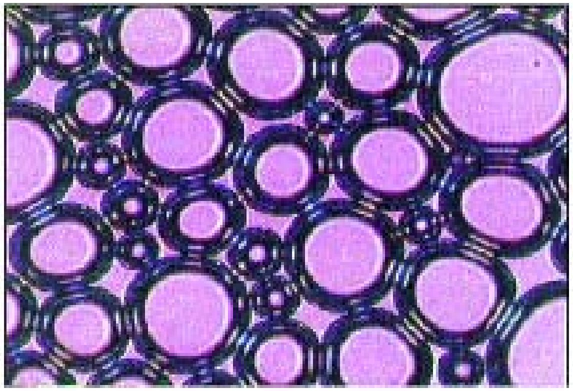
Foam Technology – Lecture 7

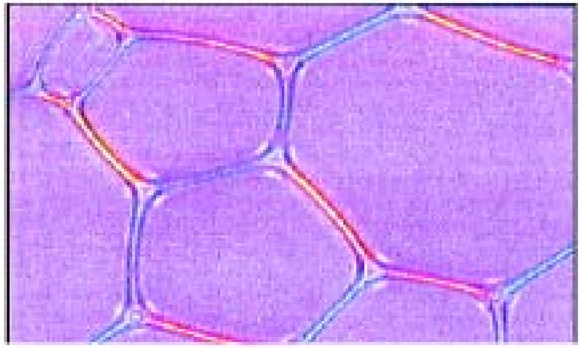
Jean Siméon Chardin (1699-1779)

Foam Structures

Foam structure of a wet spherical foam made with Sodium Caproyl Lactylate at 400X magnification

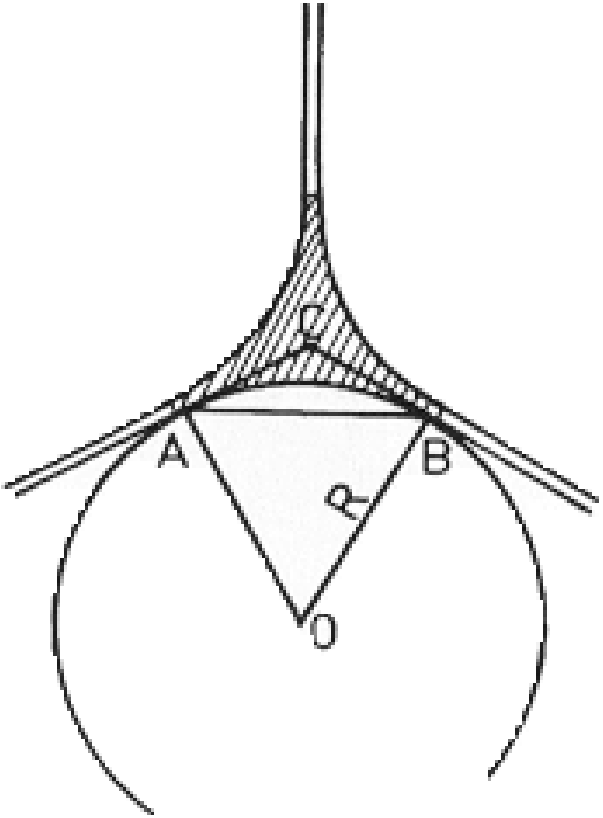


Foam structure of dry hexagonal foam from cocoamidopropyl betaine at 400X magnification



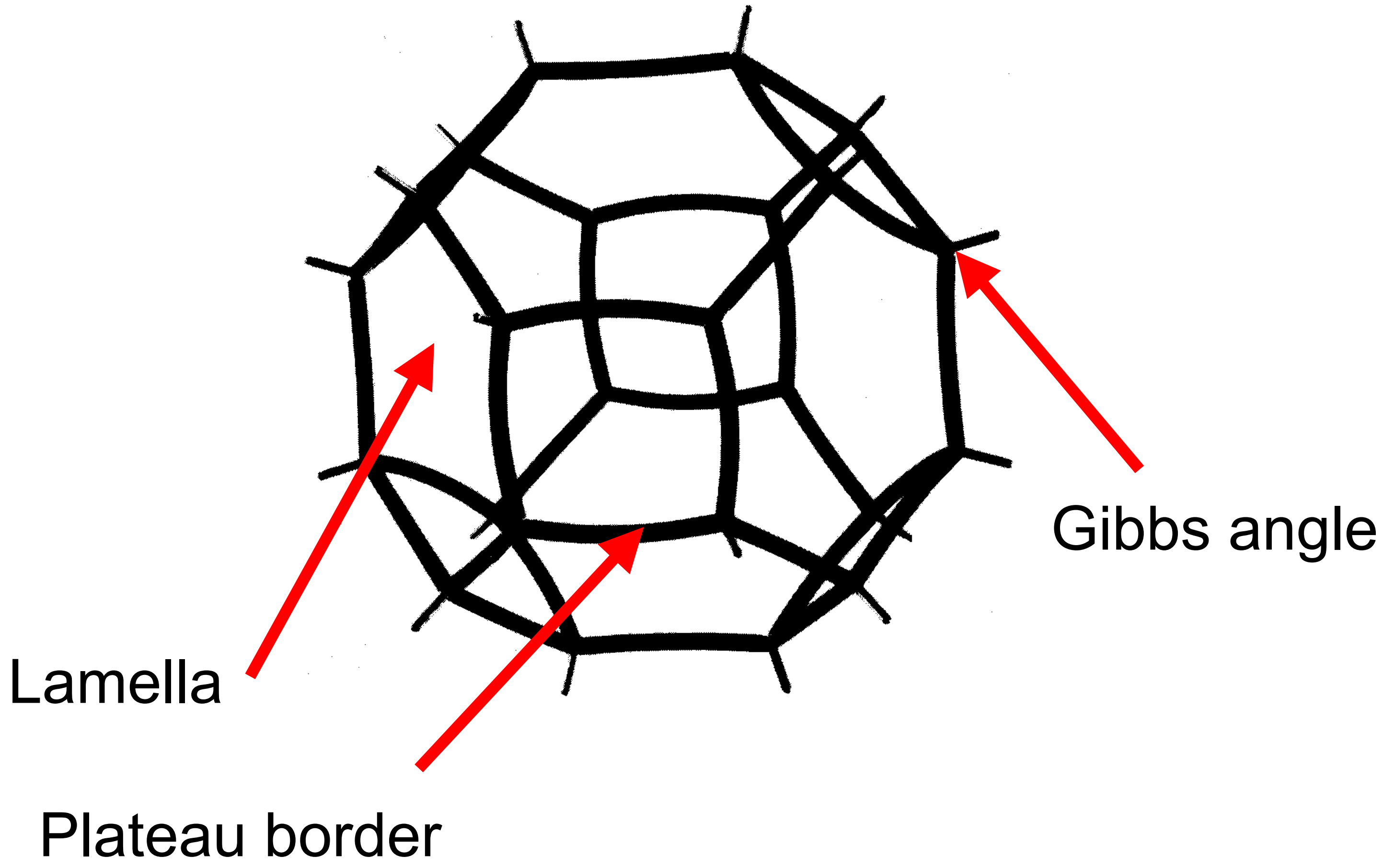
/www.ctmw.com/articles/Rita/2.htm

Plateau border

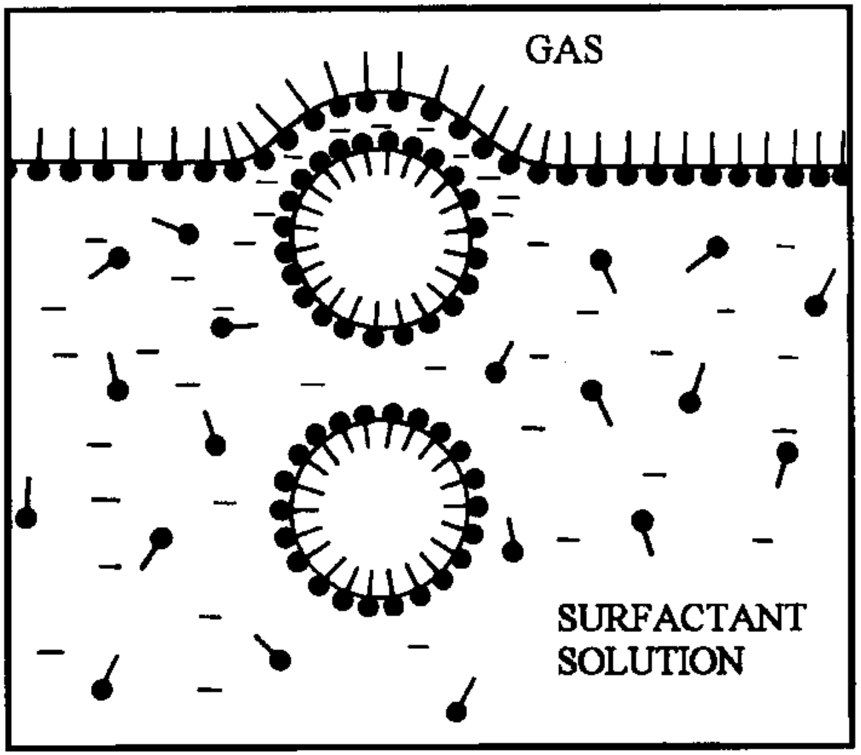


Exerowa and Kruglyakov, p. 15

The Kelvin tetrakaidecahedron



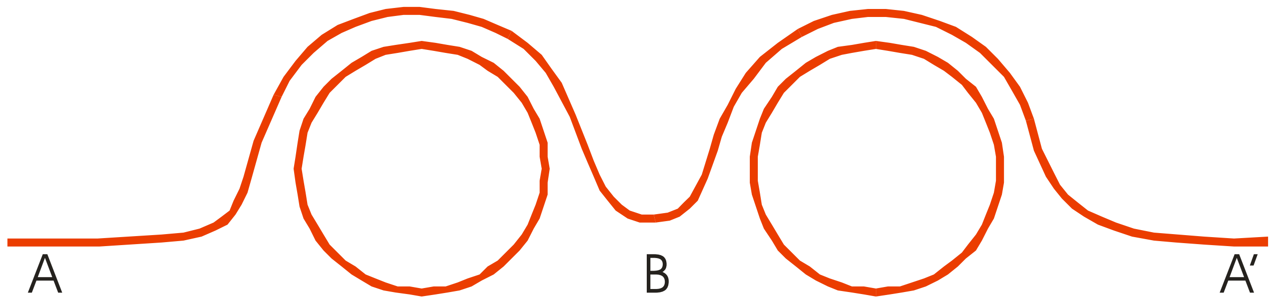
Formation of bubbles



Exerowa and Kruglyakov, p. 2

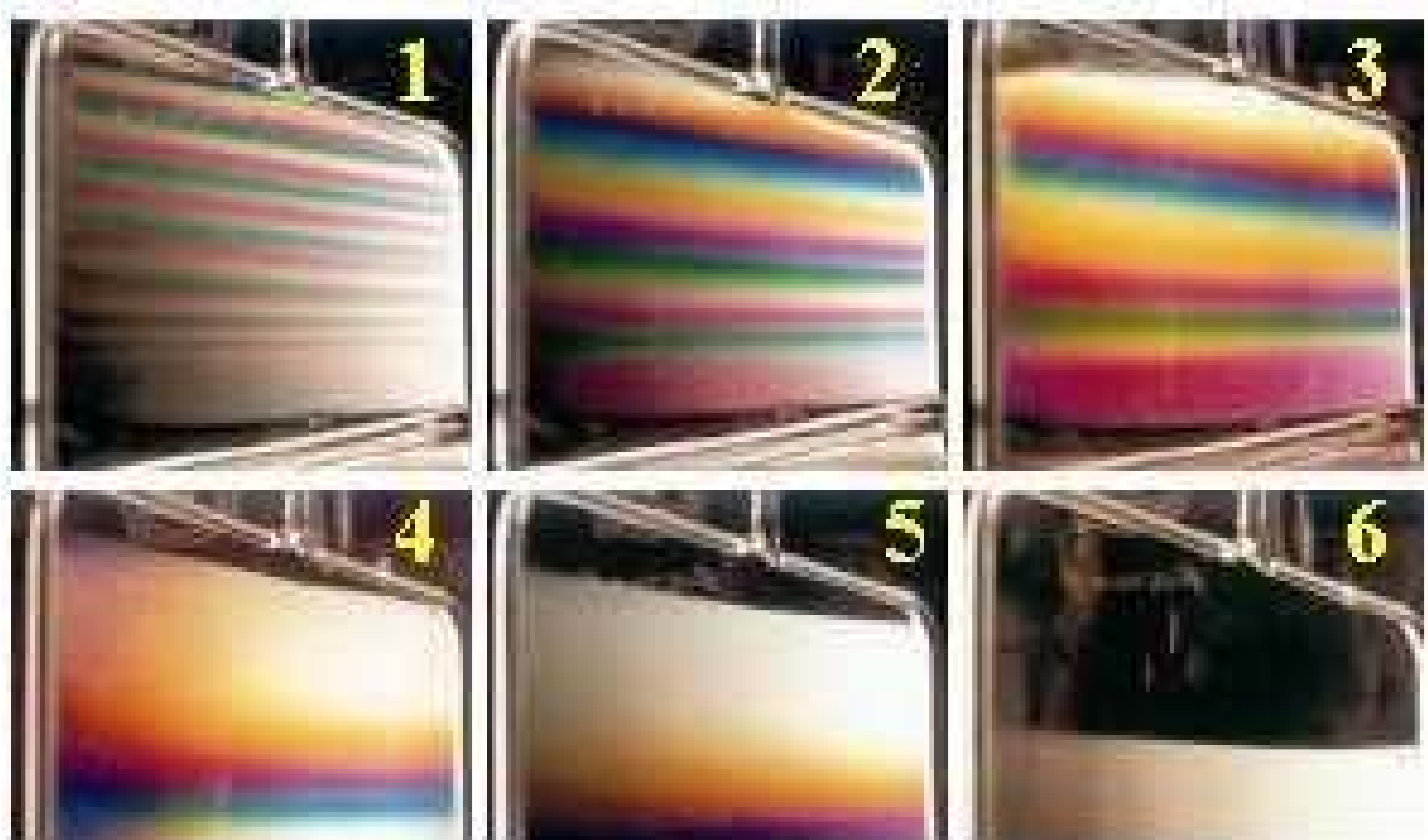
Formation of foams

Two bubbles floating at the liquid-air interface:



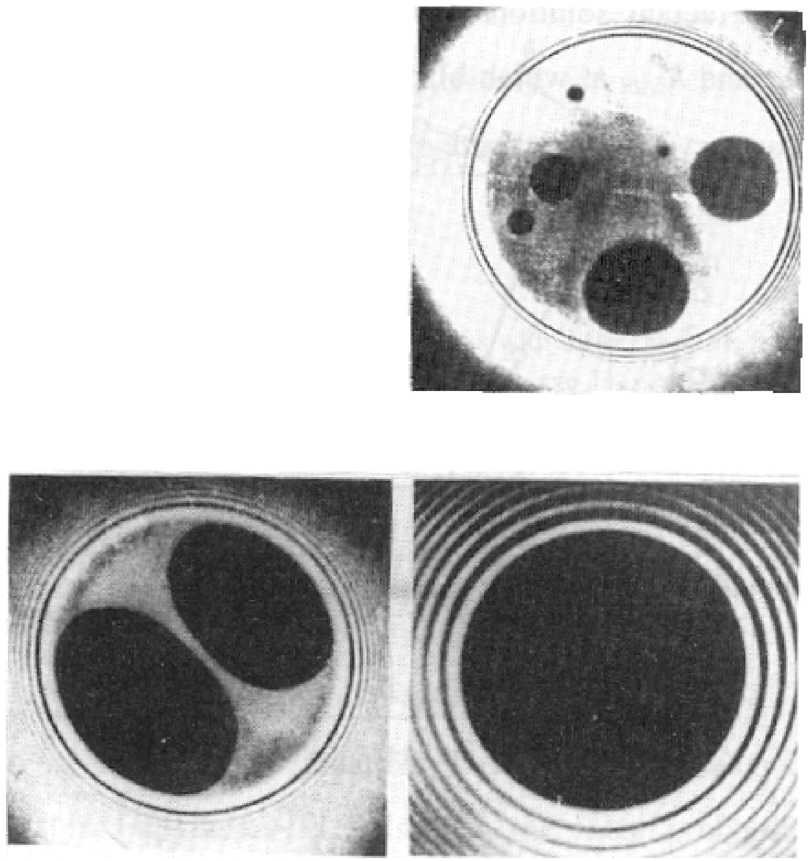
The pressure in the liquid at B is less than that at A or A'.

Draining Foam Films



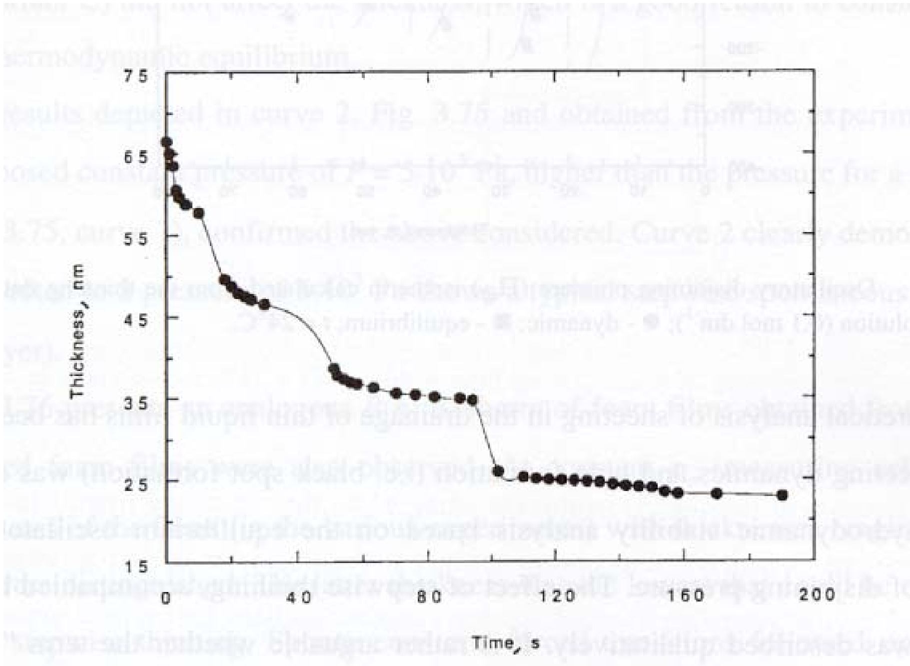
http://ptcl.chem.ox.ac.uk/~rkt/tutorials/tutimages/foam.jpg

Formation of black films



Exerowa and Kruglyakov, p. 120

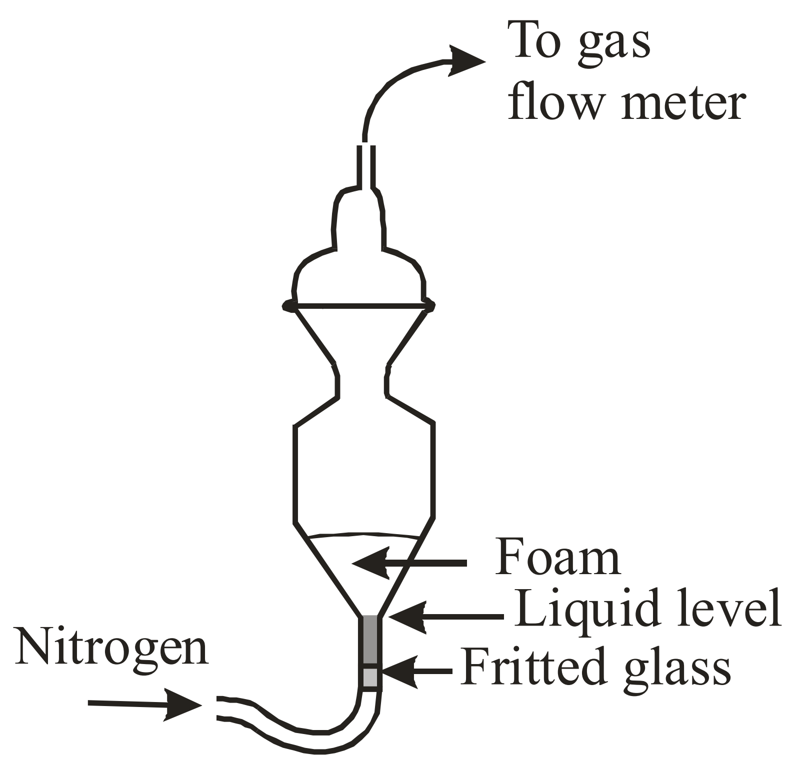
Uneven film drainage



Wasan et al. discovered the stepwise thinning of thin films.
The stable thicknesses are layers of close-packed micelles.

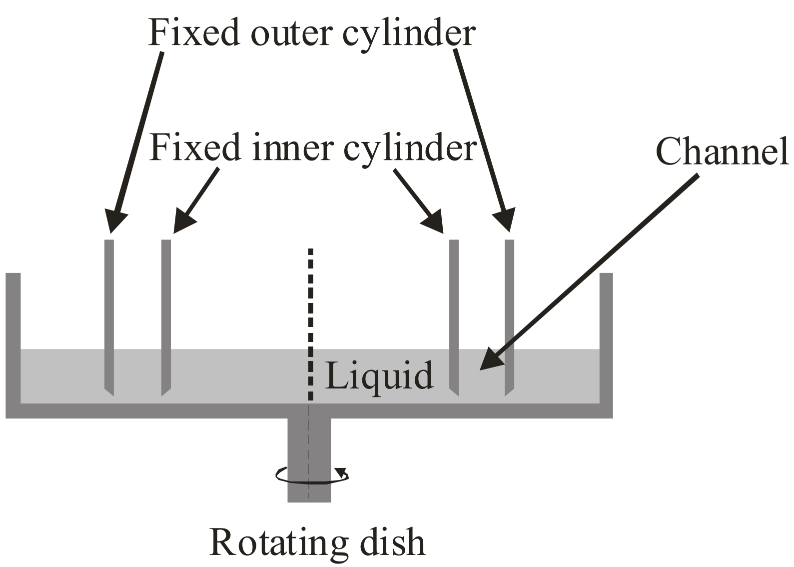
Exerowa and Kruglyakov, p. 221

Dynamic Foam Stability



Ross & Suzin, *Langmuir*, **1985**, *1*, 145-9.

Deep-channel surface viscosimeter



Equation of State of Foam

Consider a single bubble: $$p - P = \frac{4\sigma}{r}$$

For a sphere: $$\frac{V}{A} = \frac{r}{6}$$

For an ideal gas: $$pV = nRT$$

Combining gives: $$pV + \frac{2}{3}\sigma A = nRT$$

Assume this is true for a foam.

The differential form is: $$dA = -\frac{3V}{2\sigma} dP$$

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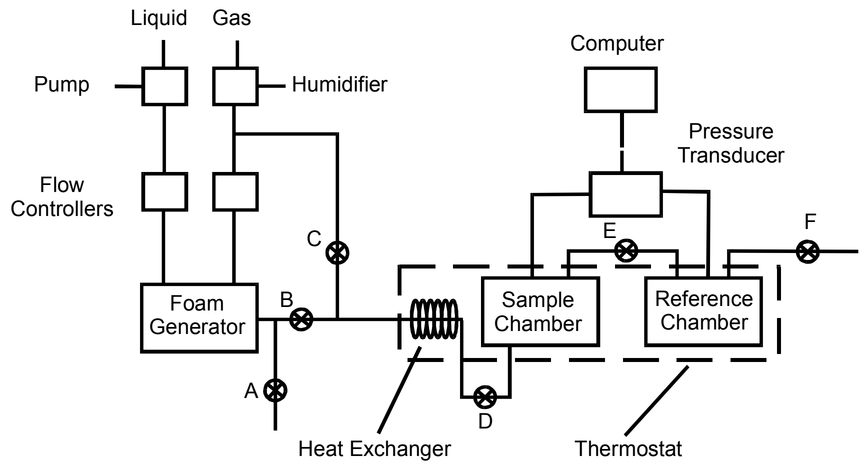
“Static” Foam Stability



A schematic of the apparatus used. The jacketed sample vessel is graduated for rough estimates of foam volume.

Nishioka & Ross, J. Colloid Interface Sci., **1981**, *81*(1), 1-7.

Theories of Foam Stability

Why doesn't a foam film fall?

•Marangoni effects. Requires slow diffusion of surfactant to stretched surface. Marangoni effects are important in spontaneous healing of thin spots and in foam destruction by antifoaming agents.*

•Fluid viscosity. Especially when high MW materials are present, e.g. gelatin or proteins.

•Surface viscosity.

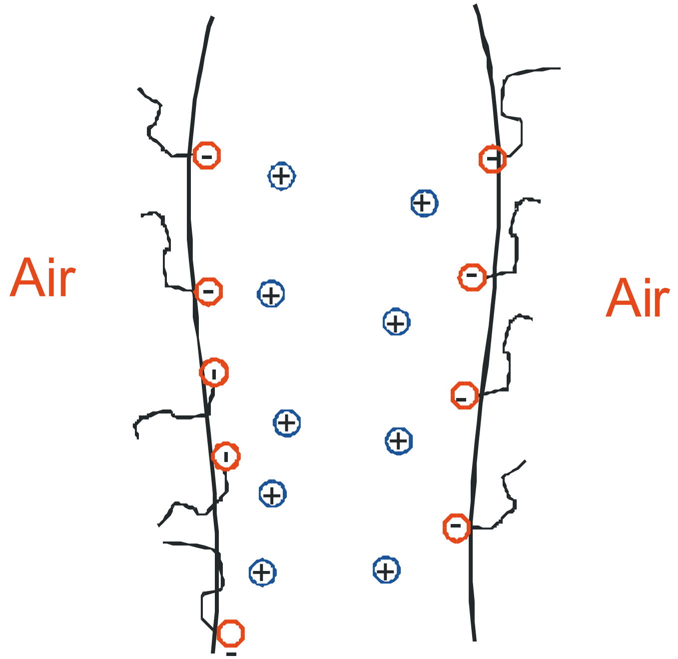
•Mutual repulsion of electrical double layers.

•Formation of layers of micelles "spacing" the surface apart.

•Formation of liquid crystalline phases in the thin films (originally associated with black films.)

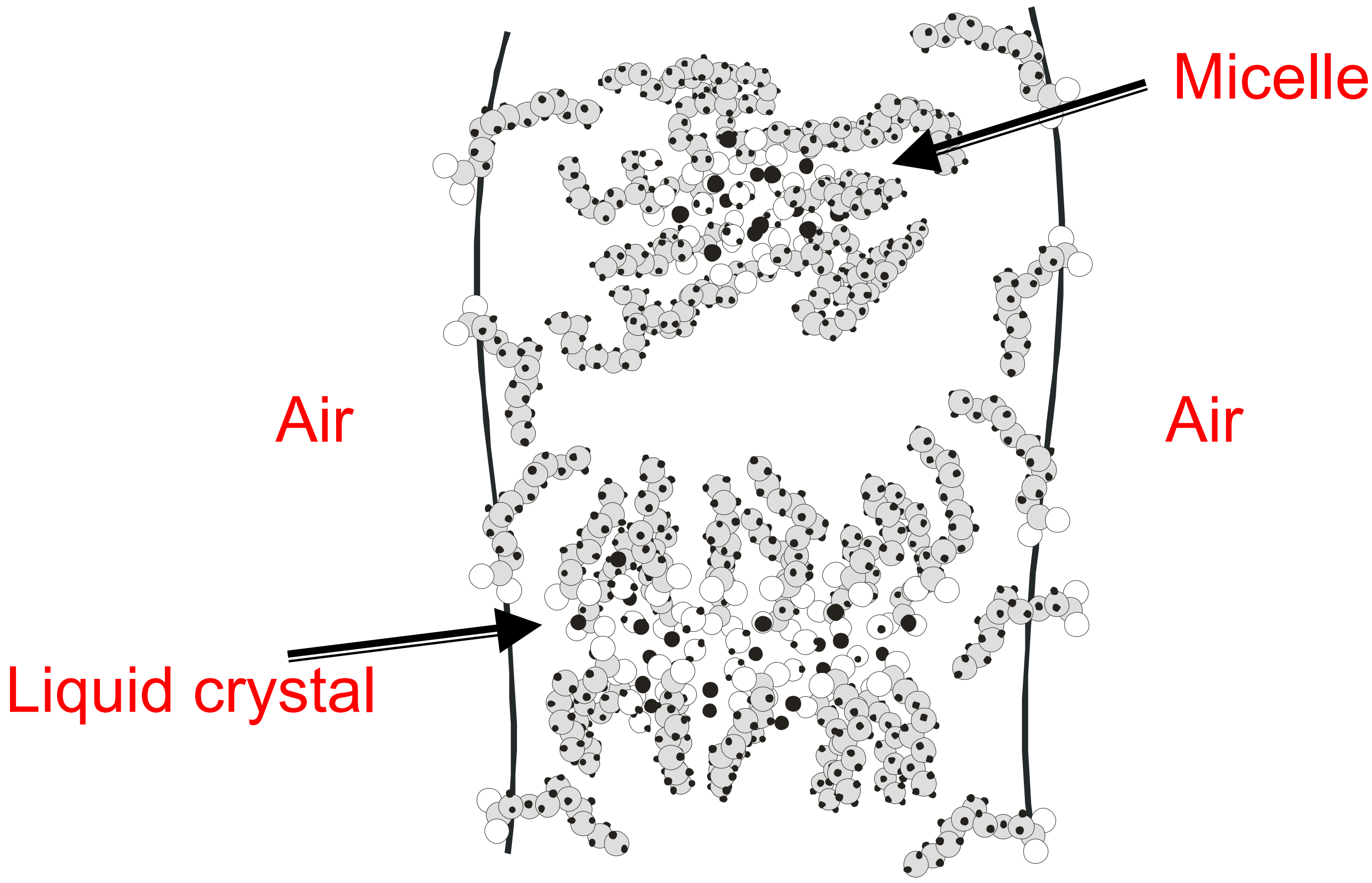
*Explains why foam stability near saturation is often diminished. Above the CMC, the micelles serve as reservoirs for the surfactant.

Electrostatic stabilization of a foam film



Each interface is electrically charged. As the film thins, the repulsion increases.

Liquid crystals stabilize foams

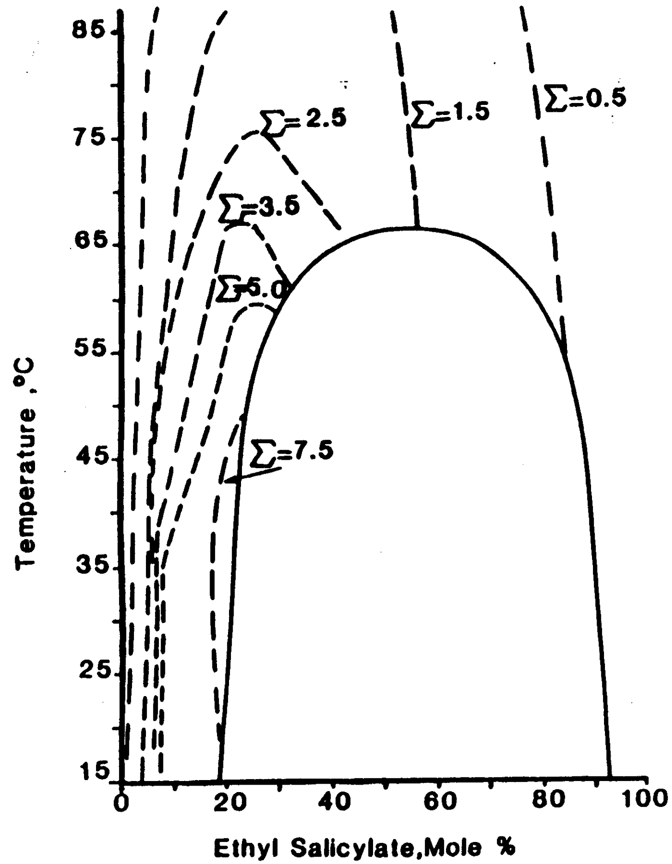


Foaminess and Phase Diagram Isophroic Contours

Not just solutions of "surfactants" foam.

Partially miscible liquids in multiple components foam near the critical point (two components) or plait point (three or more components.) Surface activity precedes phase separation.

If the separated phase has a lower surface tension, it will be a defoamer.



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Ross' Rule

Capillary effects are dramatic near phase boundaries.

"Capillarity has been shown to inhere in multicomponent systems at conditions characterized by certain locations in phase diagrams that display partial miscibilities of two liquid phases." - Ross' words

Examples:

Adsorption precedes precipitation.
Foaming can suddenly increase or disappear.
Dispersion stability suddenly changes.
Surface and interfacial tensions change abruptly near phase boundaries.
The number and size of precipitates depend strongly on the position in the phase diagram.
Sudden changes in product behavior may indicate some component is near its solubility limit.

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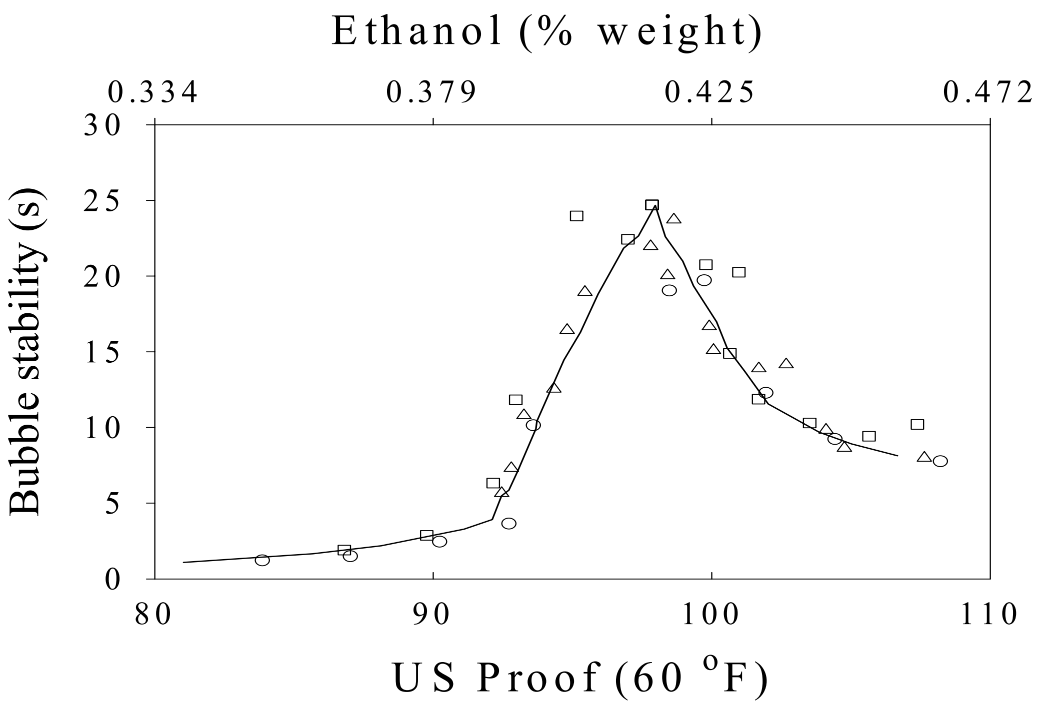
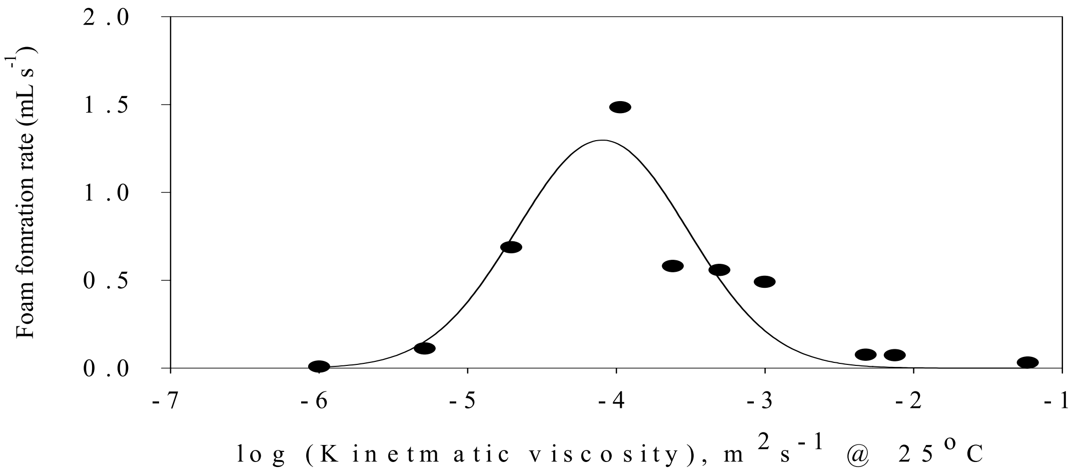
Foaming of Whiskey



Davidson, J.A. J. Colloid Interface Sci, 1981, 81(2), 541.

Effect of PDMS Viscosity on Foaming



At low molecular weight (<250) the polymer is too soluble in the ester to be surface active.

At intermediate molecular weights (*ca*. 6000) the polymer is less soluble and is surface active and is a profoamer.

At higher molecular weights (>60,000) the polymer is insoluble but spreads on the bubble surface and acts as a foam inhibitor.

Centers, *Tribology Trans.*, **1993**, *36*(3), 381.

Three Phase Foams

•Foams can also contain powders. A solid with a finite (receding) contact angle will sit at the air/liquid surface. It will move with the bubble - hence flotation. "Collectors" are added to dispersions to dewet particles.

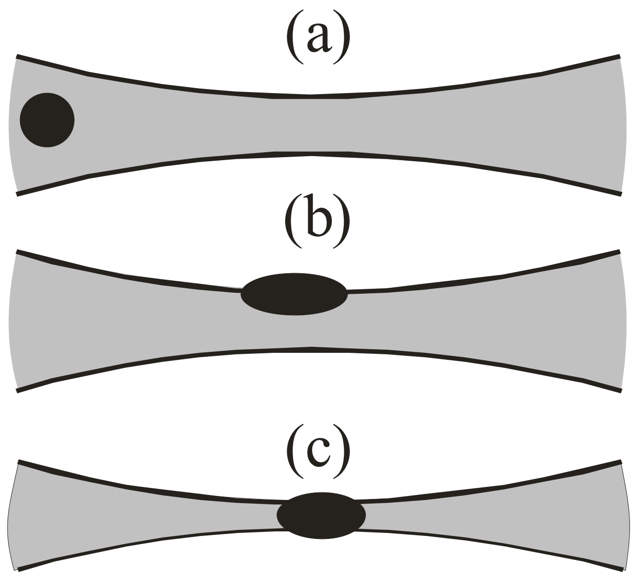
•Particle may stabilize thin films it they have low contact angles, holding the two interfaces apart.

•The finer the particles, the better the stability; lead, silica, ferric oxide are examples.

Foam Inhibition and Breaking

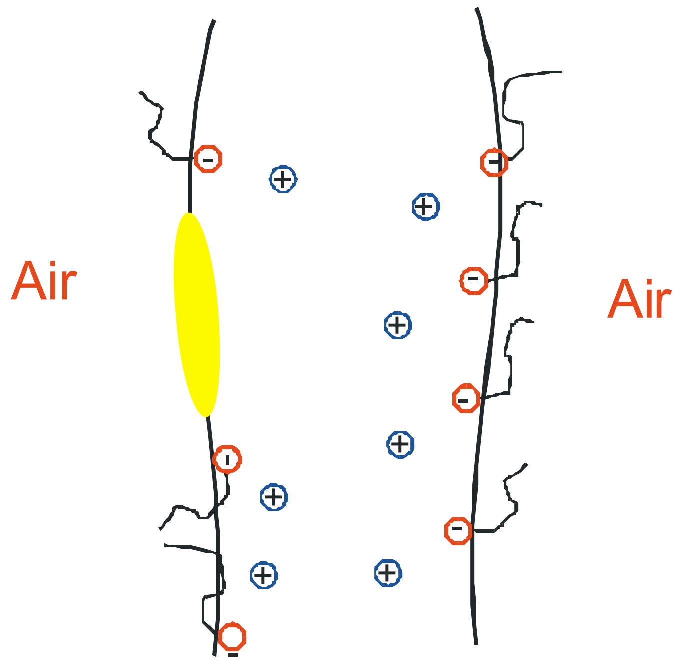
- **Differentiate:** Foam inhibition and foam breaking.
- **Foam inhibitors** - added before foam forms, displace foaming agents, or solubilizing the foaming agents (in micelles)
- **Foam breaking** - mechanical, shock waves, compression waves, ultrasonics, rotating discs, heating, an electrical spark.
- **Antifoams** - added to existing foams, in the form of small droplets, which spread on the lamellae, thinning and breaking it.
- **Antifoams for lubricating oils** - poly(hexadecyl methacrylate) plus glycerol monoricinoleate, potassium oleate, nitro-substituted aliphatic alcohols, metal salts of copolymers of styrene and maleic anhydride. (Bikerman)

Antifoams



(a) Antifoam drop
(b) Entering the surface
(c) Leading to rupture of the film.

Antifoams



With an antifoam on one surface, electrostatic stabilization is lost.

Foams in Industry

Marshmellow - foam formed from egg white, gelatin, and sugar.

Ice cream - refrigerated and aerated at the same time. Ice crystals and fat crystals form the matrix.

Dynamic foams: cakes, sponges, bead, meringes, soufflés. Bubbles change at various stages of preparation.

Foams on drying or stripping, especially in distillation columns. A foam blanket at the surface acts as an insulating layer - causing overheating.

Metallic slags foam probably because of the high viscosity. Cooling stabilizes the foam.

Paper making - Caused by lignin, resin, and fatty acids in wood, sulfate soaps from pitch. Also, sizing materials, dyes, fillers, oxidized starch, proteins, etc act as profoamers.

Beer - foam should not affect taste, but it remains important. Too little, beer looks "flat". Sources of foam: entrained air in the pouring, in the pressurizing, and from dissolved carbon dioxide. Mostly stabilized by proteins. Protein-polysaccharide complexes are especially stabilizing.

Froth floation

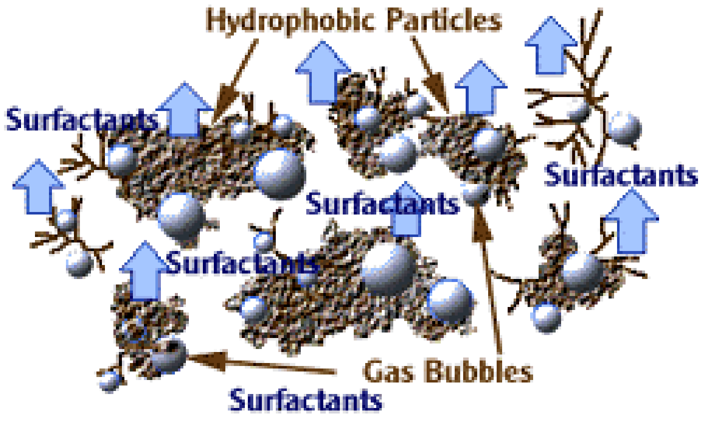


Figure 2. How does foam form?


Figure 1. Foaming in two Australian activated sludge plants. Plant on right is an oxidation ditch with foam covering the dividing wall.

From the “Activated Sludge Pages”
http://www.scitrav.com/wwater/asp/

Firefighting Foams

http://www.pacificresources.com/ff-fc.html?10744094=Fireclout.html

•Primarily for fire protection in petroleum storage. Airplane fires.

•Foam is made in a self-aspirating branchpipe: high pressure pushes the water + foaming agent down a pipe, aspirating air, foaming because of the turbulence (about 1mm bubbles) and is thrown from about 15 to 75 m.

•High expansion foams are formed by blowing through a net and laid down by coating.

•Reasons (1) Cools fuel below self-ignition temperature, (2) physically separates fuel and air, (3) dilutes oxygen supply

•Types: (1) Protein foam liquid - solution of hydrolysed protein, (2) liquid with various perfluorinated surfactants, (3) mixtures of perfluorinated surfactants with proteins

Briggs in Prud'homme and Khan, Chapter 12.

Foams to Immobilize

• To retard evaporation. Improve insulation.

• For fumigants(toxic to fungi), insecticides, contraceptives, to keep them in place.

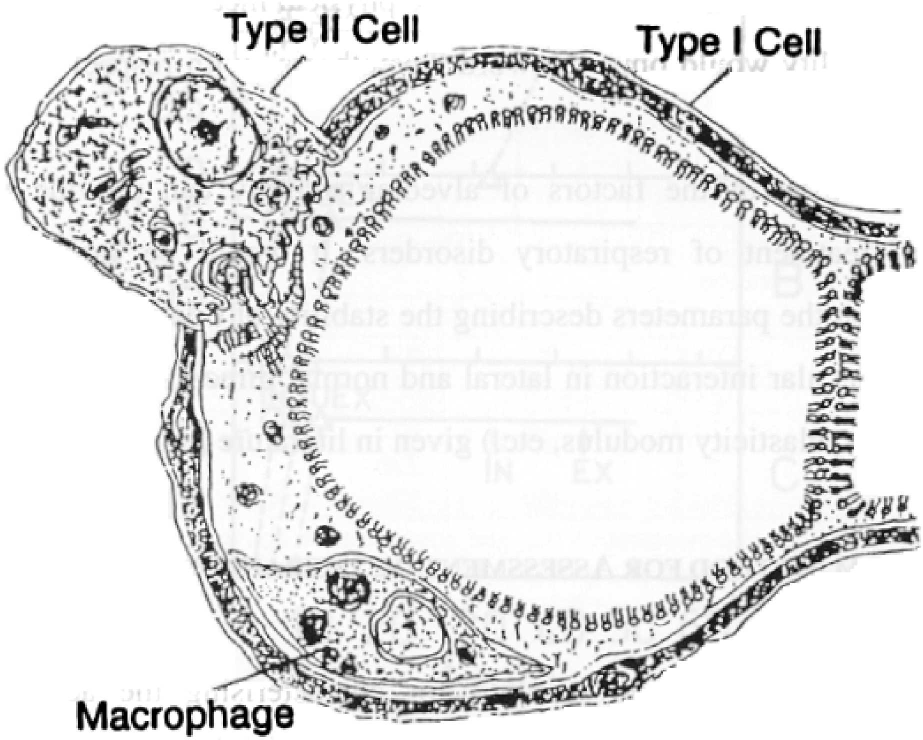
• Applying thin layers, such as adhesives or etching formulations, dyes or bleaches

• Capture of aerosols.

• Aqueous foam is an excellent suspending medium for paper fibers. Pseudoplasticity enables dispersion of long fibers. At low shear stress the fibers are "frozen" in position. Enables the use of long fibers which otherwise orient on coating.

•Shaving lather - no known use!

The alveolar surface in the lung



Exerowa and Kruglyakov, p. 753

Foam Technology

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