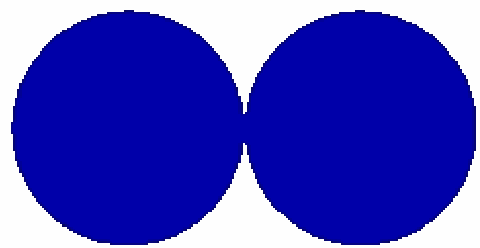
Electrocoalescence: breaking emulsions, oil-water separators, desalters, dehydrators, and more



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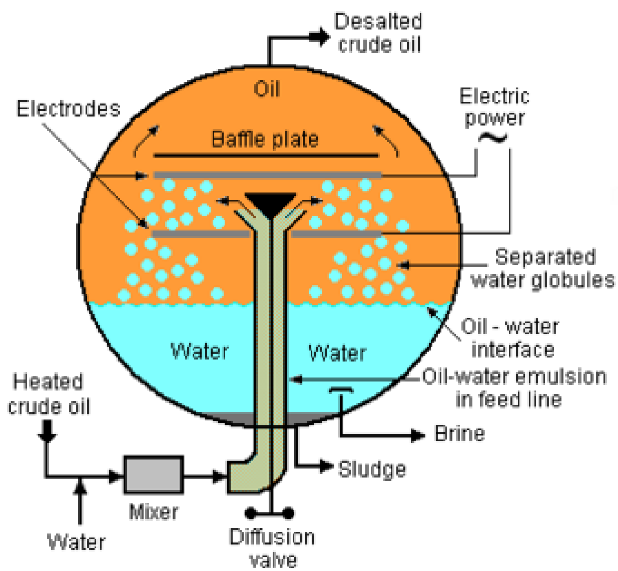
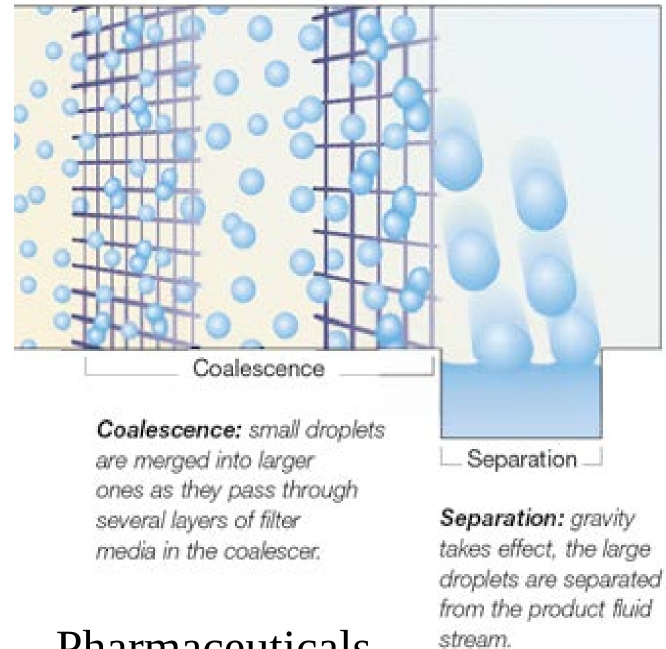
Liquid-liquid emulsions are ubiquitous

Crude oil desalters



Coalescers for L/L extraction



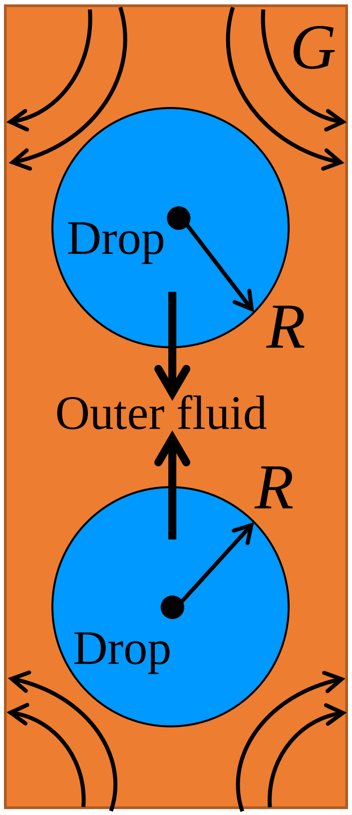
Food products

Pharmaceuticals

Intravenous lipid emulsions

Ointments

(Flow-induced) Drop coalescence



- Two drops in another immiscible outer liquid separated by a certain distance are driven towards each other by an external force

- External force can be due to:
  1. Gravity (not studied here)
  2. **Flow imposed on outer fluid (old)**
  3. **Electric fields (new)**

- A key parameter in flow-induced coalescence of drops is the capillary number:

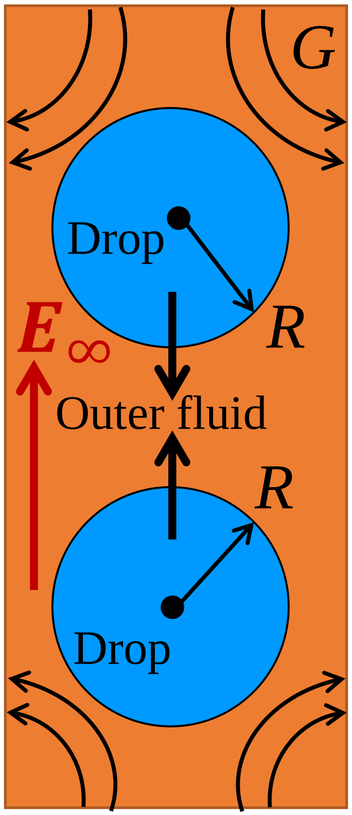
$$Ca = \frac{\mu_2 G R}{\sigma}$$

μ_2 - viscosity of the outer liquid

G - strain rate of the imposed flow

σ - interfacial tension of the liquid-liquid interface

(Electric field-induced) Drop coalescence



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- External force can be due to:
  1. Gravity (not studied here)
  2. **Flow imposed on outer fluid (old)**
  3. **Electric fields (new)**

- A key parameter in electric field-induced coalescence, i.e. **electrocoalescence**, of drops is the electric capillary Ca_E or electric Bond N_E number:

$$Ca_E = N_E = \frac{\epsilon_2 {E_\infty}^2}{\sigma/R}$$

ϵ_2 - permittivity of the outer liquid

E_∞ - strength of the imposed (applied) electric field

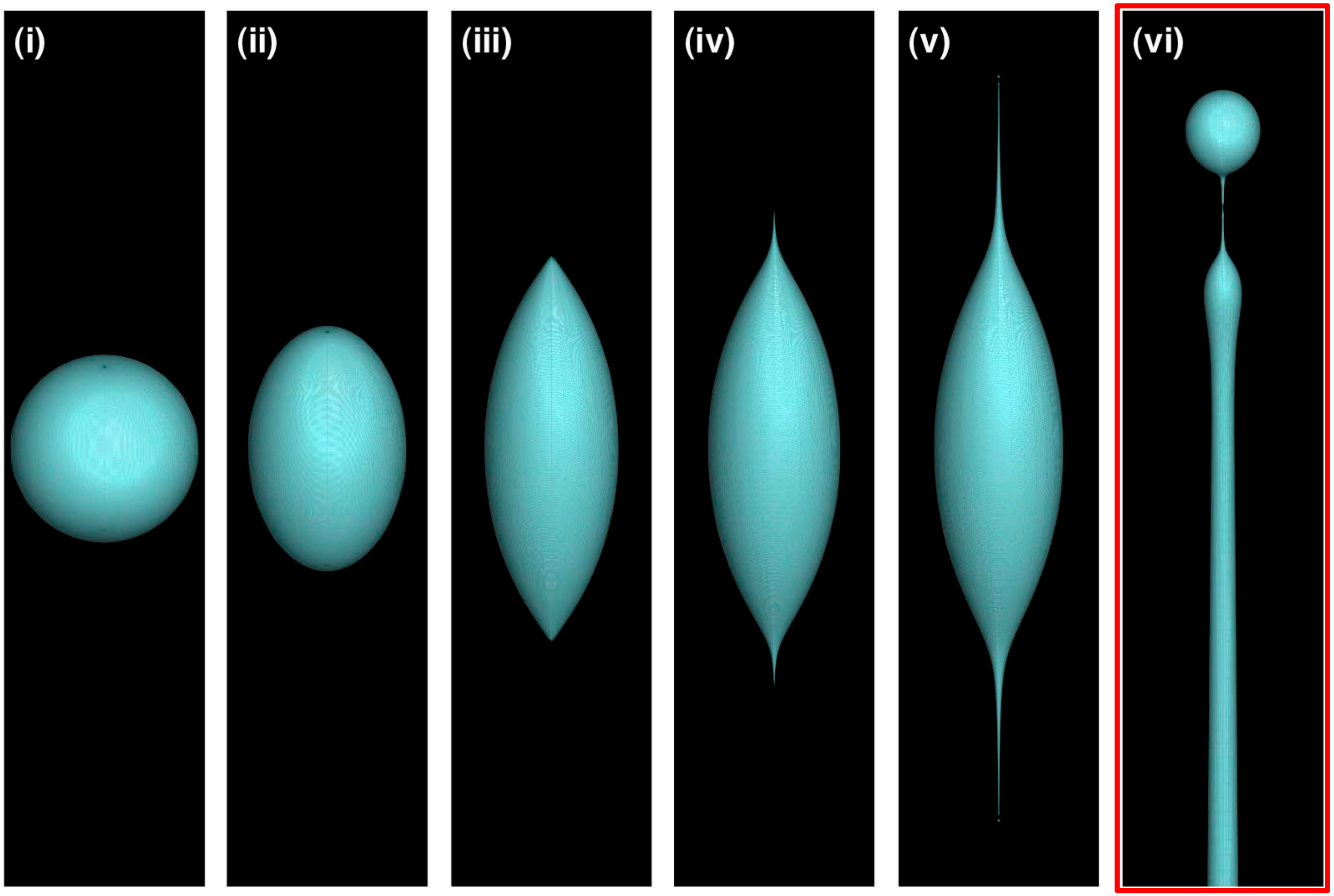
σ - interfacial tension of the liquid-liquid interface

Why is this problem interesting (aside from being of great importance in the oil and gas industry and others)?

- Drops bearing the same charge are sometimes seen to coalesce in experiments (*they should repel each other*)
- Drops bearing the opposite charge are sometimes seen to bounce off each other (*they should coalesce*)
- Two approaching drops may form conical ends (Taylor cones) and jet, or tip stream, towards each other rather than coalescing
- Electrocoalescence involves not only multi-scale dynamics (separation of length scales by 5-7 orders of magnitude) but also multi-physics (Navier-Stokes system has to be solved together with Maxwell's equations)

EHD Tip Streaming

$$N_E = 0.2,\ Oh = 0.15,\ \kappa = 7.5,\ Pe = 10^3,\ \alpha = 0.034$$



Project plan, goals, and objectives

- Analyze by high-accuracy simulation the collision and coalescence of two drops under an imposed or applied electric field
- Determine the dependence of the drainage (or coalescence) time on the strength of the applied electric field (and other problem variables)
- Ultimately, collaborate with industrial member companies so that the basic two-drop interactions can be built into population balance models widely used in engineering analysis, engineering design, and flow assurance