Chalmers University of Technology
Department of Applied Physics
Aleksandar Matic/Johan Sjöström

Exam in Soft Matter Physics TIF015/FIM110

Time and place: Saturday October 23, 14.00-18.00 2010.
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 6/11 2010
Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. The viscosity dependence of a glass forming liquid follows the Vogel-Fulcher-Tamman (VFT) equation, with the VFT-parameters $\eta_0=10^{-4}$ Pas, B=12574 K and T_0=470 K.

a) Give an order of magnitude estimate of the relaxation time for this liquid at 700 K. (6p)

b) What does the fragility of a liquid describe? (2p)

c) How, and why, does the glass transition temperature change when you change the cooling rate? (2p)

2. In a solution of the amphiphilic molecule sodium stearate (chemical formula $C_{18}H_{37}$ – COONa) micelles are formed a sufficiently high concentrations.

a) Assuming that the critical chain length is given by $l_c \approx (0.154+0.1265n)$ nm, that hydrocarbon volume is given by $v \approx (27.4+26.9n)\times 10^{-3}$ nm^3, and that the optimal head group area a_0=0.7 nm^2, determine the shape of the micelles. (4p)

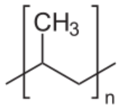
b) What do you expect can happen to the micelles and the solution if we add salt? (4p)

3. A colloidal suspension is formed by polystyrene spheres (radius 150 nm) dispersed in water. In a rheological experiment, at room temperature, the suspension is exposed to a strain rate $\dot{\gamma}$=500 s^{-1}. Is this shear rate high enough to restructure the suspension? (6p)

A useful relation to use might be the Stokes-Einstein equation $D_{SE} = \frac{k_B T}{6\pi\eta a}$

4. Sketch how the strain rate (time derivative of strain) varies with the shear stress for a shear thickening liquid, a shear thinning liquid, and a Newtonian liquid. (3p)

5. Consider a polymer of linear *atactic* polypropylene. The chemical structure is shown below:



At room temperature the melt is an amorphous rubbery material.

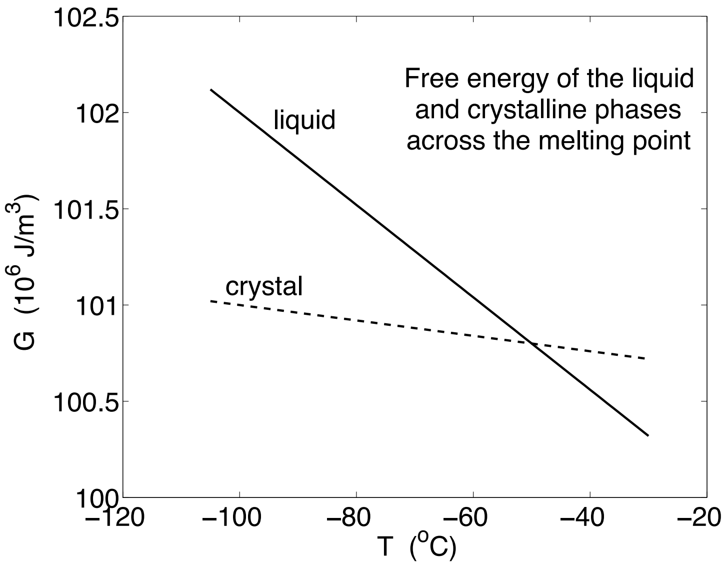
(a) If instead the polymer was *isotactic,* how would you expect the morphology (structure) of the polymer to change? (3p)

(b) 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)

(c) If one polymer chain is instead isolated in vacuum the chain is stretched. Why is that and how does the free energy scale with R for this chain? (3p)

(d) We put the atactic polypropylene in a container of water. How would you expect the free energy to scale with R now? (3p)

6. The figure below shows the free energy (per unit volume) of the liquid and crystalline phases above and below the melting point for a simple liquid. The metastable liquid is supercooled at T=-100 ºC. Crystallization is thus governed by nucleation. The liquid-crystal surface tension is $\gamma\approx5\times10^{-4}$ J/m².



(a) At T=100 K, what is the critical nucleation radius? (4p)

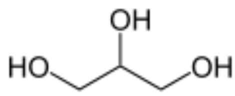
(b) Is it likely that the liquid will crystallize at T=-100ºC? Don't forget to motivate! (3p)

(c) Is it likely that the liquid will crystallize $T=T_m$ - 0.1ºC? Don't forget to motivate! (2p)

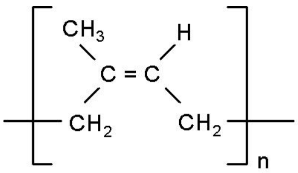
(d) What can you do to help the crystallization process at temperatures where nucleation is too slow? (2p)

7. Below you find the stress relaxation modulus (the stress after a sudden, constant strain) for the following materials:

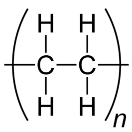
(i) Glycerol at T=0 ºC



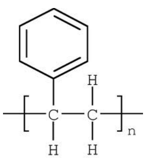
(ii) Vulcanized rubber at room temperature (crossed-linked polyisoprene of molecular weight 14000 g/mol).

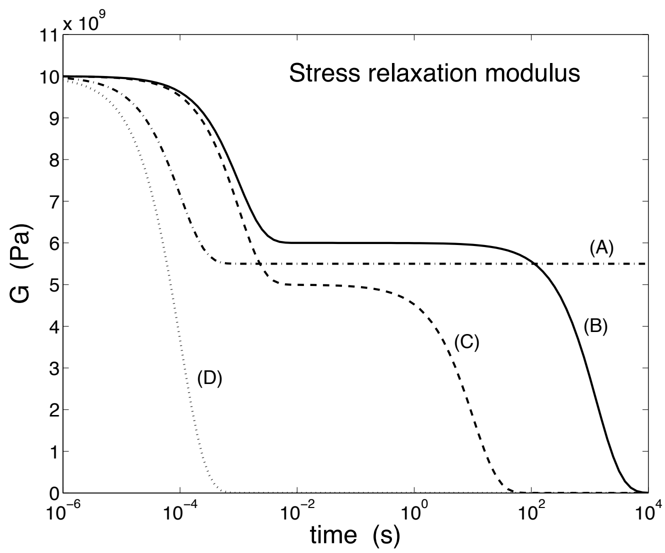


(iii) Polyethylene with molecular weight 14000 g/mol at room temperature.



(iV) Polystyrene with molecular weight 14000 g/mol at T=150 ºC.





(a) Match the different curves (A-D) with the corresponding material (i-iV). **You must motivate each assignment in order to get credits!** (8p)

(b) From the figure, estimate the viscosity of glycerol at T=0 ºC! (2p)