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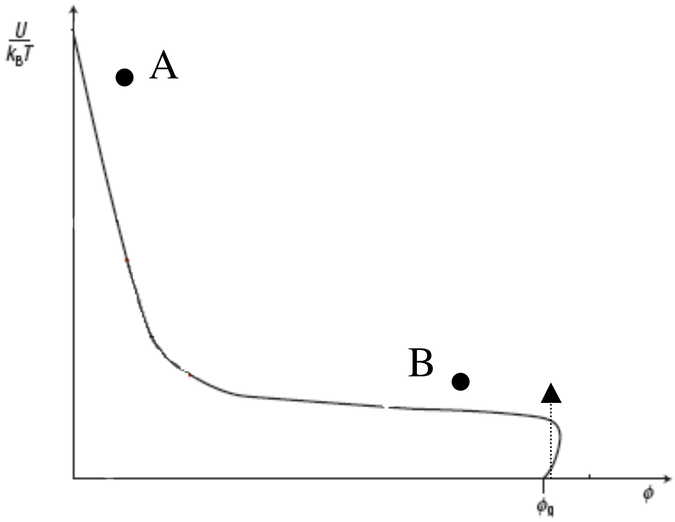
Exam in Soft Matter Physics TIF015/FIM110

Time and place: Monday October 23rd 2006 14.00-18.00, Soliden.
Examiners: Aleksandar Matic (0730-346294), Per Jacobsson (070-3088200).
Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator
Grading: 27 points, is required for a passed.
Exam results: Exam results are displayed 6/11 outside office S2046 6/11.
Review of the exam: Delfinen 6/11 12.00-12.30.
Note: Motivate all answers carefully. Answers without motivation give no credit.

1. The figure to the right shows a phase diagram for a colloidal system governed by attractive interactions.



a) What is the nature of the structures in points A and B? Motivate why they are like this. (4p)

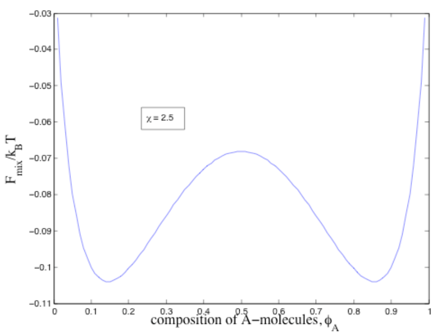
b) Describe how the system evolves as you move in the phase diagram along the dashed arrow in the figure. (4p)

c) What mechanisms can be used to tune the interactions in a colloidal suspension? Discuss the origin of these mechanisms. (2p)

2a) Consider a mixture of two liquids (of molecules A and B) described by the regular solution model. The free energy of mixing can therefore be written:

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

where ϕ_A is the volume fraction of A-molecules.



The internal and external parameters are such that the interaction parameter is $\chi = 2.5$.

Define the regions of stability/metastability/instability in terms of the composition ϕ_A. (3p)

[The numerical solution to $\ln\left(\frac{x}{1-x}\right) = 5x - 2.5$ is $x = \{0.14,\ 0.5,\ 0.86\}$]

b) Which properties determines the size (length scale) of the density fluctuations if the mixture in a) undergoes spinodal decomposition? (2p)

c) What are the main assumptions that form the basis of the regular solution model? (2p)

d) What is meant by uphill diffusion and in what region of the phase diagram does this apply? (3p)

3a) Consider a polymer solution. There are several interactions that influence the root mean square of the end-to-end distance $\langle r^2 \rangle^{1/2}$. Below are three energies corresponding to different phenomena. Identify the different energies and explain their origin. Discuss whether they are attractive or repulsive.

i. $F(r) = \dfrac{3k_B T r^2}{2Na^2}$+constant

ii. $F(r) = k_B T v \dfrac{N^2}{r^3}$

iii. $U = -k_B T v 2\chi \dfrac{N^2}{r^3}$+constant,

where r is the end-to-end distance, N is the number of monomers in the chain, a is the monomeric length, v is the volume of a monomer and χ is an interaction parameter. (4p)

b) By summing the three energies one obtains the total free energy of the chains. Explain how the dependence of $\langle r^2 \rangle^{1/2}$ on N changes when the interaction parameter is varied (perhaps by changing the temperature) from $\chi = 0.2$ to $\chi = 0.8$. Motivate your answer. (3p)

c) Discuss a DNA molecule in terms of polymer concepts. What are the characteristic properties of this polymer? (3p)

4a) An anionic amphiphilic molecule has a hydrocarbon volume v=0.296 nm^3, a critical chain length l_c=1.42 nm and a optimum head group area a_0=0.65 nm^2. What shape do you expect micelles to form by this amphiphile? Motivate the answer. (2p)

b) What might happen if you add salt to the amphiphilic solution above? (3p)

c) Phospholipids are one of the basic building blocks of cell membranes. Give a motivation to why phospholipids form membranes and not other type of aggregates. (2p)

d) Very few homopolymers are miscible. Commonly a macroscopic phase separation is observed when a polymer A is mixed with another polymer B. Explain why this can be expected based on arguments from the regular solution model. (3p)

5a) Discuss the glass transition based on thermodynamic considerations and sketch the behaviour of relevant thermodynamic quantities. (4p)

b) What arguments can be raised against thermodynamic models for the glass transition? (2p)

c) What is the Kauzman paradox, or the entropy crisis, associated with the glass transition? (2p)

d) What general properties of glasses are unique and useful from an application point of view? (2p)

6) a) Explain the three fundamental deformations of a liquid crystal: splay, twist and bend. (3p)

b) What are the basic components of a liquid crystal display? (4)

c) Describe the basic physical principles in action in a liquid crystal display. (3)

7) Seminar questions. Choose two out of these four questions:

i) Discuss the dynamics of a colloidal suspension in the limits Pe<<1 and Pe>>1 where Pe is the Péclet number. (4p)

ii) What parameters can be expected to influence the self-diffusion coefficient for a particle in a gel? (4p)

iii) Explain how a micro-emulsion could facilitate an otherwise impossible reaction? (4p)

iv) Why do you get a much higher resolution in an electron microscope compared to a optical microscope? Why is it lower than the theoretical value? (4p)