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

Time and place: Wednesday January 16 14.00-18.00, Väg och Vatten.
Examiners: Aleksandar Matic (0730-346294), Johan Sjöström (0737279624)
Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator
Grading: 28 points, is required for a passed.
Exam results: Exam results are displayed 23/1 outside office S2046.
Review of the exam: Contact Aleksandar Matic or Johan Sjöström after 23/1
Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. a) Suspensions, emulsions and foams are all colloidal systems. Describe the difference between these systems in terms of the dispersed phase and the continuous medium. Give an example of each type of colloidal system. (4p)

b) For an ideal hard sphere colloidal system crystallization occurs at a volume fraction of ϕ=0.494 and a transition to a disordered glassy state at $\phi \approx 0.58$. Consider now a colloidal suspension of charged spheres of radius 100 nm in an aqueous solution of sodium chloride at room temperature (20° C). The volume fraction of particles in the solution is ϕ=0.35 and the salt concentration in the solution is 10^{-5} mol/dm^3. Which phase do you expect this system be in, solid or liquid? Make reasonable assumptions and motivate carefully. (6p)

You might want to use the expression for the Debye screening length:

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

2. The mixing of 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: $\chi = 600/T$, and T is the temperature in Kelvin. The two liquids are mixed at T=20°C in the proportions of $\phi_A = 0.25$.

a) If you keep the liquid at T=20°C for a long time, what will happened? (1p)

b) For an optical reason you are interested in forming two distinct phases of the liquid. To what temperature do you need to cool in order to be **sure** that a phase separation will begin? (2p)

c) Consider lowering the temperature to T=-173° C and keeping it there until equilibrium is reached. Estimate what concentrations of A-molecules you find in the two phases formed? Make reasonable assumptions to simplify the problem. (4p)

3. a) The free volume theory is commonly used to explain glass transition phenomena. What are the basic assumptions in this theory? What are the shortcomings? (2p)

b) Based on the basic assumptions of the free volume theory show that the typical Vogel-Fulcher behaviour for the viscosity is obtained assuming a simple relation between the free volume and the viscosity:

$$\eta = a \exp\left(\frac{bv}{v_f}\right)$$

where v_f/v is the fractional free volume (4p).

c) What is the typical value of the viscosity and relaxation time at the glass transition? What is the high temperature limit of the same parameters. Give a motivation to your answers! (2p)

d) Sketch in a scaled Arrhenius diagram the viscosity behaviour of a strong and a fragile glass (i.e. η/η_0 vs. T_g/T). (2p)

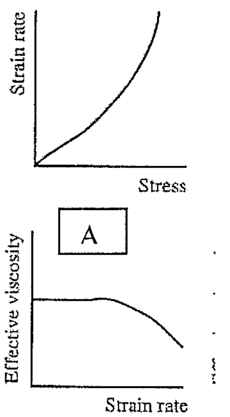
4. a) Write down a working definition for a gel (3p)

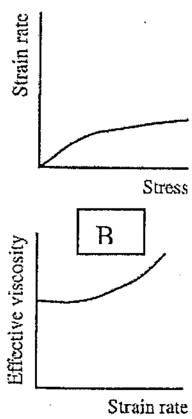
b) There are plenty of different mechanisms that can result in the formation of a gel. Discuss three different mechanism and explain what class of gel the mechanisms result in. (3p)

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

5. a) What are the characteristic features of soft matter? Give four examples. (2p)

b) The graphs below show two different behaviour found in complex liquids (A&B). What are these two cases called and describe the physical properties of the two cases? What is the difference to a simple liquid (sketch the corresponding diagrams)? (4p)





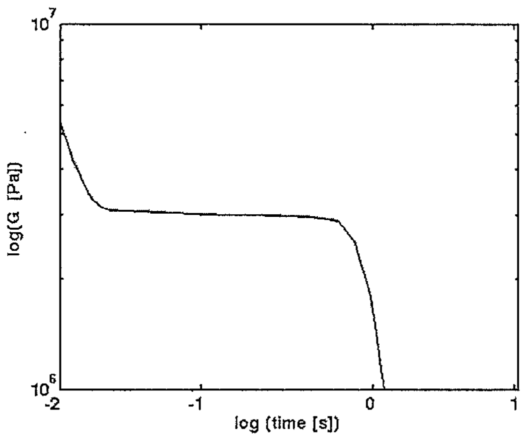
6. Consider a supercooled organic liquid at room temperature. Suppose that the liquid is pure enough such that the only route to crystallization is via homogeneous nucleation.

a) Write an expression for the change in free energy $\Delta G(r)$ on forming a spherical nucleus of crystal of radius r given the following data:
   - The crystal/liquid surface tension is $\gamma_{lc}= 0.03$ J/m^2 and
   - The change in free energy per unit volume, if the whole sample would crystallize, is $\Delta g_{bulk}=-10^7$ J/m^3. (3p)

b) What is the critical radius of the nucleus in order for it to spontaneously grow? Don't forget to motivate your answer. (3p)

c) Discuss qualitatively if the liquid is likely to crystallize at room temperature via homogeneous nucleation at room temperature. (3p)

7. The figure below shows the stress relaxation modulus for a specific linear polymer melt.



a) How would you define the stress relaxation modulus? How do you measure it (given that equipment for determining positions, velocity, angles, forces, rotations, masses or whatever you might need is available)? (2p)

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

c) Estimate the shear modulus plateau value and the viscosity changes if the number of monomers would be twice as many. Don't forget to motivate your answers! (5p)

8.a) An ideal polymer is one which does not exhibit any restrictions to the angle between adjacent monomers. Derive an expression of the mean end-to-end distance $\langle r^2 \rangle^{1/2}$ given that the polymer has N monomers of length a. (2p)

b) In reality, for example a dilute solution (good solvent) of a polymer, the polymer coils are stretched above the ideal configuration. Why is that? What is the dependence of $\langle r^2 \rangle^{1/2}$ on the number of monomers, N? (4p)

c) What is the situation if the solution becomes more and more concentrated such that it eventually becomes a polymer melt? (3)