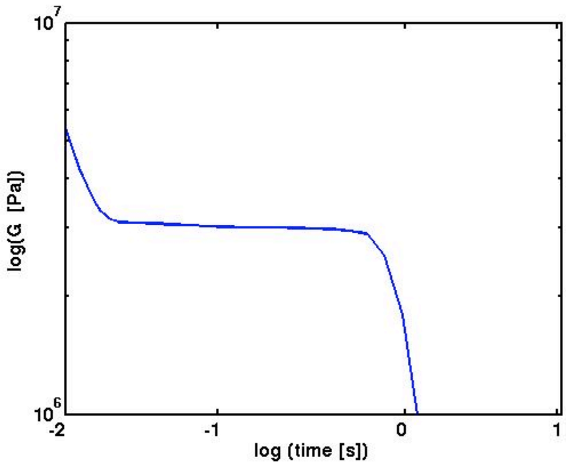
a) Derive this expression. (2p)

A small droplet of very pure water is cooled below T_m. For the droplet to crystallize a nucleus of critical size (critical radius, r^*) must be formed by thermal fluctuations.

b) Derive an expression for r^*.in terms of the variables in the above and the water/ice interfacial tension. (2p)

c) At what temperature do you expect crystallization assuming that:
   - Crystallization occurs via homogeneous nucleation when each droplet, of average radius 10 μm contains on average one nucleus of the critical size.
   - Due to the thermal fluctuations each molecule makes about 10^{13} attempts to form a nucleus during the experimental time.
   - The increase in free energy of forming a nucleus is about $2.2 \cdot 10^{-19}$ J. (2p)

d) Discuss qualitatively what would happen to the temperature at which the droplets crystallize if we add large colloidal particles in small amounts to the liquid. (2p)



6. The figure above shows the stress relaxation modulus for a specific polymer melt.

a) Why does the modulus exhibit a constant value for intermediate timescales? (2p)

b) Discuss and motivate what might happen to the shear modulus plateau value and the viscosity if the number of monomers would be
  - Doubled
  - Halved

  Estimate also the shear modulus plateau value and the viscosity in these cases (6p)

c) Explain time-temperature superposition. (2p)

7. Consider a dilute solution of a polymer. What is the *N*-dependence of the mean end-to-end distance if the interaction parameter of the solvent-solute interaction, χ, is:

a) $\chi=1/4$
b) $\chi=1/2$
c) $\chi=3/4$

Motivate all your answers and describe the mechanisms involved. (7p)

8. a) A cationic surfactant has an optimum head group area a_0=0.65 nm^2 and forms in a water solution spherical micelles. We would like to instead make bilayers using this surfactant. Propose a way to induce a transition from spherical micelles to bilayers. Discuss if this is physically possible? (3p)

b) Discuss the optimum size and distribution of sizes of spherical and cylindrical micelles considering energetic and entropic considerations. (4p)