Soft Matter exercise, Chapter 11: Emulsions

1. Fabrication of emulsions

A 1-liter can with a diameter of 1 cm is shaken with an amplitude of 20 cm at a rate of 10 s^{-1}. To do the calculations, make a few rather strong assumptions: Assume that all the liquid is displaced by the full amplitude. Moreover, assume the center of the liquid to remain stationary within a full cycle.

a. Estimate the shear rate inside the can using $\dot{\gamma} = \frac{8v}{d}$, where v is the average velocity and d the diameter of the can.
b. What is the order of magnitude of the viscous stress assuming the liquid is 10 times more viscous than water that has a viscosity of 1 mPa.s?
c. The shear force pushes the air at the top of the can into the fluid and breaks it up into small bubbles. Estimate the average size of drops that form. Assume the surface tension of the liquid to be that of clean water, 73 mN/m.
d. What is the average drop size if water is shaken with the same frequency and amplitude?

2. Stability of emulsions

The interfacial tension between water and hexane is 50 mN/m at 20°C.

a. Is it possible to form a stable emulsion composed of 50 vol% hexane, 50 vol% water? If yes, why, if not why not?
b. What is the critical surface tension to form an emulsion with a drop diameter of 20 nm if ϕ_b = 50%?
c. What is the critical surface tension to form an emulsion with a drop diameter of 20 nm if ϕ_b = 10%?
d. How can you lower the surface tension?

3. Stabilization of emulsions

Name two possibilities to stabilize emulsions. What are the advantages and disadvantages of each possibility?

4. Surfactants

What are surfactants and where are they used?

5. Adsorption of surfactants

What technique would you use to measure the adsorption kinetics of surfactants at air-liquid interfaces? What is the underlying principle of this technique?

6. Stabilization of vinaigrette

What types of surfactants (activity, charge, and composition) would you use to stabilize vinaigrette?

7. Emulsions in our daily life

Name two products that are oil-in-water emulsions and two products of water-in-oil emulsions that are consumed/used in our daily life.

8. Pickering emulsions

The removal of SiO_2 particles that are adsorbed at the drop surface costs a significant amount of energy.

a. Why is this the case?

What is the energy in k_BT required to remove a SiO_2 particle from the surface of an oil drop in water if the interfacial tension γ = 30 mN/m, the particle diameter is

b. 200 nm and the contact angle is θ = 90°
c. 200 nm and the contact angle is θ = 120°
d. 20 nm and the contact angle is θ = 90°
e. 20 nm and the contact angle is θ = 120°?

Assume the temperature to be 25°C and the density of water to be 1 g/cm^3.

9. Foams

Why do foams coarsen and how can the coarsening kinetics be influenced?