EXAM 21.2.2024 **CHEM-E2150 Interfacial Phenomena in Biobased Systems**

Note: only a calculator and pens are allowed. Maximum mark: 25 points. Minimum mark to pass the exam: 12 points.

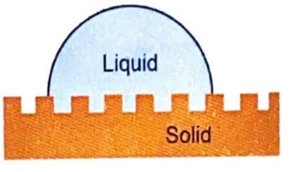
1. Answer the following questions:

a) What are superhydrophobic surfaces? How would you modify a surface to make it superhydrophobic? (1 point)

b) The contact angle of a drop of water on a flat surface of a solid material A is 40°. The surface energy of material A is 67 mN/m and the surface tension of water is 72 mN/m. Calculate the surface energy of the interface water/material A. (2 points)

c) The apparent contact angle of a drop of water on a rough surface of material A, where the water fills all the grooves, is 28°. Considering the information given in b), calculate the roughness ratio r of the surface. (2 points)

System in c)



2. Answer the following questions:

a) What is the critical micelle concentration (CMC) of a surfactant? (1 point)

b) Sodium octyl sulfate [CH_3-$(CH_2)_7$-SO_4^- Na^+], sodium dodecyl sulfate [CH_3-$(CH_2)_{11}$-SO_4^- Na^+], and sodium octadecyl sulfate [CH_3-$(CH_2)_{17}$-SO_4^- Na^+] are three anionic surfactants. Which one has the highest CMC? Justify your answer. (1 point)

c) The CMC of an anionic surfactant is 8 mM. Will the CMC change if NaCl is added to the surfactant solution? If so, how and why? (1 point)

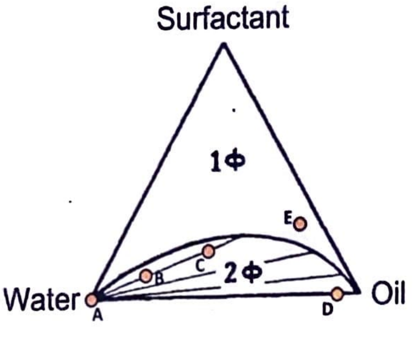
d) An anionic surfactant of 8 mM CMC and a nonionic surfactant of 0.2 mM CMC are mixed at a molar ratio 1:1. Calculate the CMC of the mixture (assume similar interactions between the surfactants). (2 points)

3. Answer the following questions:

a) What is an emulsion? What is the difference between O/W and W/O emulsions? (1 point)

b) Describe qualitatively the system (number of phases, components in each phase) in the points A, B, C, D, and E of the given SWO phase diagram. (2.5 points)

c) Compare the points B and C. What are the main differences? (1.5 points)

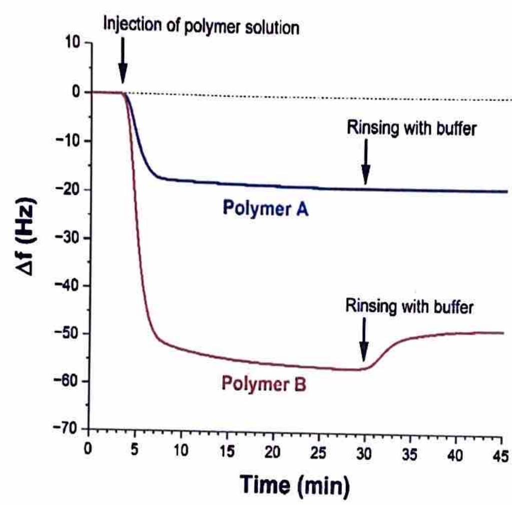


4. Answer the following questions:

a) The adsorption of a cationic polymer on negatively charged colloidal particles can give rise to bridging forces or steric forces between the particles. Explain the differences between bridging and steric forces and in what conditions they appear. (2 points)

b) The adsorption of polymers A and B on thin films of cellulose nanofibrils (CNF) was studied by QCM-D and the results are presented in the graph below. Indicate which polymer adsorbed more on CNF and explain your answer. (1.5 points)

c) In the same experiment introduced in b), explain what happened after rinsing the system with buffer. (1.5 points)

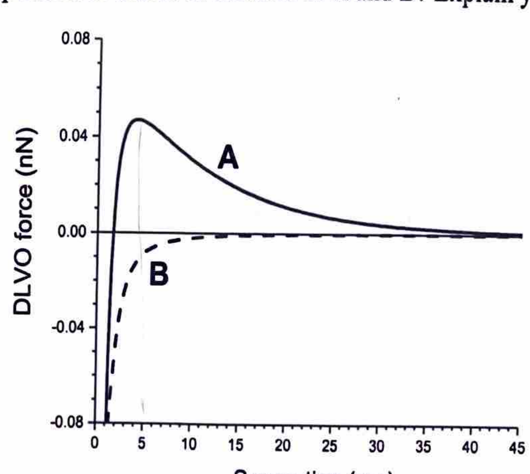


5. The figure below shows the DLVO interaction force *versus* the separation between two colloidal particles in 1 mM NaCl and 1 M NaCl solution.

a) Identify which curve corresponds to 1 mM NaCl and which one to 1 M NaCl. Explain why the shape of the curves is different at different NaCl concentrations. (2 points)

b) The DLVO theory considers that two types of forces contribute to the total interaction between two colloidal particles. What type of force is the dominant when the separation between the particles is 5 nm in A and B? (1 point)

c) Would the colloidal dispersion be stable or unstable in A and B? Explain your answer. (2 points)



Equations

Young's equation: $\cos\theta = \dfrac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$

Wenzel's equation: $\cos(\theta') = \dfrac{r(\gamma_{SV} - \gamma_{SL})}{\gamma_{LV}} = r\cos(\theta)$

Cassie-Baxter's equation: $\cos(\theta') = f\cos\theta + (1-f)\cos 180° = f\cos\theta + f - 1$

Gibbs' equation (non-ionic surfactants): $\Gamma = -\dfrac{1}{RT}\dfrac{d\gamma}{d\ln C} = -\dfrac{C}{RT}\dfrac{d\gamma}{dC}$

Gibbs' equation (ionic surfactants): $\Gamma = -\dfrac{1}{2RT}\dfrac{d\gamma}{d\ln C} = -\dfrac{C}{2RT}\dfrac{d\gamma}{dC}$

Cross-section area per surfactant at air-water interface: $a_m = \dfrac{1}{N_A\Gamma}$

CMC of a mixture of surfactants (similar interactions): $\dfrac{1}{CMC} = \dfrac{x_1}{CMC_1} + \dfrac{x_2}{CMC_2}$

CMC of a mixture of surfactants (different interactions): $\dfrac{1}{CMC} = \dfrac{x_1}{f_1\,CMC_1} + \dfrac{x_2}{f_2\,CMC_2}$

Debye length: $\kappa^{-1} = \sqrt{\dfrac{\varepsilon_0\,\varepsilon_r\,k_B\,T}{2\,e^2\,N_A\,I}}$; $\kappa^{-1}(nm) = \dfrac{0.304}{\sqrt{I(M)}}$

Ionic strength: $I = \frac{1}{2}\sum_i z_i^2\, c_{i0}$

Electrical double layer force between 2 spherical particles: $F_{EDL} \approx 2\pi\varepsilon_0\varepsilon_r\kappa R\Psi_0^2\exp(-\kappa x)$

Van der Waals force between 2 spherical particles: $F_{vdW} = -\dfrac{A_H R}{12x^2}$

Constants

$R = 8.31$ J K^{-1} mol^{-1}

$k_B = 1.38\times10^{-23}$ J K^{-1}

$N_A = 6.022\times10^{23}$ mol^{-1}

$\varepsilon_0 = 8.85\times10^{-12}$ C^2 N^{-1}m^{-2}

ε_r(water) = 78.5

e = 1.6×10^{-19} C