Physical chemistry of water-in-water Pickering emulsions

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Project description

Emulsions are an important aspect of many everyday products. Think of mayonnaise, soap, dairy products, or creams. In all of these, oil or fat droplets are dispersed in a continuous water phase or vice versa. Concentrated emulsions are an important means to texturize foods.

An inherent disadvantage of using oil-based emulsions in food is their high caloric content. We are studying the fundamental physical chemistry of a new system to serve as the basis of next-generation low-fat food. This system consists of two water-soluble polymers that are immiscible with each other: dextran and gelatin. Dextran is a branched polysaccharide composed of glucose monomers, while gelatin is a hydrolyzed form of collagen, a linear protein.

When aqueous solutions of dextran and gelatin are mixed, the mixture quickly undergoes spinodal decomposition into dextran- and gelatin-rich regions. Over the course of a few hours, the slightly denser gelatin droplets sink to the bottom and two macroscopic phases are formed, as can be seen in Figure 1.

![Figure 1](image)

**Figure 1:** (a) An aqueous mixture of dextran and gelatin phase separates into a gelatin-rich bottom phase and a dextran-rich top phase. (b) Experimental phase diagram determined using polarimetry showing the compositions of the coexisting phases and the initial composition of the sample in which these coexisting phases were formed.
A short-lived emulsion can be prepared by vigorously stirring the aforementioned mixture, which will rapidly undergo coalescence to form two macroscopic phases again. To prepare more stable emulsions, stabilizers or emulsifiers are necessary, which unfortunately are currently unknown for these systems.

A possible route towards stable emulsions would be through so-called Pickering emulsions. This is a type of emulsion in which solid particles are attached to the interface to prevent or slow down droplet coalescence. By introducing suitable particles into our system, we have recently succeeded in creating water-in-water Pickering emulsions that seem to be stable for months, yet the microscopic structure of these emulsions has still to be elucidated and optimized.

However, much of the physical-chemical aspects of these emulsions are completely different from regular (Pickering) emulsions. For instance, the interfacial tension of a typical oil-in-water emulsion is on the order of 10 mN/m, so a colloidal particle of 100 nm will typically stick to the interface with an energy of tens of thousands $k_B T$, which is clearly irreversible. The interfacial tension of a water/water interface is much lower, typically only 1 µN/m, so the same particle would only stick with an energy of just a few $k_B T$, which makes the adsorption reversible.

In this project, you will investigate the fundamental physical-chemical aspects of these emulsions stabilized by well-defined inorganic model particles, and optimize their stability and microscopic structure. Many parameters can be changed in the preparation of these emulsions. A few examples are:

- the concentrations of the two polymers;
- the pH, ionic strength, and polymer molecular weights;
- the interfacial tension between the coexisting phases;
- the size, shape and concentration of the solid particles;
- the method of emulsifying (e.g. high-shear mixing, vortex mixing or more gentle methods).

During your research, you will be using a variety of techniques available in our lab, such as analytical centrifugation, optical and confocal microscopy, (cryogenic) electron microscopy, light scattering, and rheometry.

This project is intended for master students with a strong interest in fundamental physical-chemical characterizations. It is carried out within the framework of the PhD project of Mark Vis, who is co-supervised by Hans Tromp (NIZO food research, Ede). If you are interested in this project or have any questions, feel free to contact one of us or our student coordinator.

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