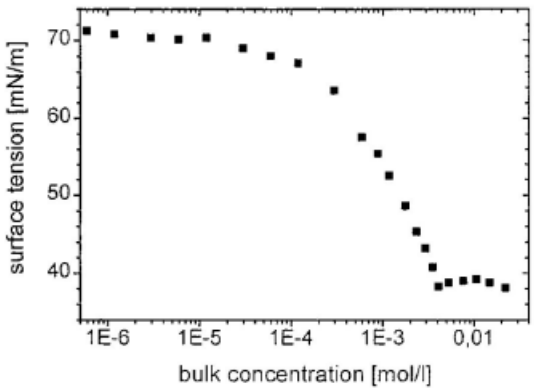
Self-assessment test with focus on COSOM subjects (2) (solutions)

1. How is the interfacial tension γ thermodynamically defined?

$$\gamma = \left(\frac{dG}{dA}\right)|_{p,T}$$

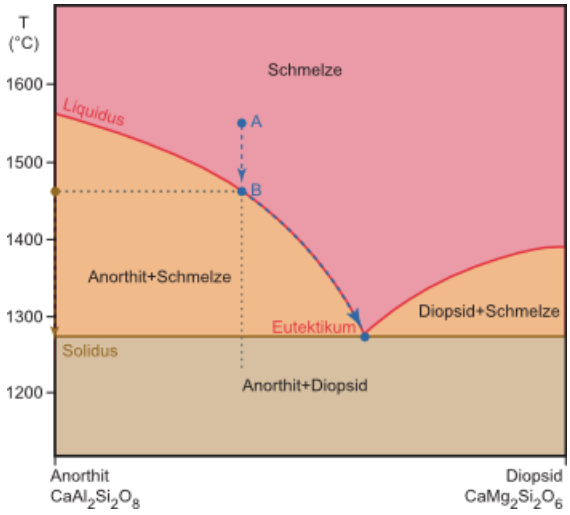
dG is the change in Gibb's free enthalpy while dA is the change in (surface) area.

2. Amphiphiles greatly reduce the interfacial tension of water which normally has a value of 72 mN/m. A characteristic equilibrium stress isotherm is shown in the following figure. Are the spherical micelles produced by the CMC monodisperse with one well-defined radius or do they form aggregates with a wide distribution in size? Rationalize your answer.



One well defined radius. Otherwise, another surface at the inside of the micelles would occur resulting in a thermodynamically unfavorable state.

3. Two substances A and B are completely immiscible in their solid state, but can be mixed at will when liquefied. Sketch the phase diagram of this system in a temperature / molar fraction (T/x) diagram. Identify the phases present.



4. Give a definition for Raoult's law.

$$p_i = x_i \cdot p_i^*$$

P_i is the partial pressure of component i in a mixture, x_i is its molar fraction within this mixture and p_i^* is the partial pressure of the pure component i (no mixture).

5. The Sebatier process allows us to convert CO_2 into methane with the help of hydrogen gas at high temperatures: $CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

   a) Calculate the standard reaction enthalpy $\Delta_r H$ from the standard formation enthalpies $\Delta_b H$. ($\Delta_b H(CO_2)$ = -392 kJ/mol; $\Delta_b H(H_2O; gas)$ = -242 kJ/mol; $\Delta_b H(CH_4)$ = -75 kJ/mol)

$$\Delta_r H = \Delta_b H(\text{products}) - \Delta_b H(\text{starting materials})$$

$$= \left(-75\,\frac{\text{kJ}}{\text{mol}} + 2 \cdot -242\,\frac{kJ}{mol}\right) - \left(-392\,\frac{kJ}{mol}\right) = -167\,\frac{kJ}{mol}$$

   Note that $\Delta_b H$ of H_2 is zero because it is a pure element in its most stable form.

   b) Is this reaction exothermic or endothermic? What is the effect of a temperature increase on the equilibrium position?

   This reaction is exothermic. An increase in temperature leads to an equilibrium shift to the side of the starting materials.