Experimental Methods in Interfacial Chemistry

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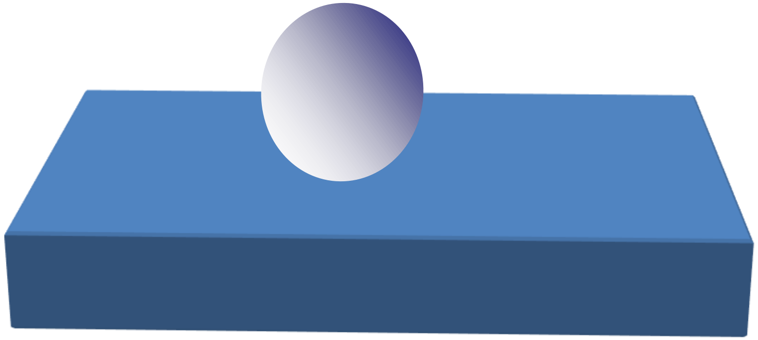
Outline

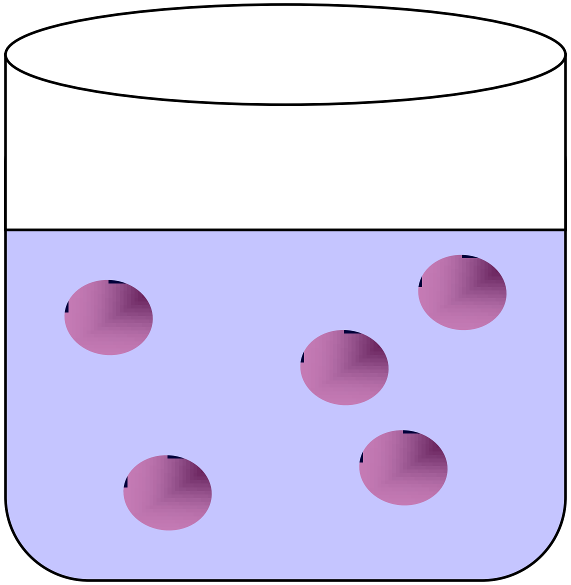
- ☞ Introduction to Interfaces
- ☞ Surface tension and CMC
- ☞ Self assembly - structure and dynamics
- ☞ Applications

Surfactants as Interface modifiers

Solid- liquid interface:

Cleaning of oil droplet on floor or clothes
Dispersion of particles in Paints and pigments

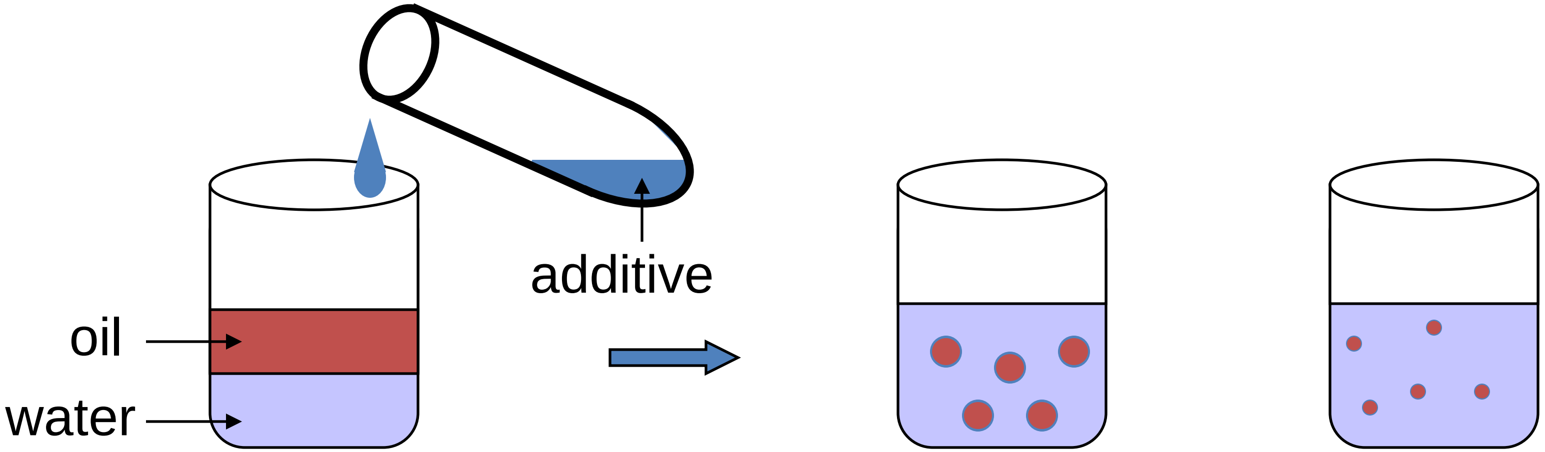




Interfaces

Liquid-liquid interface

Dispersion of one liquid in other



Emulsion
(unstable)

Microemulsion
(stable)

Liquid-vapour interface

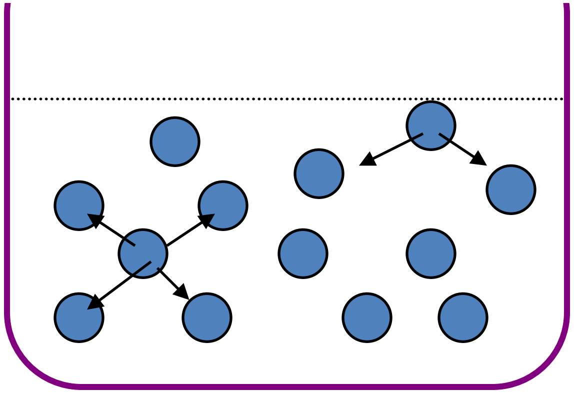
Bubbles and Foams,
In Froth floatation, shaving creams, ice cream, fire fighting etc.

Free energy of the interface

Surface / interfacial tension – Free energy per unit area of the interface

Molecules at the surface behave differently from that at the bulk

Lesser number of nearest neighbours at the interface - Interaction energy is different.



$n_b > n_s$

W_{11} – interaction energy of a pair

Energy per molecule is

For bulk, $E_b = n_b W_{11}/2$
For surface , $E_s = n_s W_{11}/2$

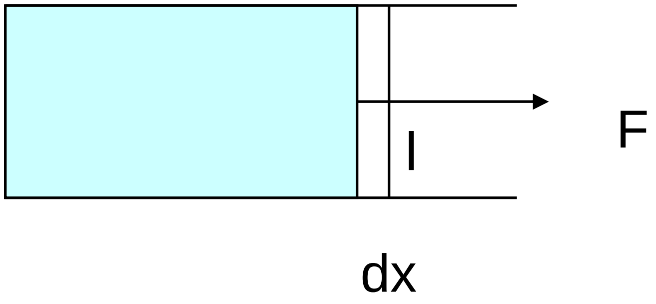
Energy and Force

Extra energy required to create a new surface of unit area,

$$\gamma = \frac{W_{11}(n_s - n_b)}{2a_0}$$

Energy/ area ; J/ m^2

Molecules at the surface are under tension due to inward pull



An opposite force is required to expand the liquid film

A 2-D analog of P-V work

Force/ length.; N/m

Surface tension and its consequences

Pressure across a curved surface is different

Surface tension tends to decrease the surface area and is counter balanced by a change in pressure

For sphere of radius r, changes in surface area and volume for a small change in radius (dr) is given by

$$dA = 8\pi r dr \qquad dV = 4\pi r^2 dr$$

Change in surface energy $= \gamma 8\pi r \, dr$

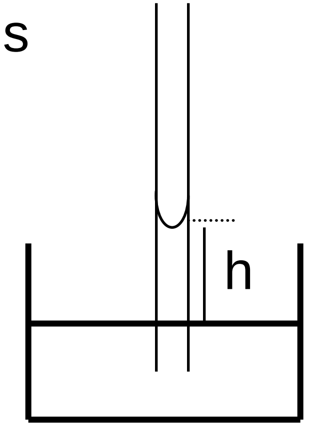
Pressure-volume work $= 4\pi r^2 dr \Delta P$

$$\Delta P = \frac{2\gamma}{r}$$

Laplace equation

Measuring surface tension – Capillary Rise

Changes in pressure across a curved surface leads to capillarity

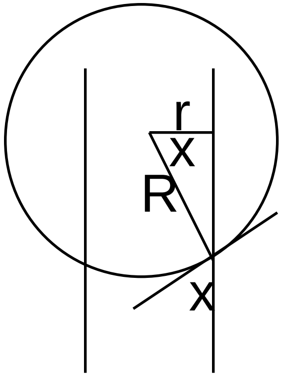


Height h , radius r, contact angle q

Capillary pressure balanced by hydrostatic pressure

$$\frac{2\gamma\cos\theta}{r} = h\rho g$$

$$\gamma = \frac{hrg\rho}{2\cos\theta}$$

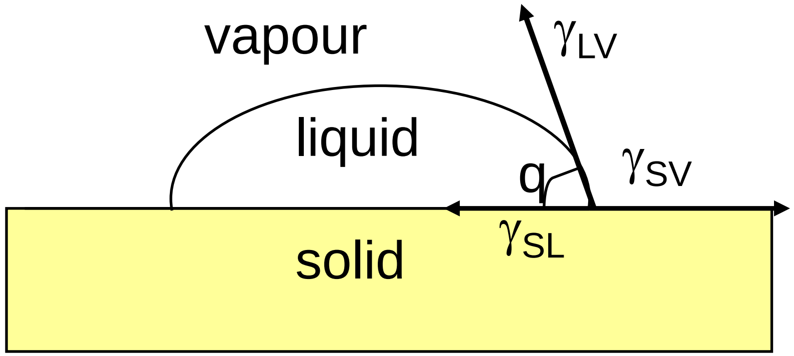


R.cos x = r

Flow of liquid in a capillary can be tuned by g

Solid-Liquid interface by Contact Angle

Shapes of liquid drop on solid



At equilibrium

$$\gamma_{SV} = \gamma_{SL} + \gamma_{LV}\cos\theta$$

Young equation

For spreading $\gamma_{SV} \geq \gamma_{SL} + \gamma_{LV}$

Spreading coefficient, $S = \gamma_{SV} - \gamma_{SL} + \gamma_{LV}$

$S \geq 0$ spreading

$S < 0$ droplets

Contact angle and wetting can be tuned by g

Surface tension by Ring method

How to characterize the surface activity and aggregation?

1.By measuring surface tension

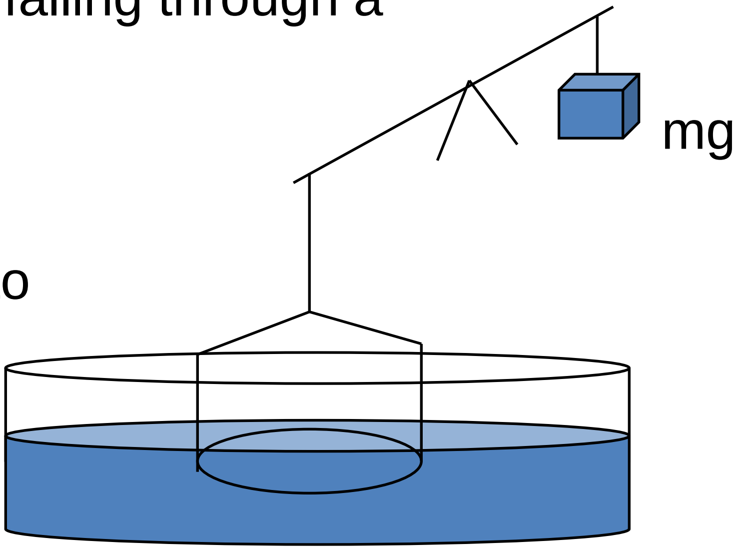
Drop weight (volume) method $mg = 2\pi r\gamma$

Measure the weight of a drop of liquid falling through a capillary tube

2. DuNuoy ring method

Measure the force or weight required to detach a ring from the surface

$$F = mg = 4\pi r\gamma\cos\theta$$



Measuring surface tension

Courtesy: Kruss, GmbH

Measuring surface tension

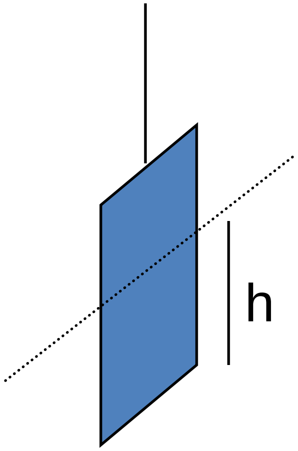
Wilhelmy plate method – can measure the contact angle if g is known

Length l, thickness b and immersion height h

$2(l+b)\gamma\cos\theta$ = F – correction due to buoyancy

$$= F - [lbh\rho_s g - lbh(\rho_s - \rho_l)g]$$

weight in air   weight in liquid

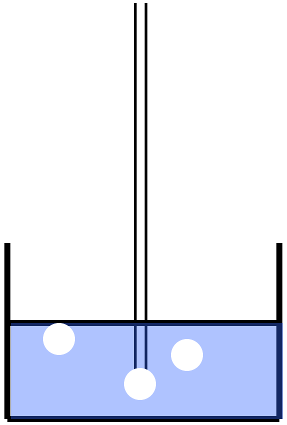


$$= F - lbh\rho_l g$$

Can measure contact angle
(advancing and receding)

Dynamic surface tension

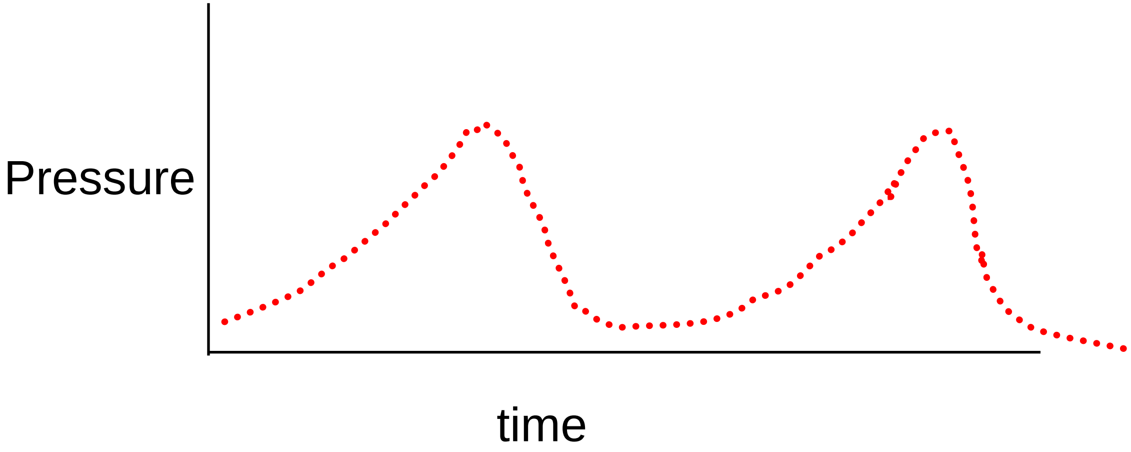
Bubble pressure method



Using Laplace equation
Change bubble frequency (period ~ ms to secs)

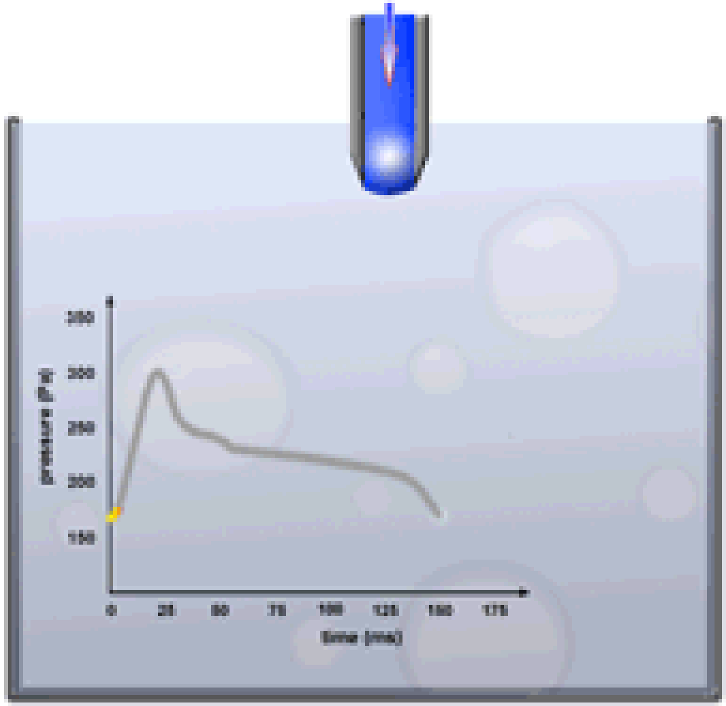
$$\gamma = \frac{(p_{\max} - p_0)r}{2}$$

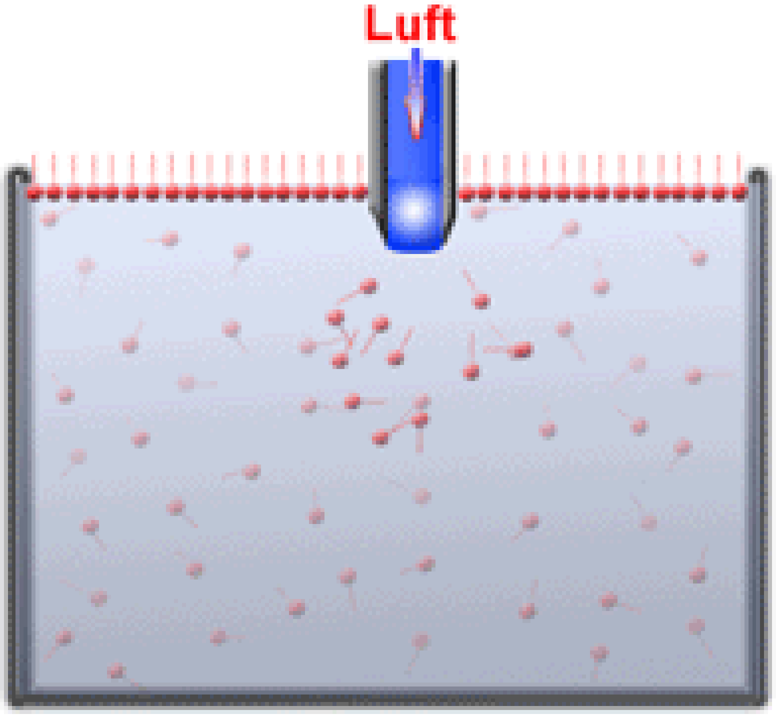
$$p_0 = \Delta\rho h g$$



A measure of diffusion of surfactant molecules to the interface

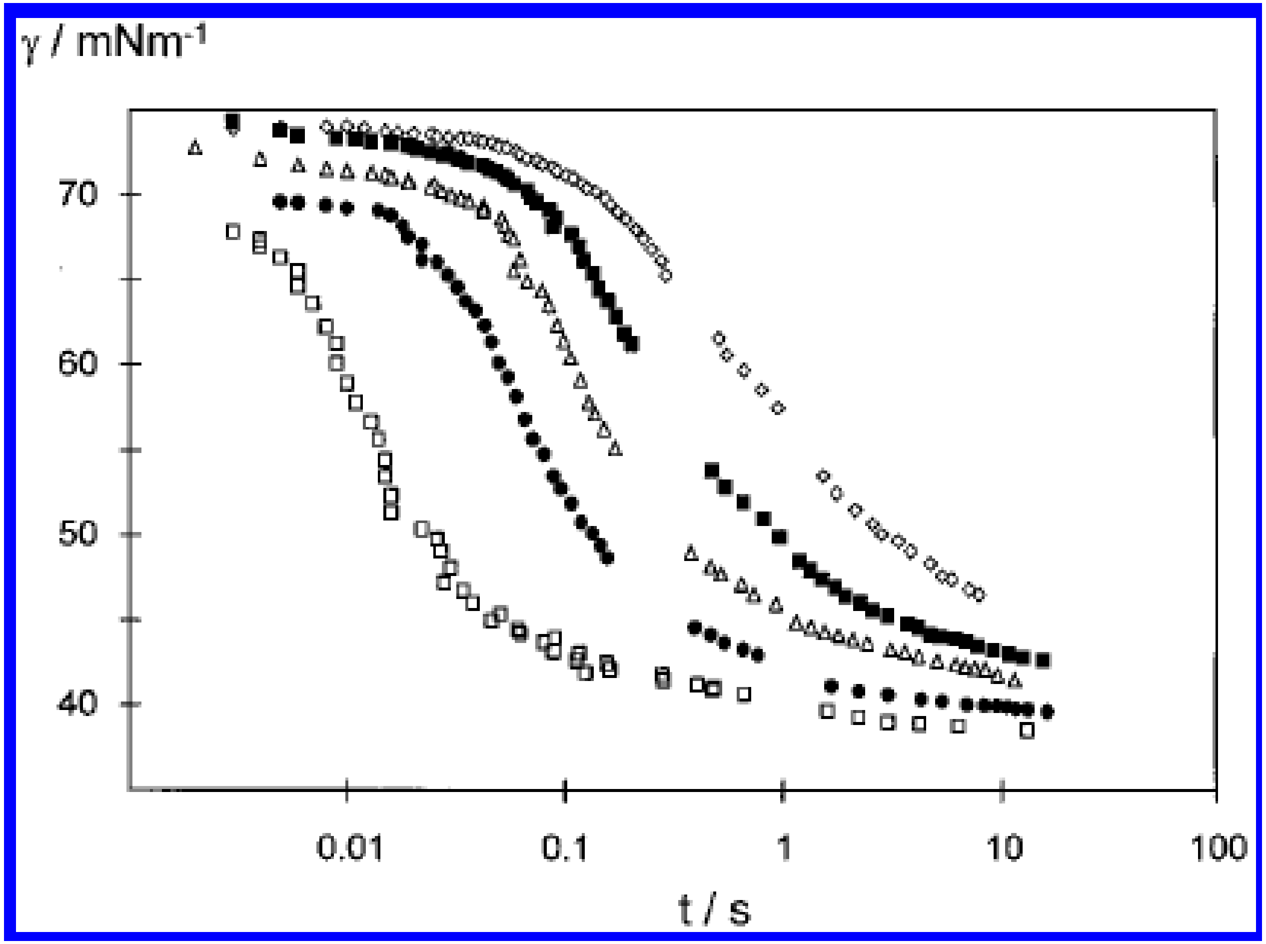
Bubble Pressure method





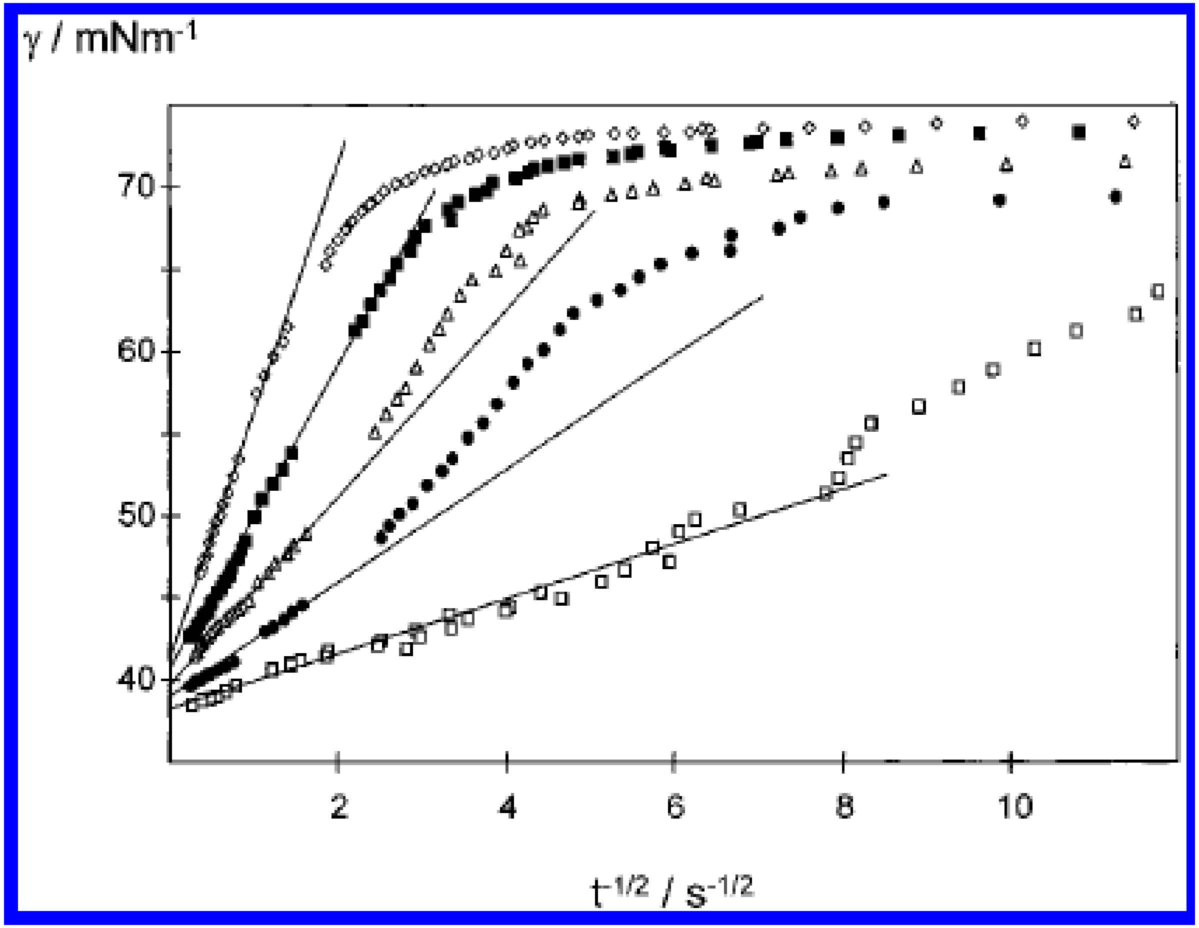
Courtesy: Kruss, GmbH

Dynamic surface tension

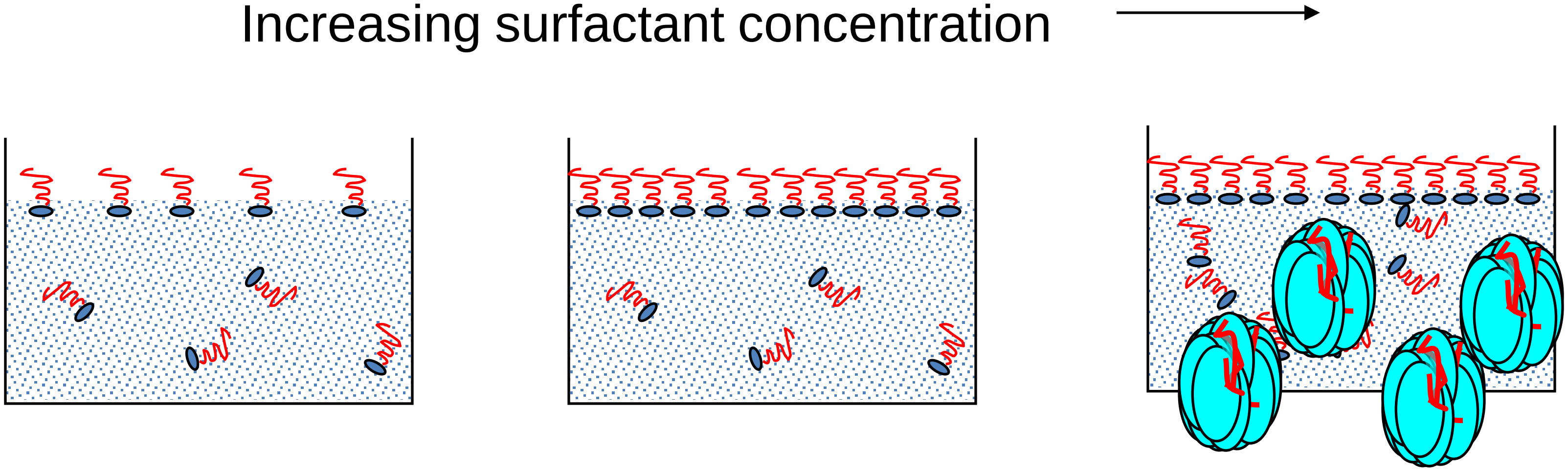


Langmuir **1998**, *14*, 979−981

$$\gamma(t)_{t\to\infty} = \gamma_{\text{eq}} + \frac{RT\Gamma^2}{2c}\left(\frac{\pi}{Dt}\right)^{1/2}$$



Surface activity and aggregation

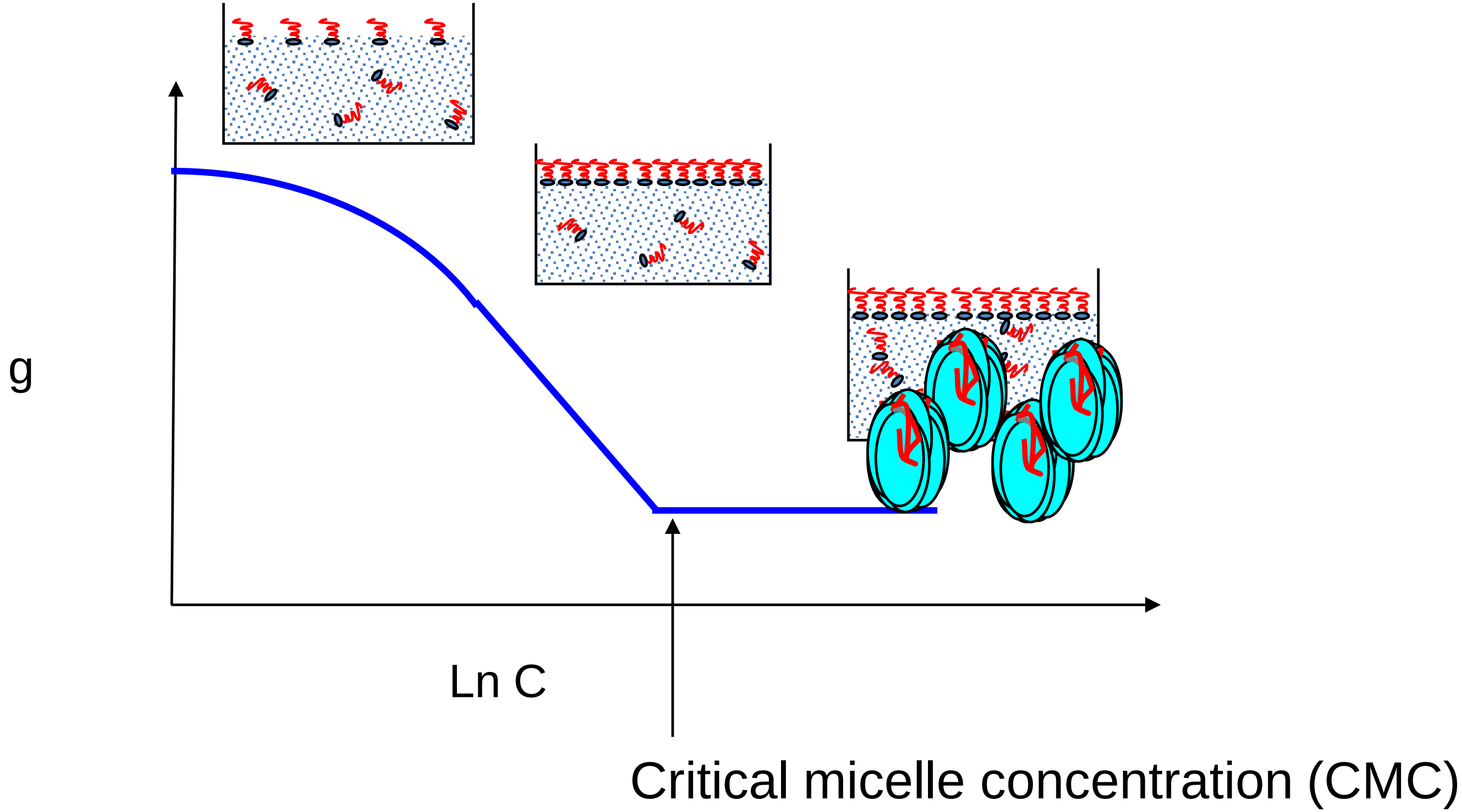


- Tries to orient in such a way to evade water from the hydrophobic part
- Hydrophobic effect – leads to surface adsorption and aggregation

- Since it sits on the surface/interface, it can change the surface tension! Useful to adjust capillarity and contact angle

- It can also change the charge on the surface – if ionic head group is used Useful to prevent aggregation as like charges repel each other

Variation of surface tension with concentration



Gibbs equation

Gibbs equation predicts the variation of g with C using surface thermodynamics for adsorption

At equilibrium DG = 0

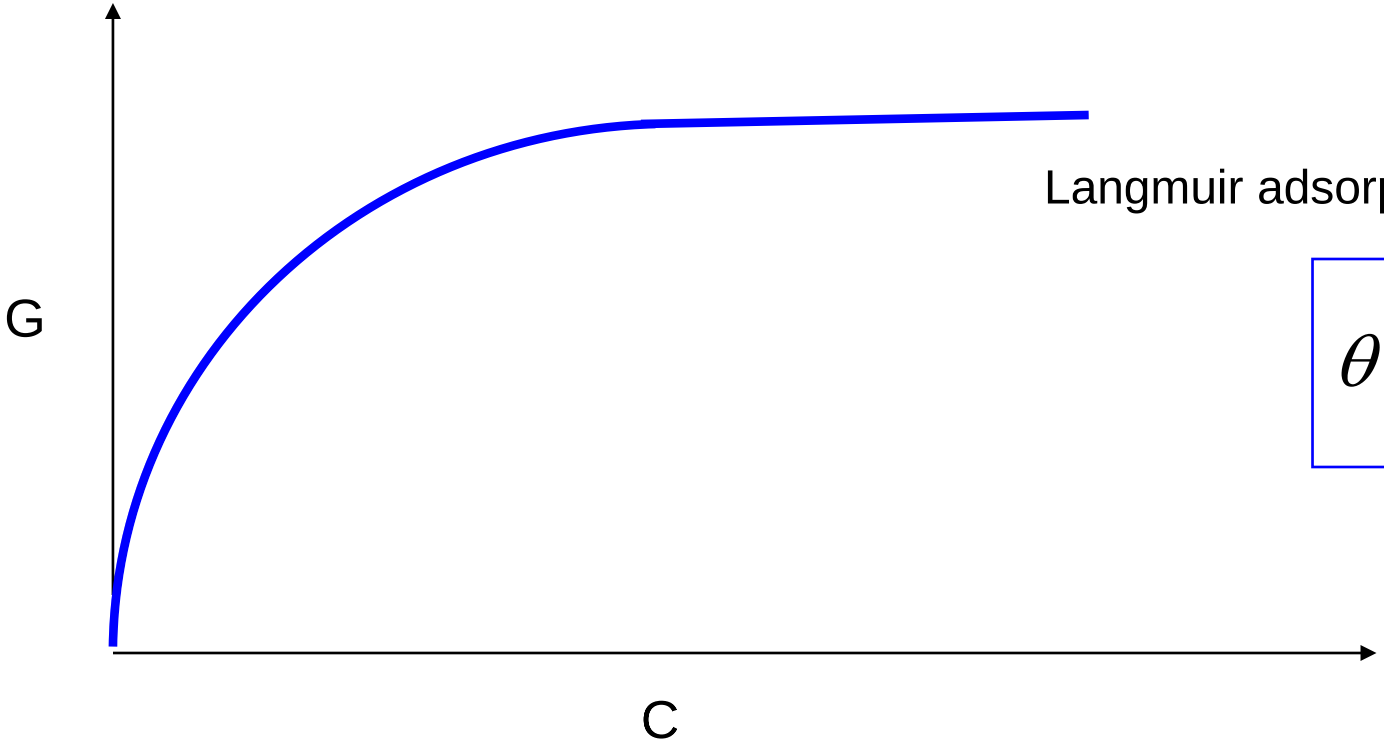
$$A d\gamma + \sum_i n_i d\mu_i = 0$$

$$\Gamma_i = -\frac{1}{RT}\left(\frac{d\gamma}{d\ln c}\right)$$

- Surface tension decreases with surfactant concentration
- Above CMC, the chemical potential of the surfactant scarcely change.
- Thus S.T. vs. ln C plot shows a break at CMC
- Surface saturation occurs much below CMC (see Gibbs equation)
- Huge change in surface area required to bring about change in CMC.

Surface excess concentration

Gibbs equation permits calculation of surface concentration from surface tension measurements

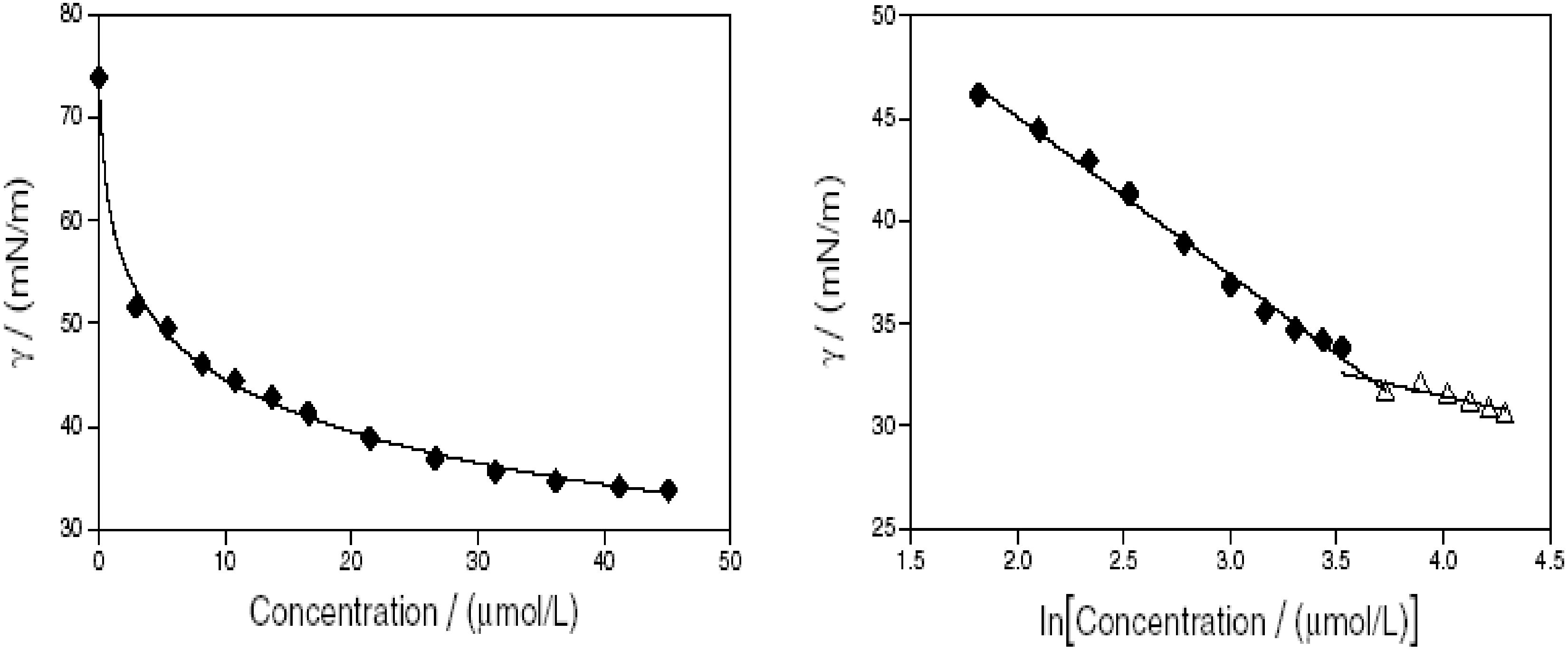


Langmuir adsorption isotherm

$$\boxed{\theta = \frac{Kc}{(1+Kc)}}$$

$$\theta = \frac{\Gamma}{\Gamma_{\max}}$$

K and area per molecule can be calculated



J. Chem.Ed. 85, 269 (2008)

CMC of Mixed micelles

CMC – To measure interaction parameter

The interaction of two surfactant in a mixture can be expressed in terms of b

$$\beta = \frac{\left(w_{11} + w_{22} - 2w_{12}\right)}{kT}$$

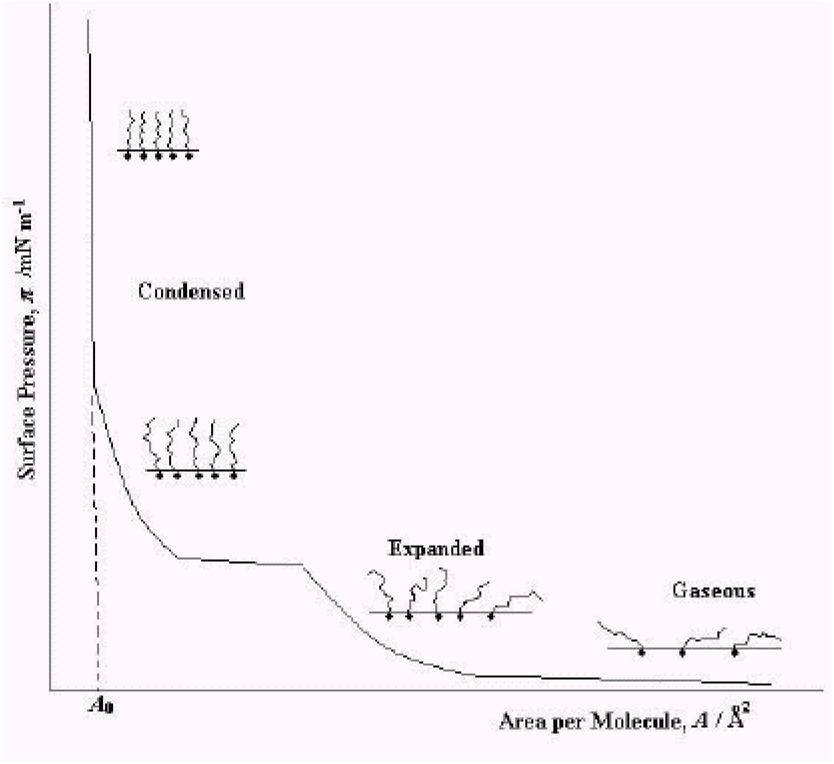
b –ve : attractive interaction(synergism)
b +ve : repulsive interaction(antagonism)

$$\frac{1}{CMC^*} = \sum_i \frac{\alpha_i}{CMC_i}$$ Ideal mixing

Monolayers at interface

A 2-D analog of P-V isotherm

Pressure, P is related to no. of molecules/unit volume
Analogously surface pressure p is related to number/ unit area $\pi = \gamma_0 - \gamma$

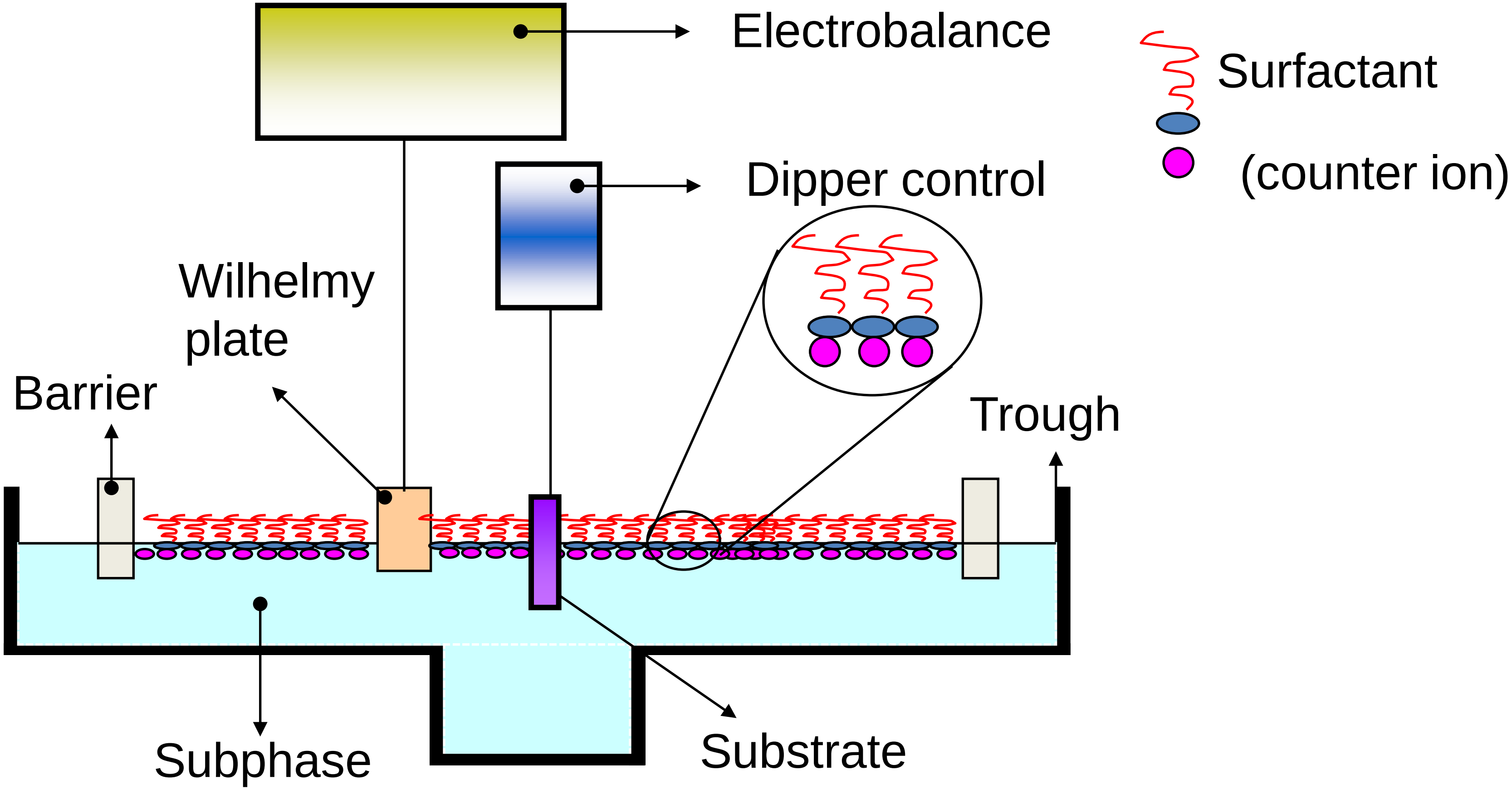


Discontinuity in the gradient indicates a phase transition

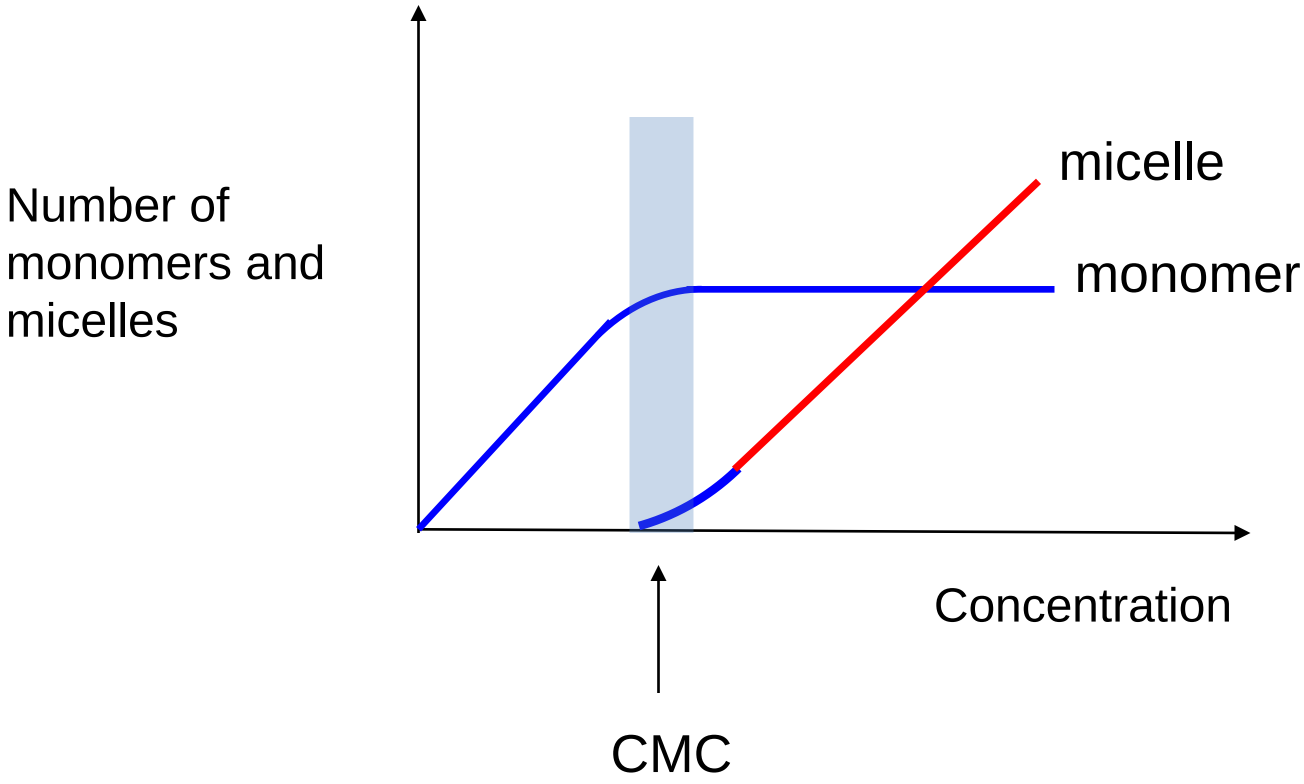
Langmuir-Blodgett apparatus for measuring p-A isotherm

In the solid film the limiting area = cross section area of headgroup

Schematic of LB technique



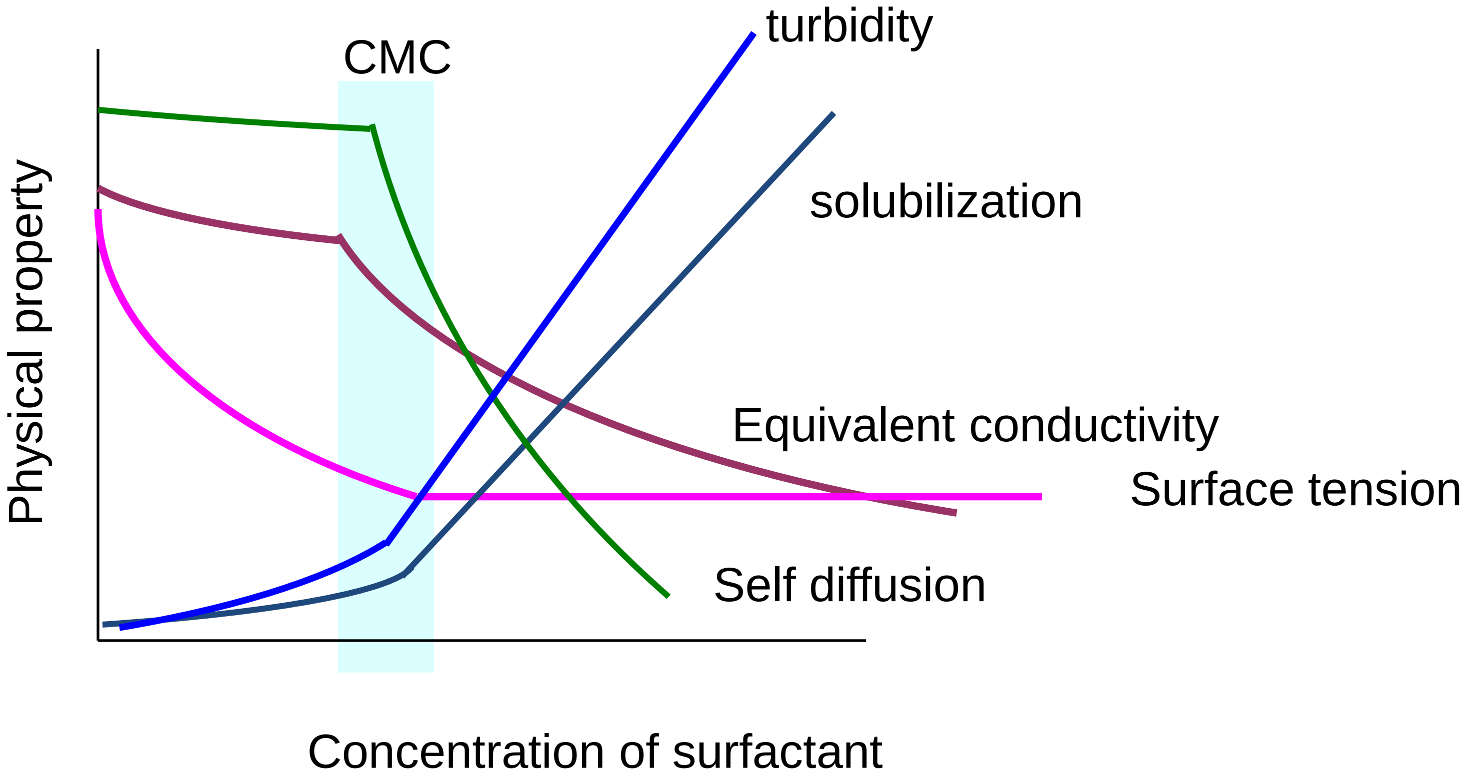
Surfactants as monomers and micelles



CMC

Above a critical concentration, (CMC or CAC) self assembly occurs

Self assembly is associated with a change in physical properties



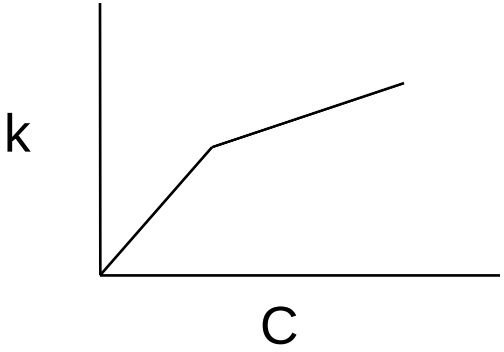
Other methods of determining CMC

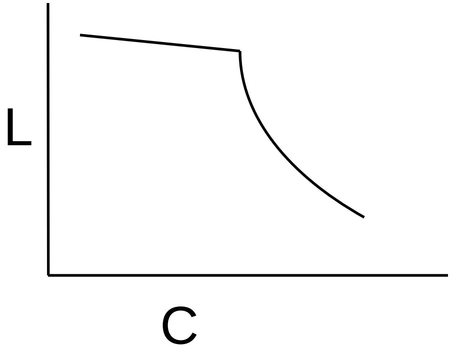
2. Conductivity of ionic micelles

Resistance R = (1/k).L/A L= length, A= area

K = sp. Conductance ; $\text{ohm}^{-1}\ \text{cm}^{-1}$ Conductance of 1 cc of solution

Equivalent conductance is the conductance of one eq. wt. of the electrolyte. L = k.1000/C





The degree of dissociation is low above CMC: hence slope changes

Useful for ionic surfactants

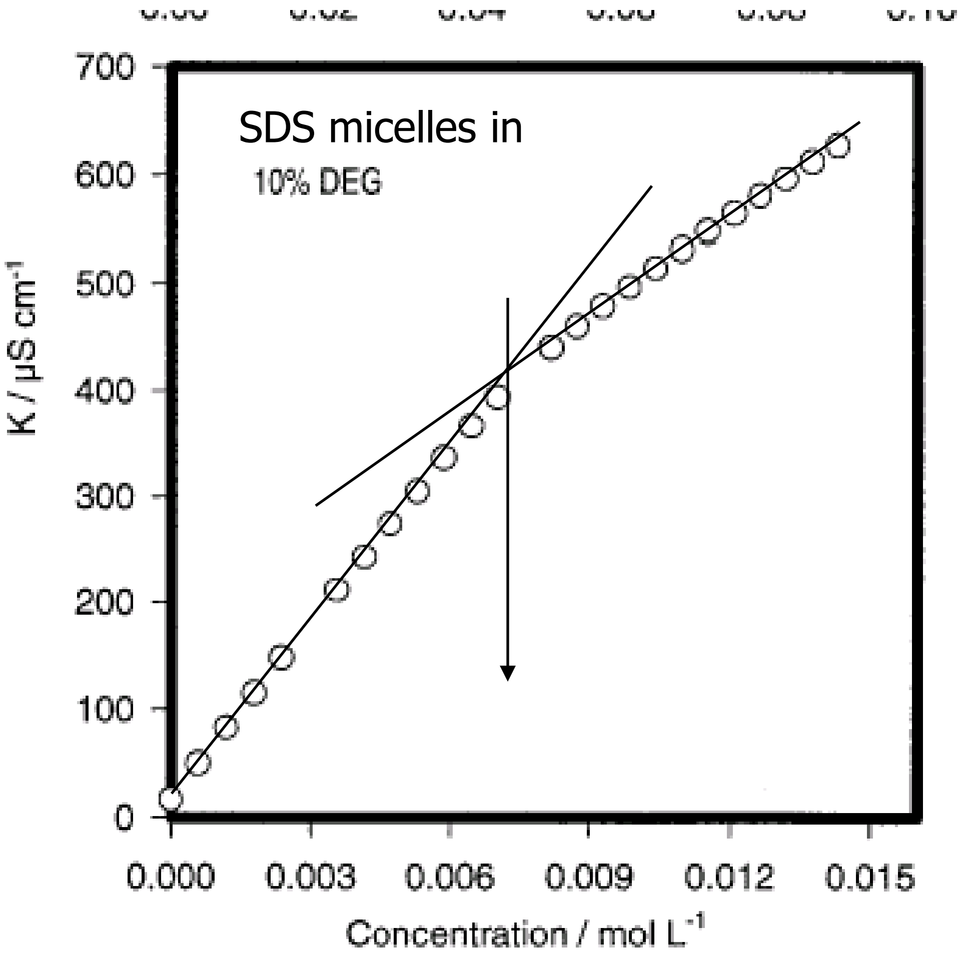


FIG. 1. Specific conductance (K) vs concentration of SDS in aqueous mixtures of DEG at 298 K.

Counter ion binding can also be obtained

CMC by spectral change method

l_{max} at different environments

Either the surfactant or an external indicator is used
Eg: pinacyanol; rhodamine- 6G

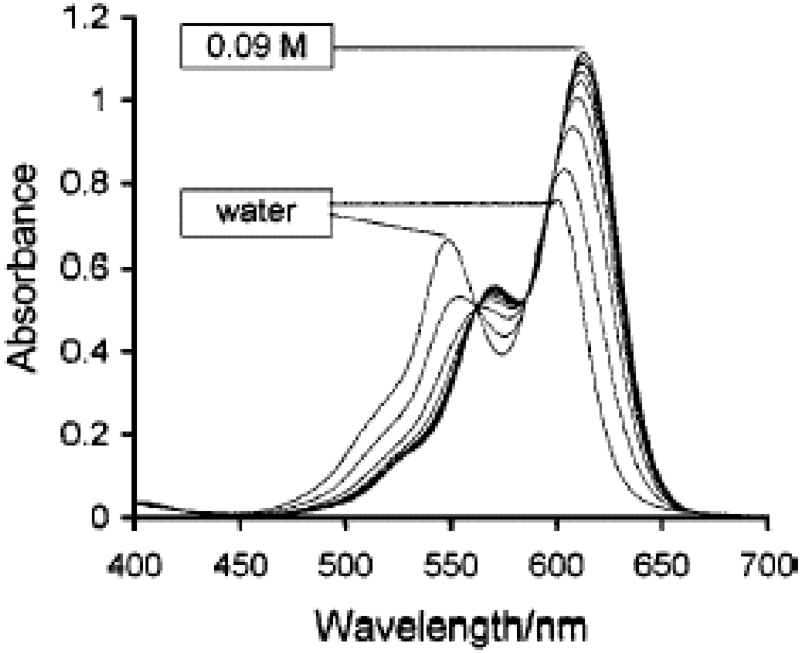


FIG. 3. Visible absorption spectrum of 10^{-5} M PIN in several concentra-ions of TTAB (from 10^{-2} to 9.0×10^{-2} M) at pH 5.5 and 25°C.

l_{max} – solvent dielectric constant dependant

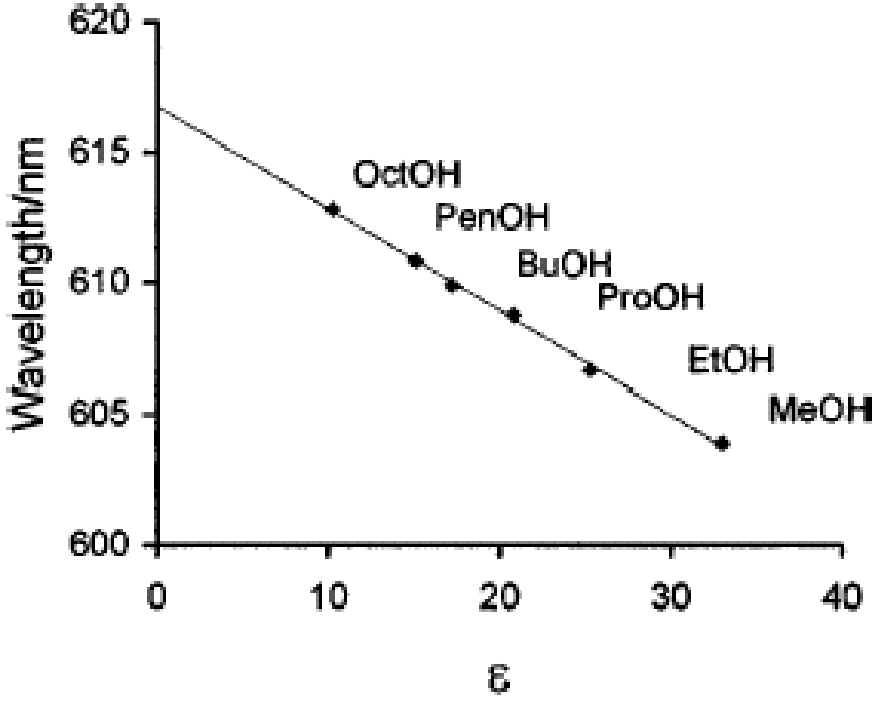


FIG. 4. λ_{max} values for the monomeric band of PIN in a series of *n*-alcohols (methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol, and 1-octanol) as a function of the dielectric constants of the media at 25°C as taken from (26).

Dimer to monomer conversion

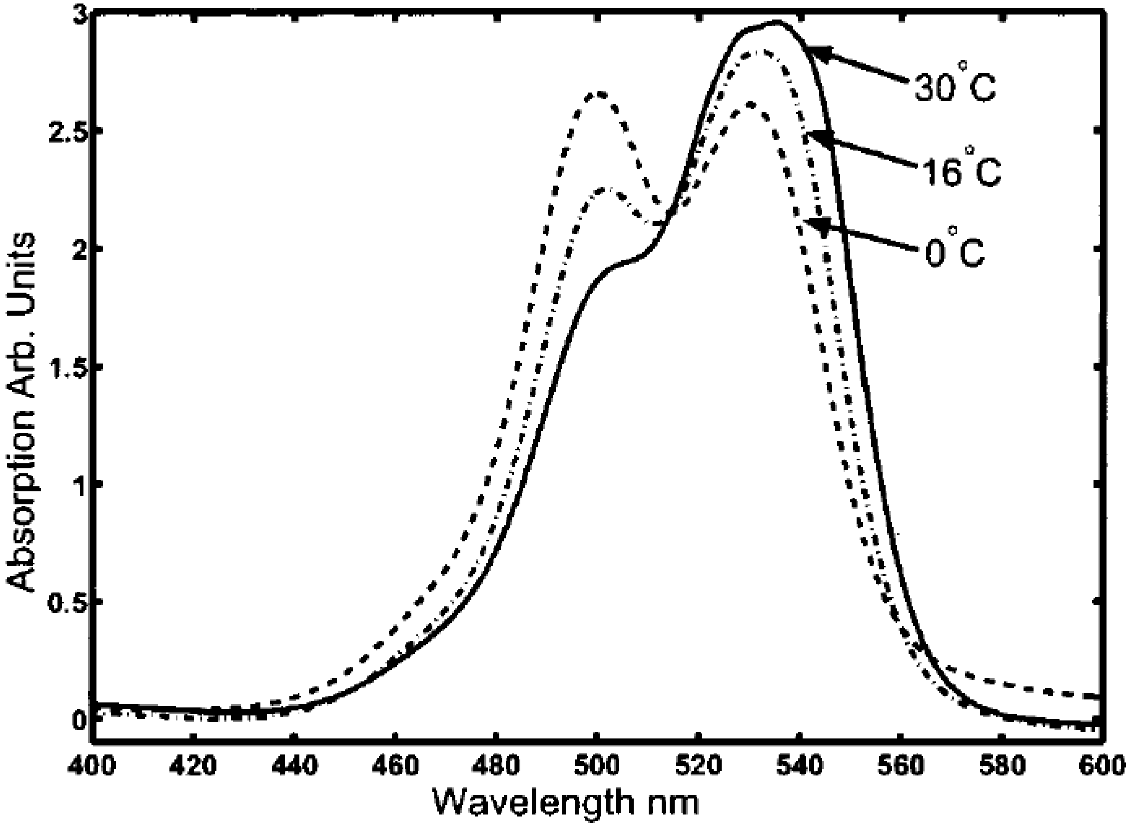
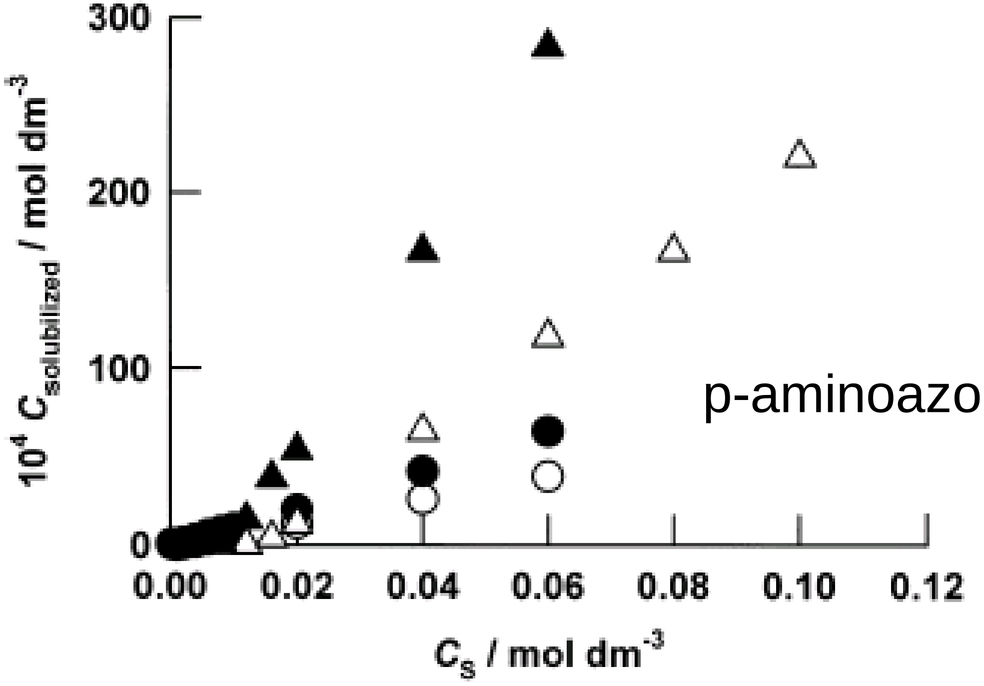


Figure 1. Absorption spectra at 0, 16 and 30 °C measured for a 5 wt % aqueous solution of P123 containing 1×10^{-3} mol/L R6G. The spectrum exhibits two peaks corresponding to the monomer and dimers of R6G in the solution.

CMC by dye solubilization

A suitable insoluble dye is used.   Conc. determined by absorption
Eg: Orange- OT, azobenzene etc.



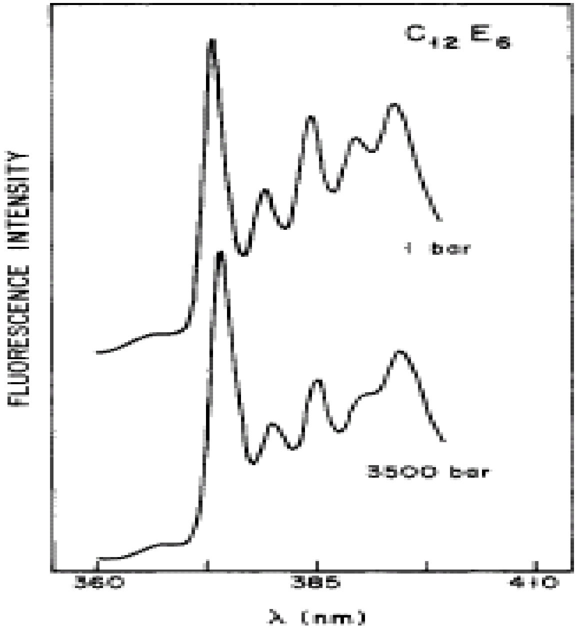
p-aminoazobenzene

Fig. 5. Dependence of amounts of dye solubilized, $C_{solubilized}$, on the surfactant concentration, C_S, for 4-PAA at 298 K: ○, DC3-12; ●, DC6-12; △, C12C1NBr; ▲, C12C2NBr.

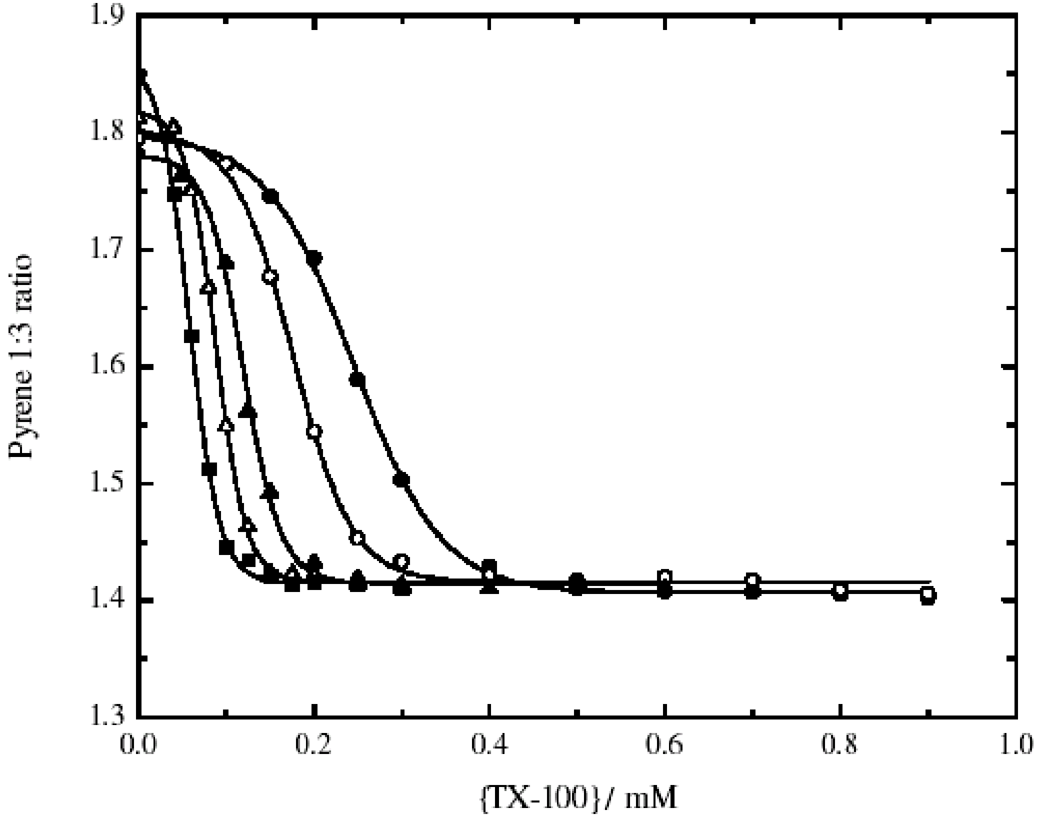
CMC by Fluorescence

Pyrene is a suitable fluorescent probe for identifying the microenvironment Excitation at 335 nm produces five vibronic peaks in fluorescence.

The ratio of $I_{1\ (372)} / I_{3(383)}$ is a measure of local polarity



In water, ~1.6 , in micelle ~ 1.1; Can show excimer emission due to increased local conc.



1. Pyrene 1:3 ratio versus total concentration of surfactant in water (●) and in solutions with different KCl concentrations at 25.0 °C: ○, 0.5 M; ▲, 1.0 M; △, 1.5 M; and ■, 2.0 M.

Thermodynamics of micellization from CMC

The standard Gibbs free energy change of formation of micelles

$$\Delta G_{mic} = -RT \ln K$$

$$\mathrm{N\,[S]} \rightleftharpoons \mathrm{S_N}$$

Per surfactant

$$\Delta G_{mic} = -\frac{RT}{N} \ln X_N + RT \ln X_1$$

Since N is high the first term is negligible

At CMC , X_1 = Xcmc

$$\Delta G_{mic} = RT \ln X_{cmc}$$

The enthalpy change can be obtained using Gibbs-Helmholtz equation

$$\left(\frac{\partial \Delta G / T}{\partial T} \right)_p = -\frac{\Delta H}{T^2}$$

$$\Delta H_m = -RT^2 \left(\frac{\partial \ln CMC}{\partial T} \right)_p$$

Isothermal titration calorimetry can also be used

Factors influencing CMC

- Nature of surfactant and length of chain

  CMC decreases with increase in chain length; Log(cmc) = a- b. c_n

  Branching and unsaturation increases CMC

  Fluorocarbons lower CMC

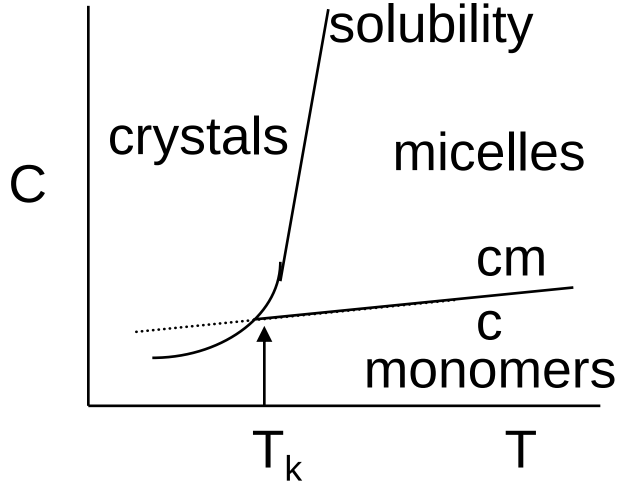
  Counterions, electrolytes, alcohols etc. decreases the CMC

Factors influencing aggregation

Temperature – Kraft point and Cloud point

Ionic surfactants precipitates out as hydrated crystals below Kraft point.

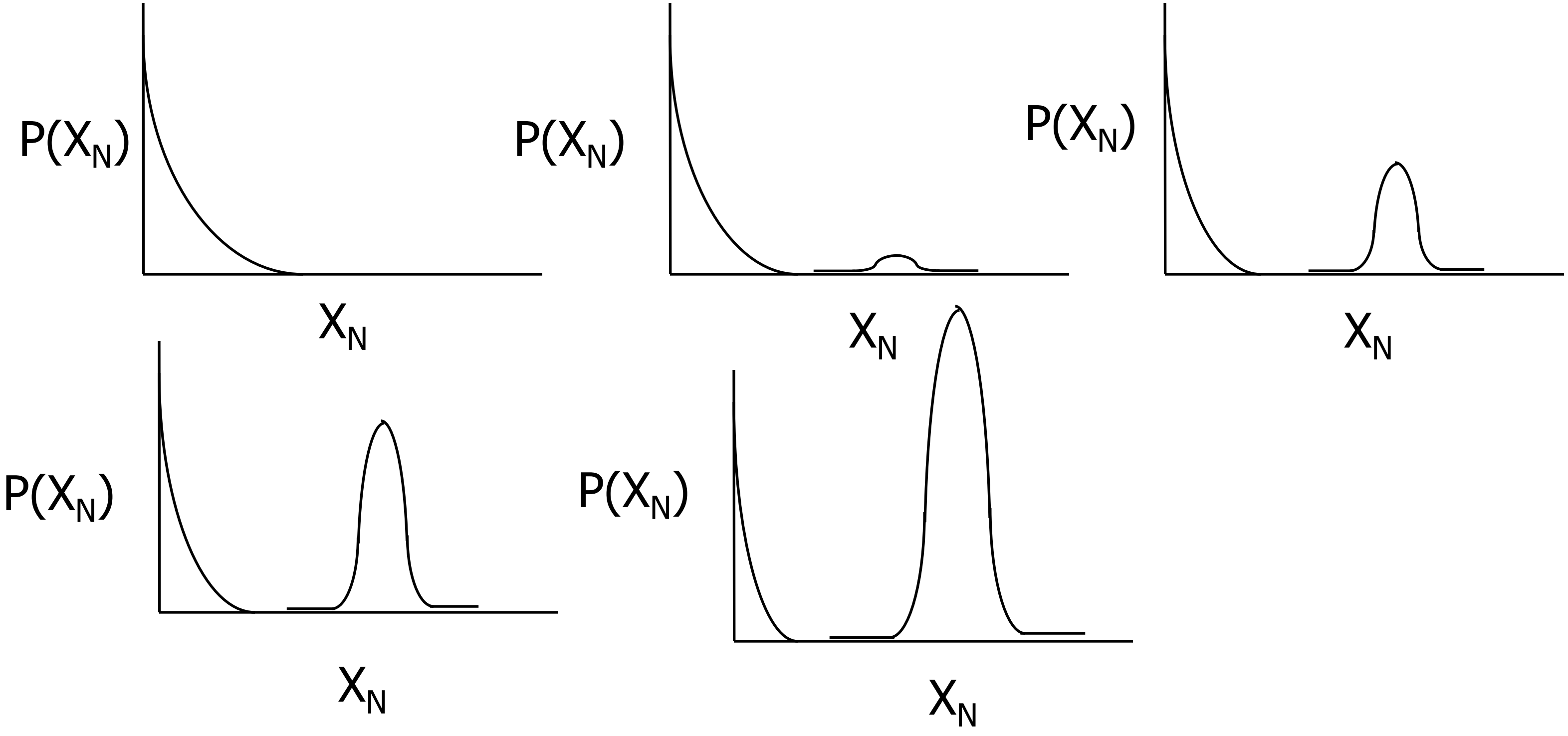
At Kraft point solubility= cmc



For nonionics, increasing the temperature causes clouding due to changes in the conformation and hydration of the oxyethylene groups as well as intermicellar interactions
Clouding is followed by phase separation
(critical phenomena)

Micelle formation

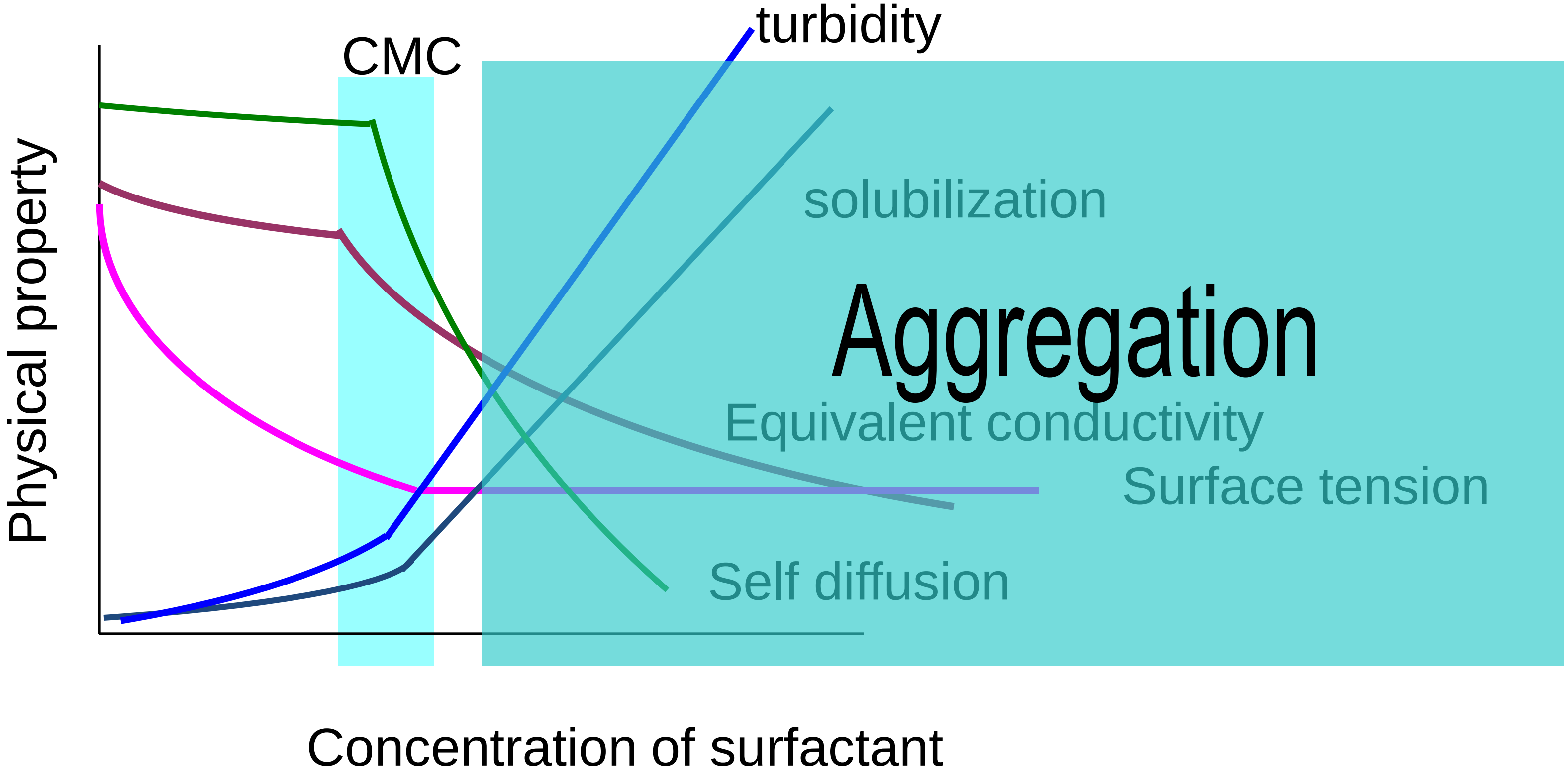
Size distribution of aggregates with increasing surfactant concentration →



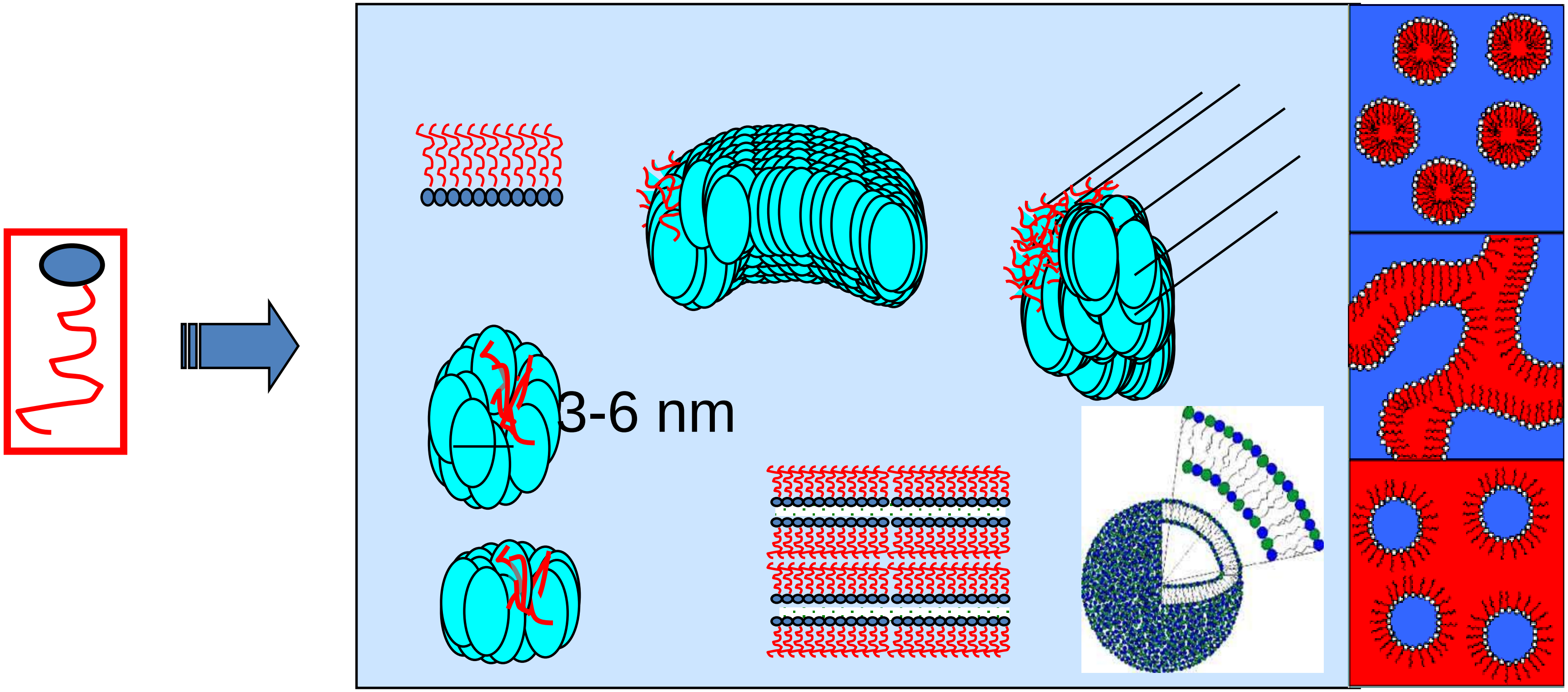
Self assembly beyond CMC

Above a critical concentration, (CMC or CAC) self assembly occurs

Self assembly is associated with a change in physical properties



Structure of aggregates



1 nm = 1 nano meter – 1/ 10,00,000 of a mm

Microstructure of aggregates

How to characterize the structure in the sub-micron range?
(size, shape, polydispersity etc)

1. Cryo - Electron microscopy (SEM/TEM)
2. Indirect imaging possible with AFM, STM etc
3. Scattering of radiation (light, X-rays, Neutrons)
(Similar to Crystal structure from X-ray diffraction)

4. Fluorescence quenching, Electrochemical methods, NMR

Fluorescence quenching method

A fluorophore(probe) and a quencher soluble in micelles is used
Eg:Ru(bpy)$_3^{2=}$ and 9-methyl anthracene

Intensity of fluorescence decreases with quencher concentration.

$I = I_0 e^{-[Q]/[M]}$ [M]= (c-CMC)/N Plot ln(I/I$_0$) vs [Q]

Assumptions:
Probe and quencher are totally soluble in micelles
Residence time of the probe is higher than the life time of fluorescence
Quenching rate is faster than the lifetime
Only one probe per micelle.

The distribution is decided by Poisson statistics $P(x) = \frac{e^{-\mu}\mu^x}{x!}$

[M] >> [Q]

Aggregation number

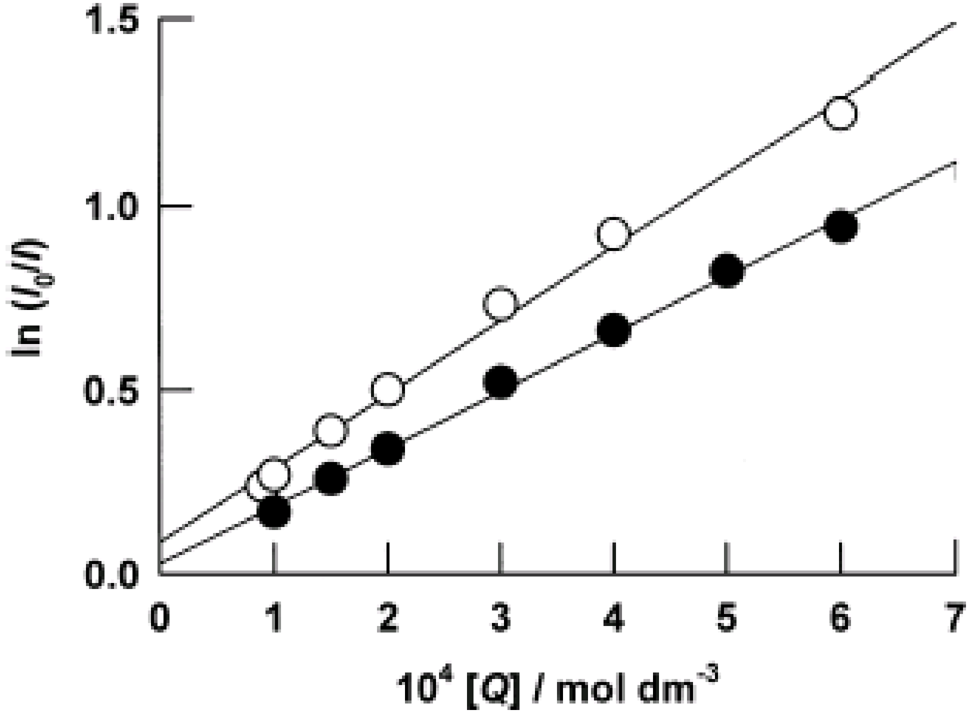


Fig. 6. Plots of $\ln(I_0/I)$ against $[Q]$ for the gemini surfactant micelles at 298 K: ○, DC3-12; ●, DC6-12.

$$\ln(I_0/I) = [Q]N/([C] - \mathrm{CMC})$$

Time resolved fluorescence

Steady state fluorescence does not work for large aggregation numbers.

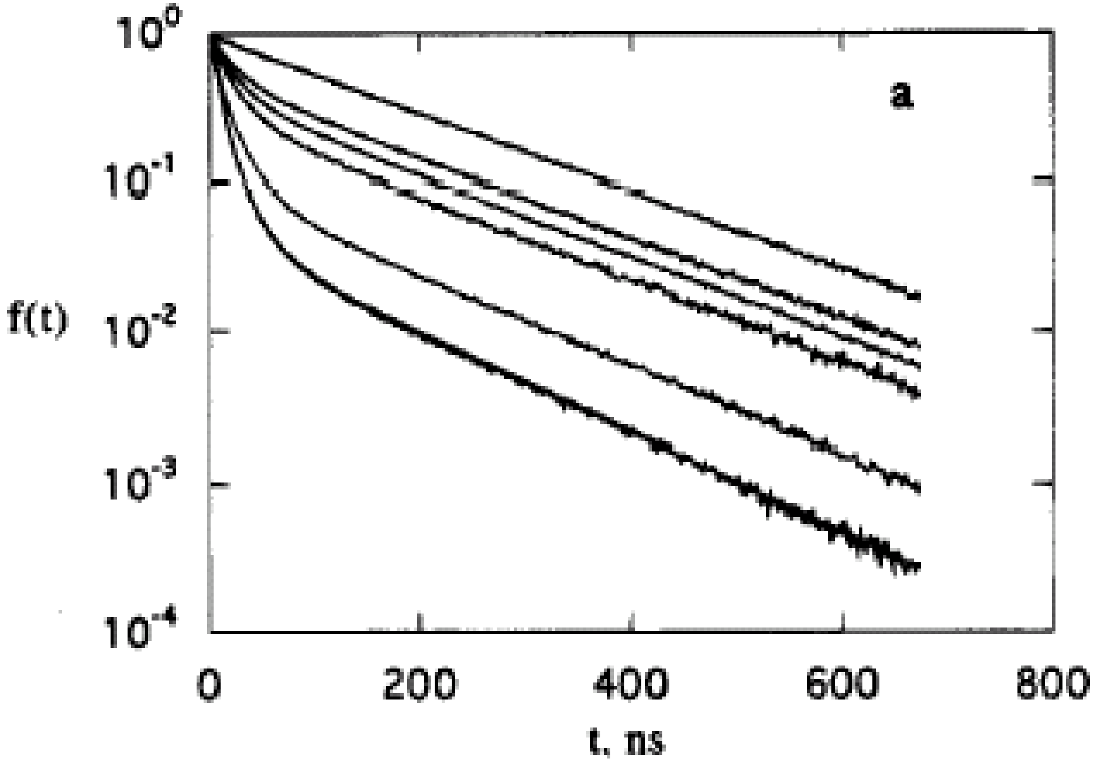
In the absence of quencher, $I(t) = I(0)e^{-t/\tau_0}$

In the presence of quencher $\ln\frac{I(t)}{I(0)} = \frac{-t}{\tau_0} + \overline{Q}[e^{-k_q t} - 1]$

A rough estimate can be obtained from the long time behavior

$$\ln\frac{I(t)}{I(0)} = \frac{-t}{\tau_0} - \overline{Q}$$

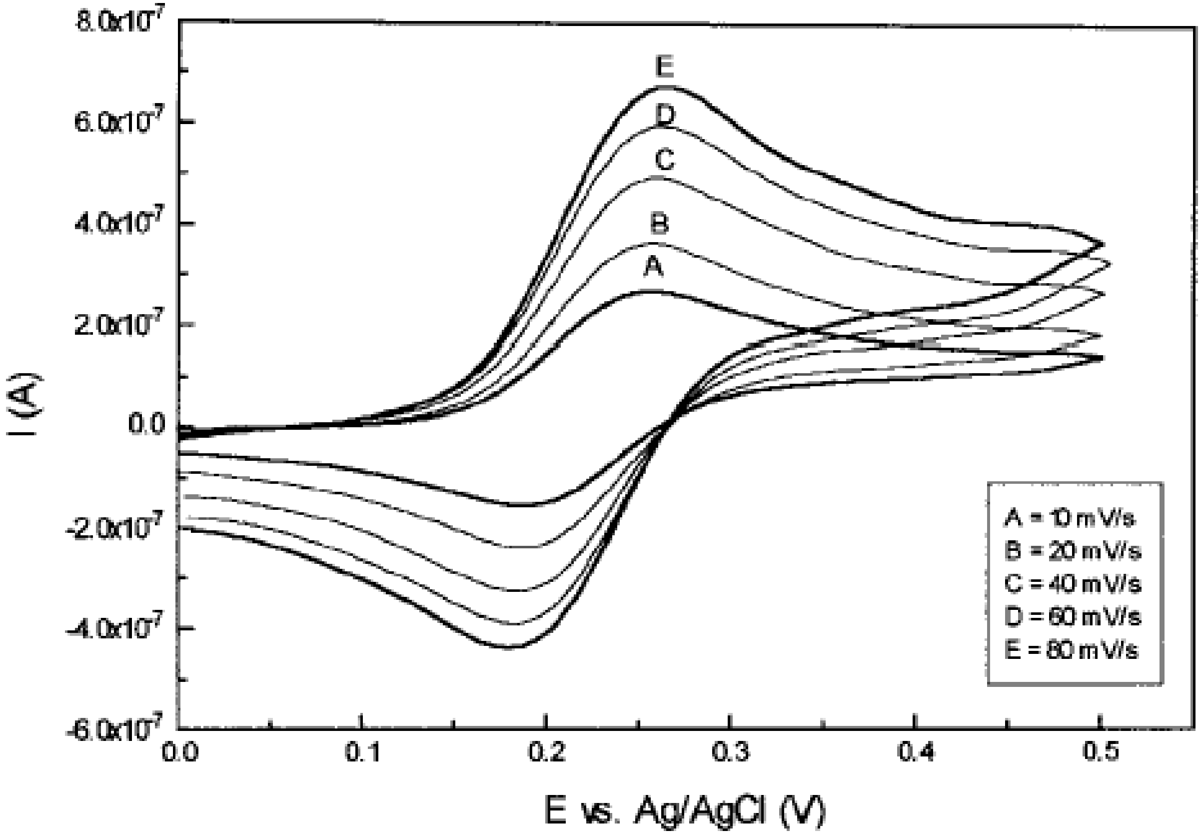
Time resolved fluorescence



Electrochemical methods

Solubilization of electroactive molecules (probes)

Ferrocene



Electrochemical methods

$$i_{pa} = 0.4463 FAC(F/RT)^{1/2} v^{1/2} D^{1/2}$$

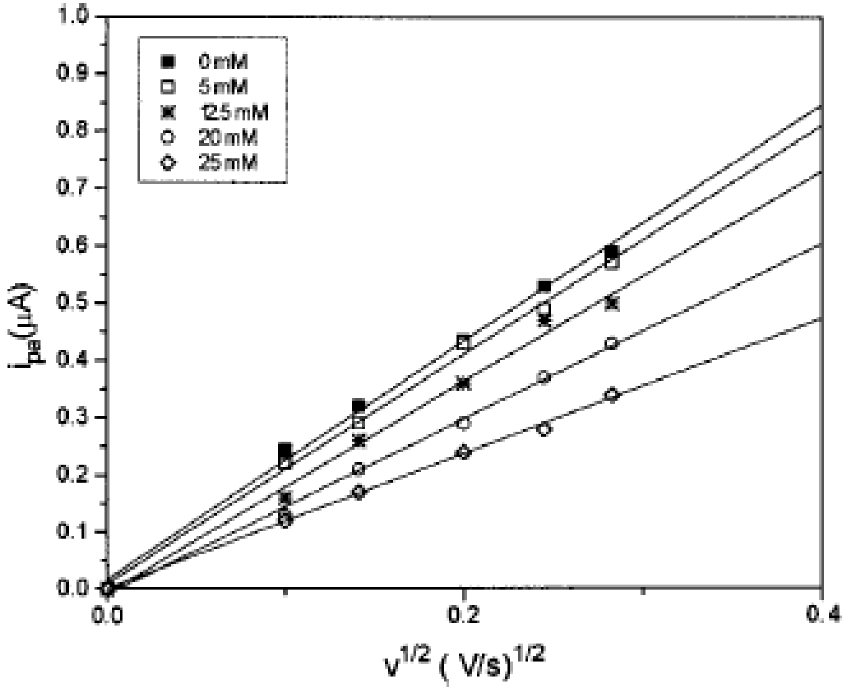


Figure 3. Plot of i_{pa} vs $v^{1/2}$ for ferrocene in aqueous CTAB solution in the absence and presence of various concentrations of SS. Scan rates vary from 10 to 80 mV/s.

NMR Line width

Measuring rotational diffusion of micelles

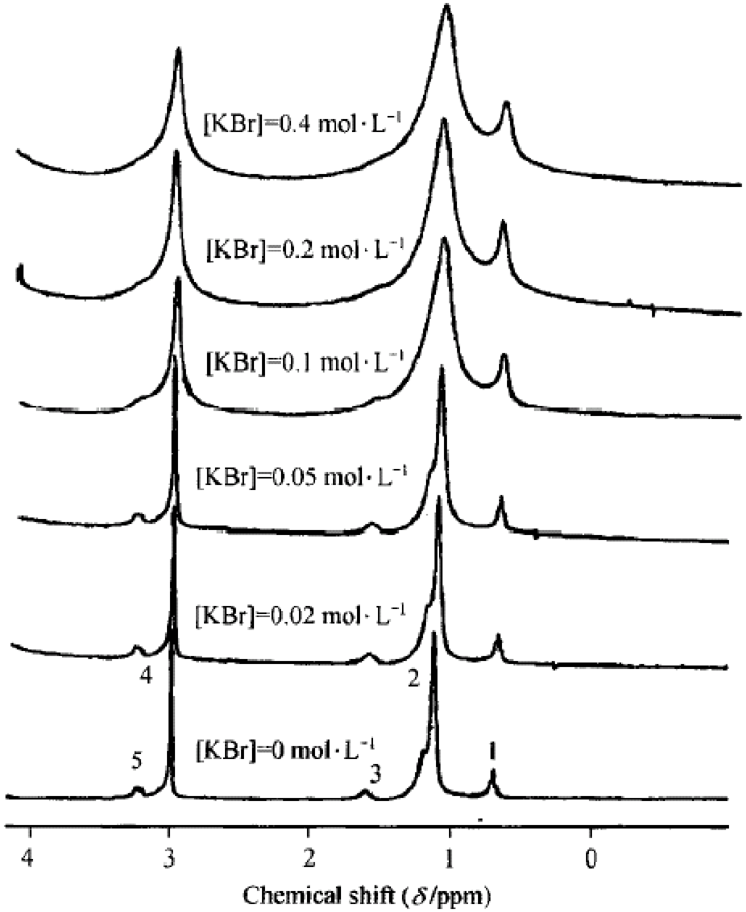
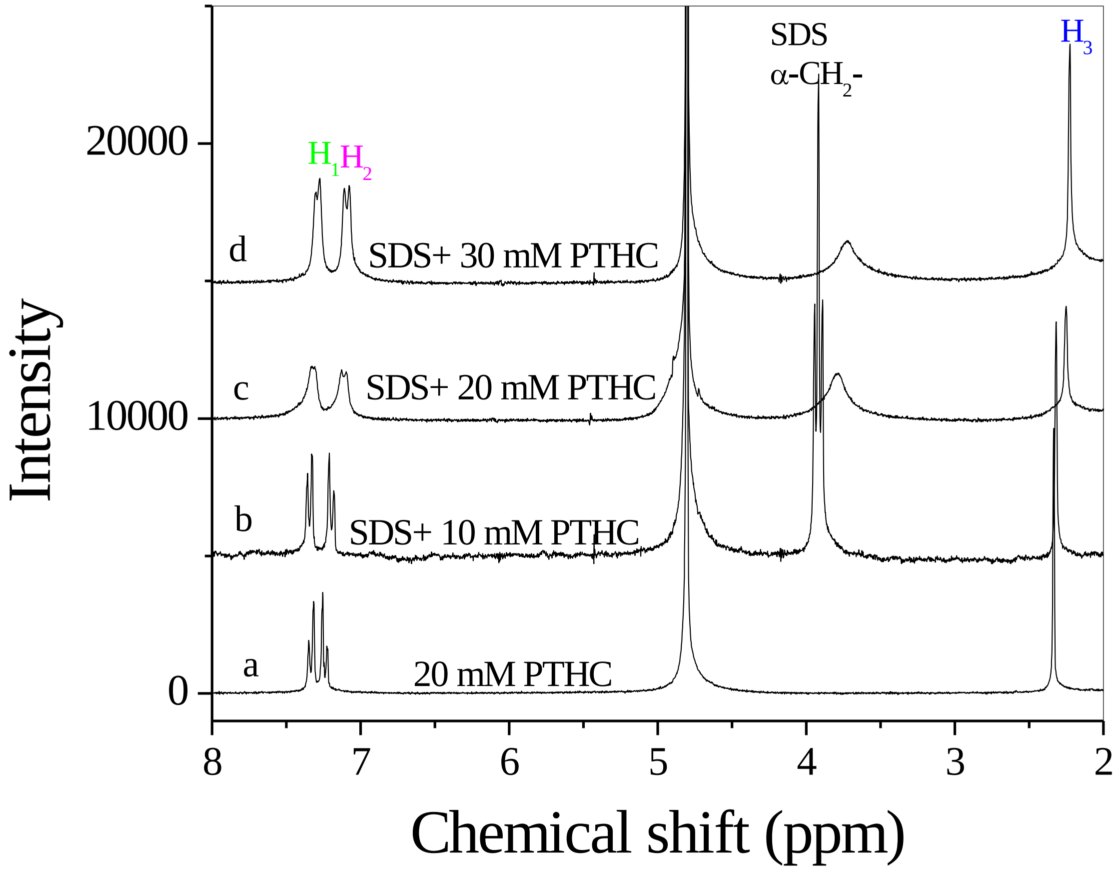
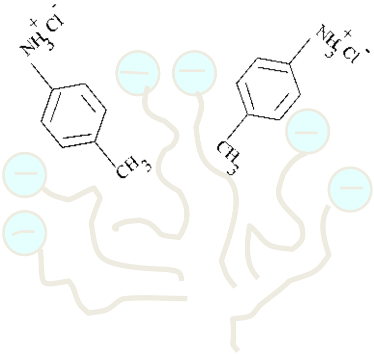


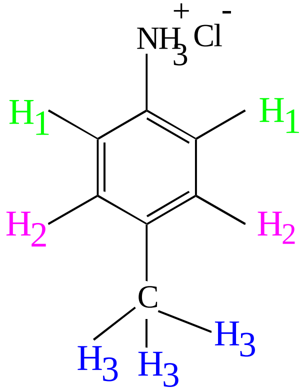
Fig. 1. Effect of KBr salt concentration on the ^{1}H NMR of CTAB molecules in the 0.01 mmol • L^{-1} micellar system. 1, ω-CH$_3$; 2, -(CH$_2$)$_{13}$; 3, β-CH$_2$; 4, N-(CH$_3$)$_3$; 5, α-CH$_2$.

Counterion Adsorption: ^{1}H NMR

SDS = 50 mM







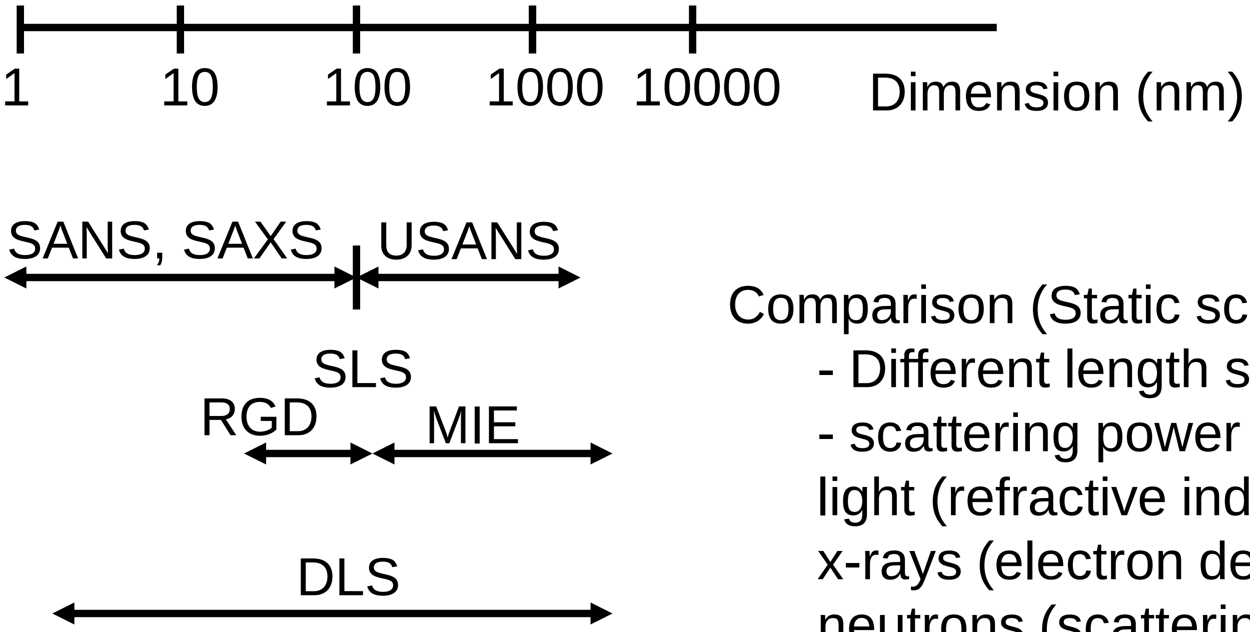
- Upfield shift of m- and p- protons while o- is unshifted
- Line broadening ⇒ Formation of rod like micelles

Langmuir **2002**, 18, 2543

Scattering - Explore the nano world

Light, neutron and X-ray scattering

Size range of different scattering methods



Comparison (Static scattering)
- Different length scales
- scattering power

light (refractive index)
x-rays (electron density)
neutrons (scattering length density)

Works in a range where optical microscopy fails !

Scattering from particles

In general, the angular dependence of scattering follows:

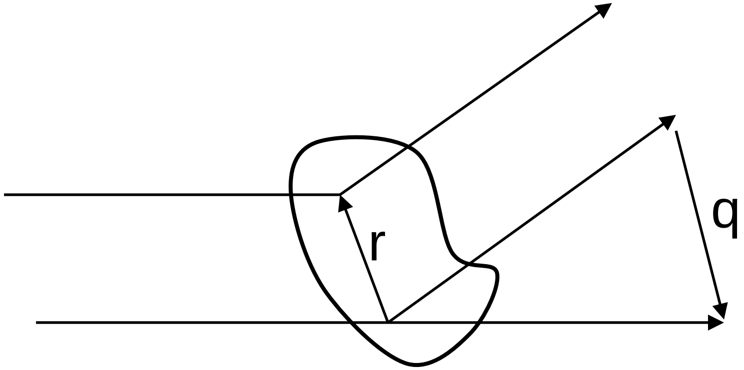
I(q) ~ P(q) S(q)

q = 4p n Sin (q/2)/l

Intraparticle Interference
(Form factor)
size, shape, polydispersity
Dilute system

Interparticle Interference
(Structure factor)
Interactions-charge
Concentrated system

Integrated intensity from all the regions of the scatterer

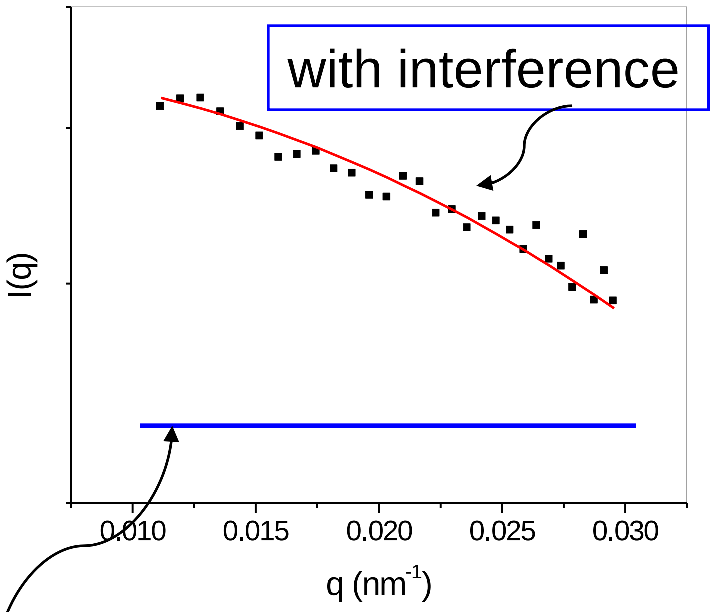


The phase difference of the waves scattered by points separated by vector r = q.r

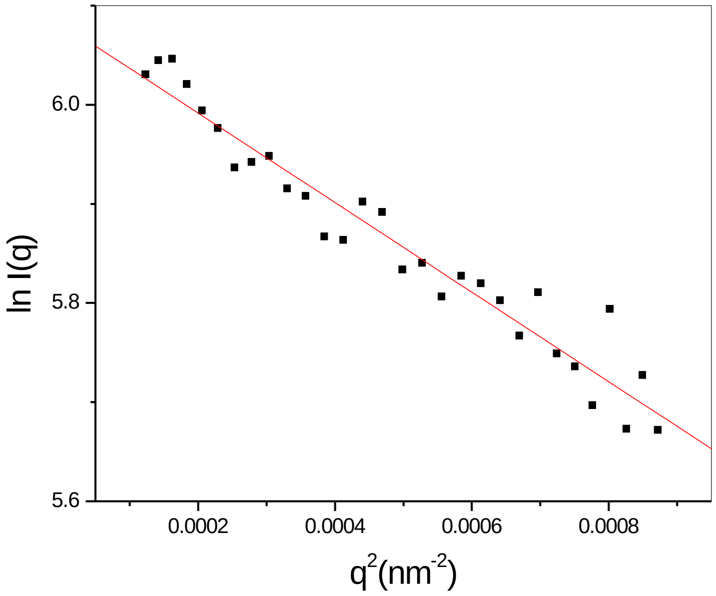
Guinier regime

Dilute sphere with radius 50nm

Guinier plot



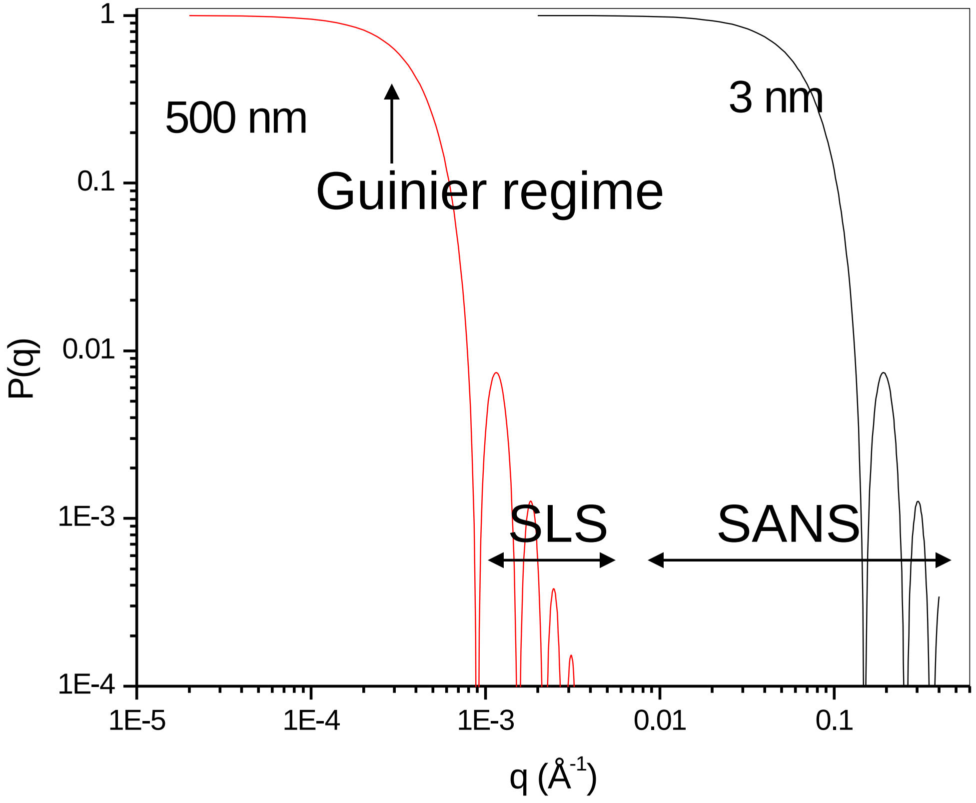
No interference



Rg = 36.8 +/- 0.8 nm

Expected Rg = 38.7 nm

P(q) at different length scale



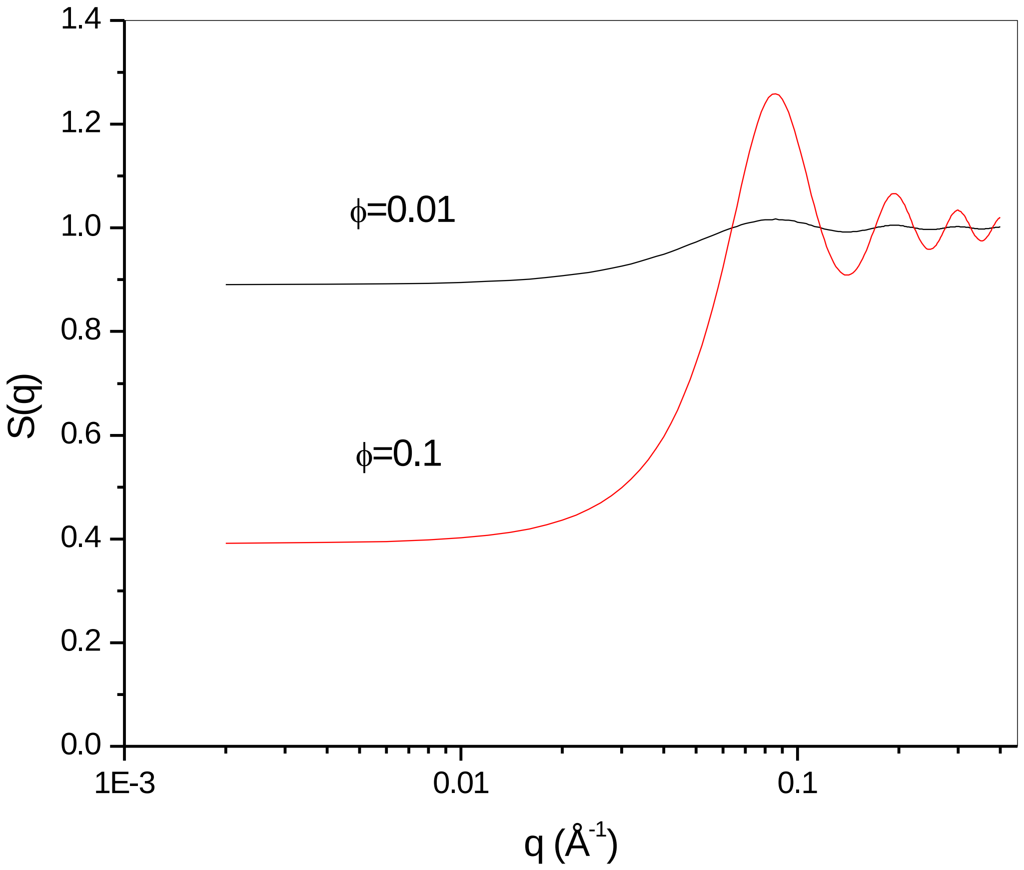
Size
Shape
polydispersity

SANS is ideal for the length scale of micelles

SLS can be used to obtain R_g or R depending on size
For SLS, P(q) ~ Guinier law
S(q) ~ S(0)

Minima occurs at qR= tan(qR), for sphere
qR= 4.49, 7.72 etc

S(q), Interparticle interference



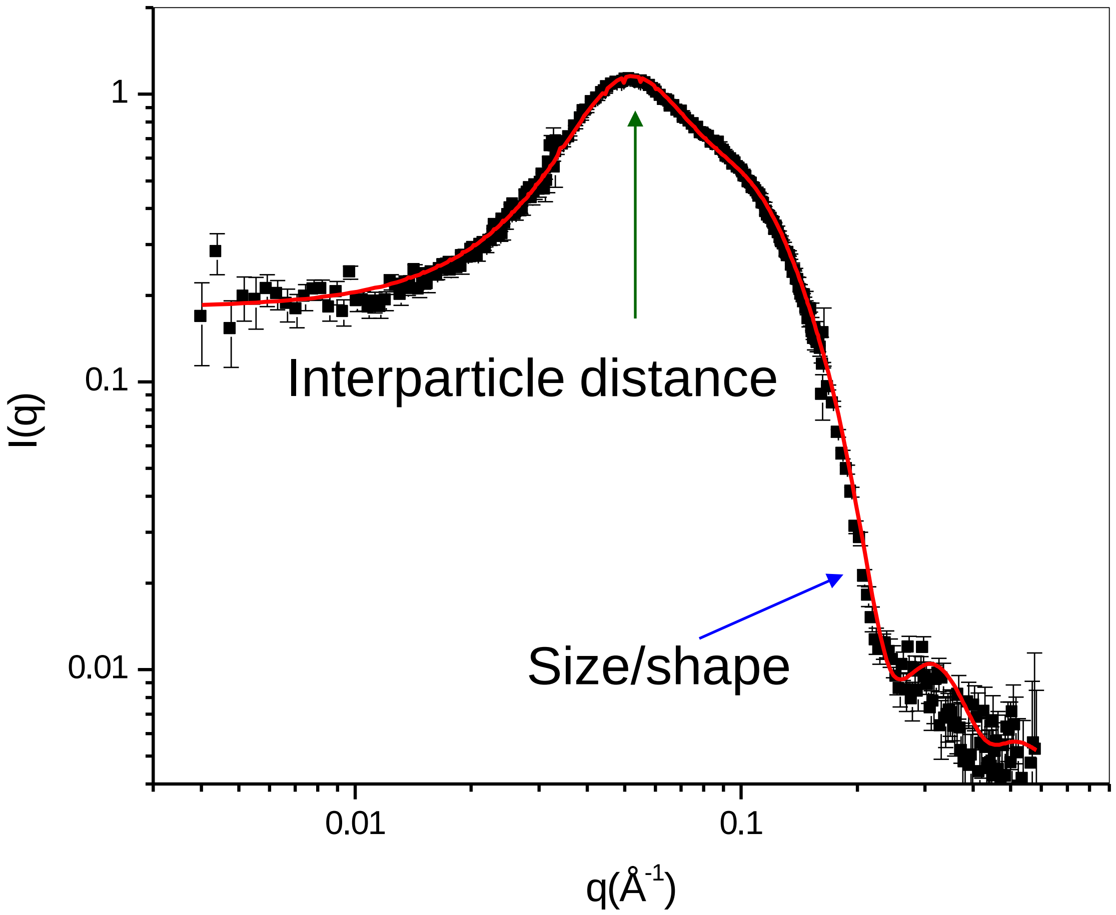
Vol. Fraction
Charge
Ionic strength

As concentration increases, peak develops at ~ 2p/d

d is the average interparticle distance

SANS data for interacting micelles

SANS study of SDS micelles



50 mM SDS
Agg. No. = 79; a = 0.42

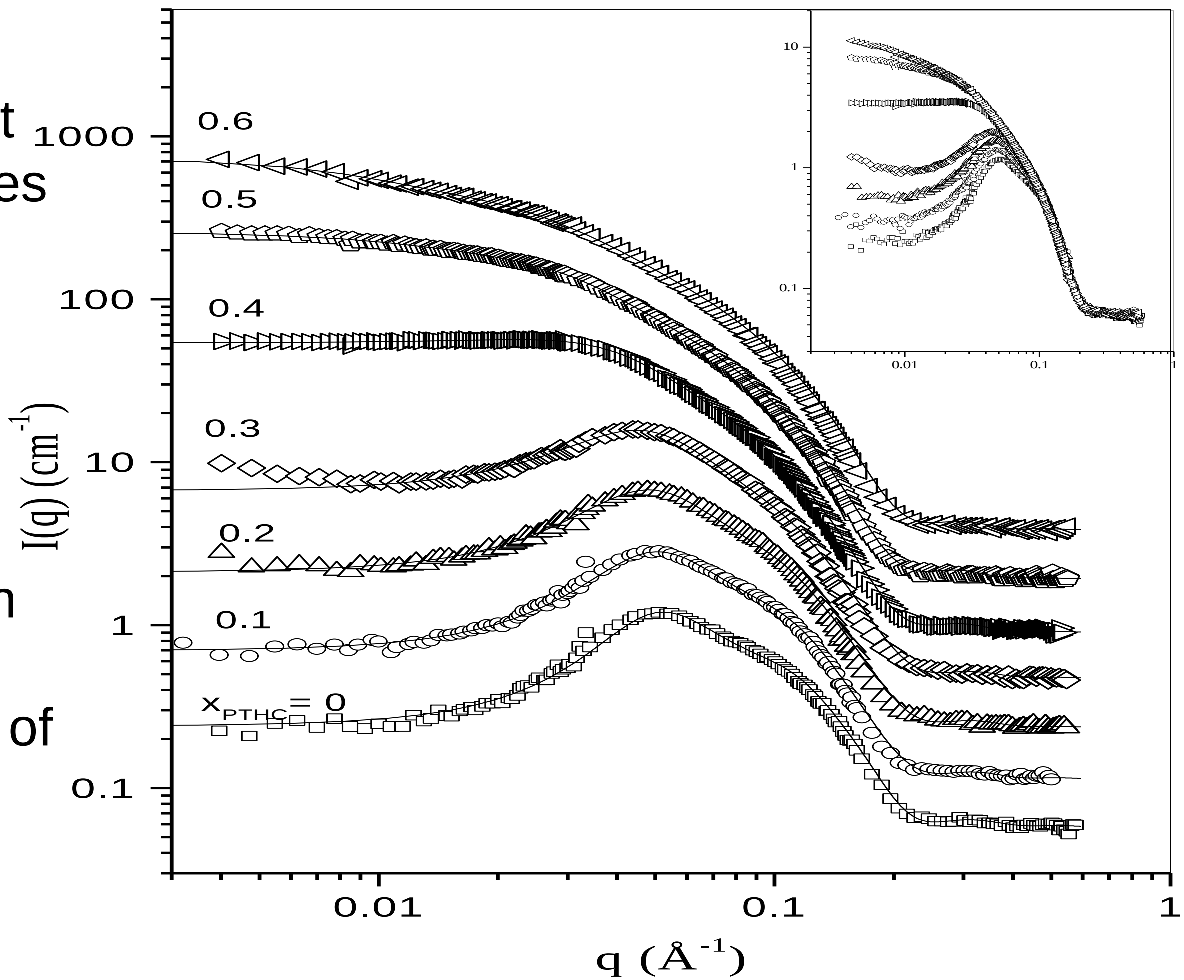
P(q) - ellipsoid
S(q) - RMSA

Hassan etal.
J. Coll. Interface Sci.
(2003) 257, 154.

SANS of micelles

Correlation peak at $x_{PTHC} < 0.4$ indicates strong intermicellar repulsion

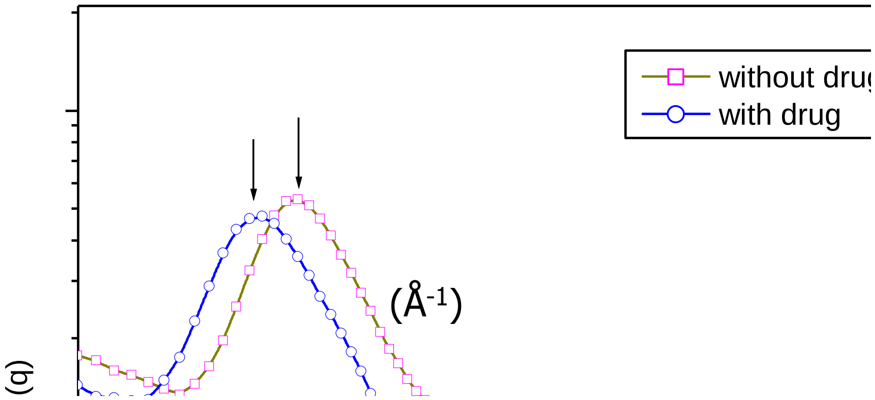
Increase of I(0) with increse in x_{PTHC} indicates decrease of interaction and growth

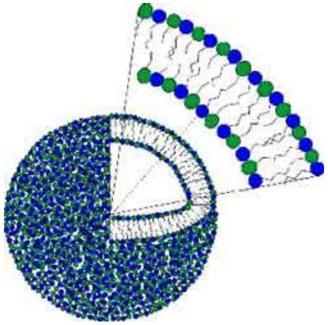


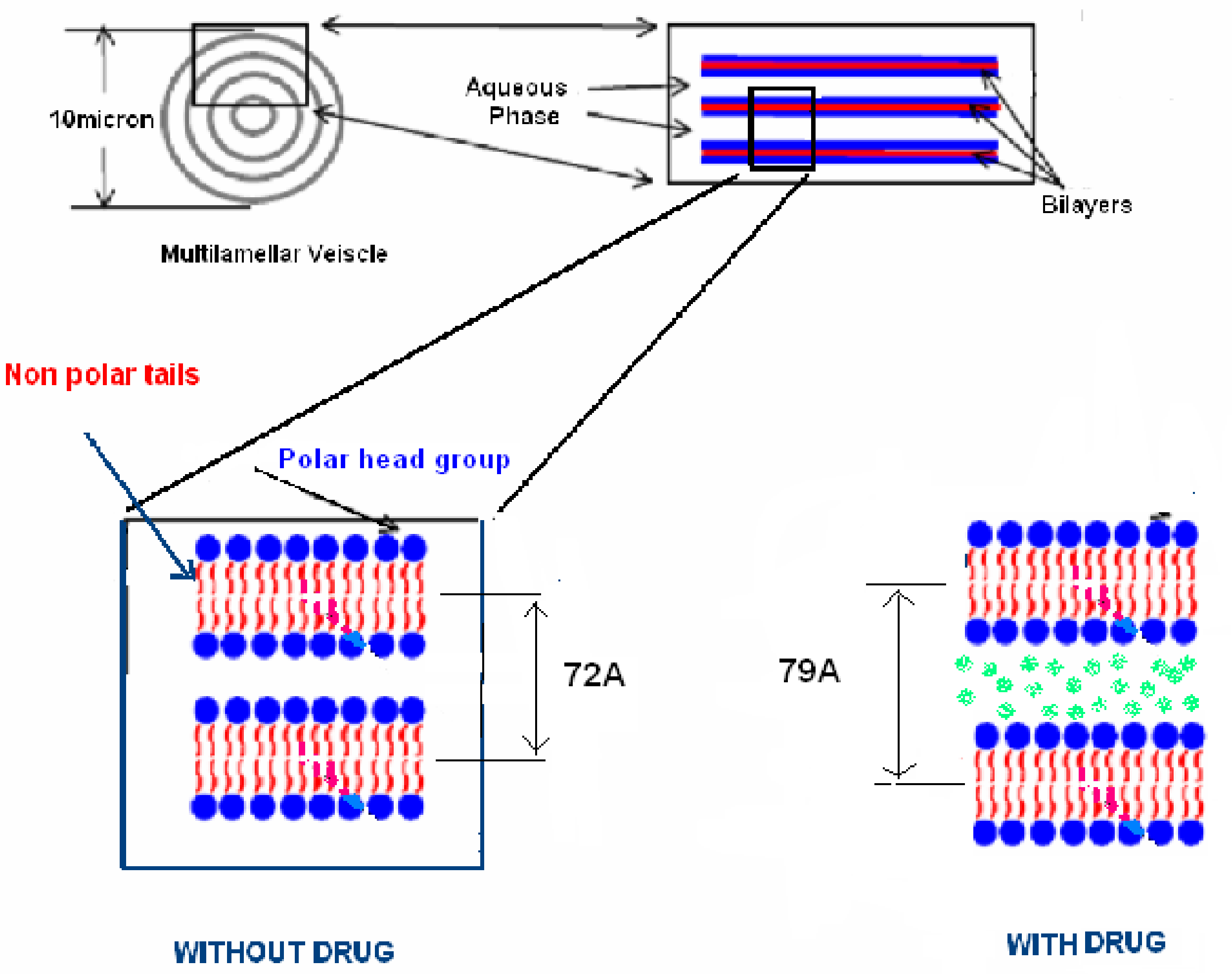
SANS of drug loaded vesicles

with drug without drug

Drug solubilization increases the bilayer spacing from 72 Å to 79 Å



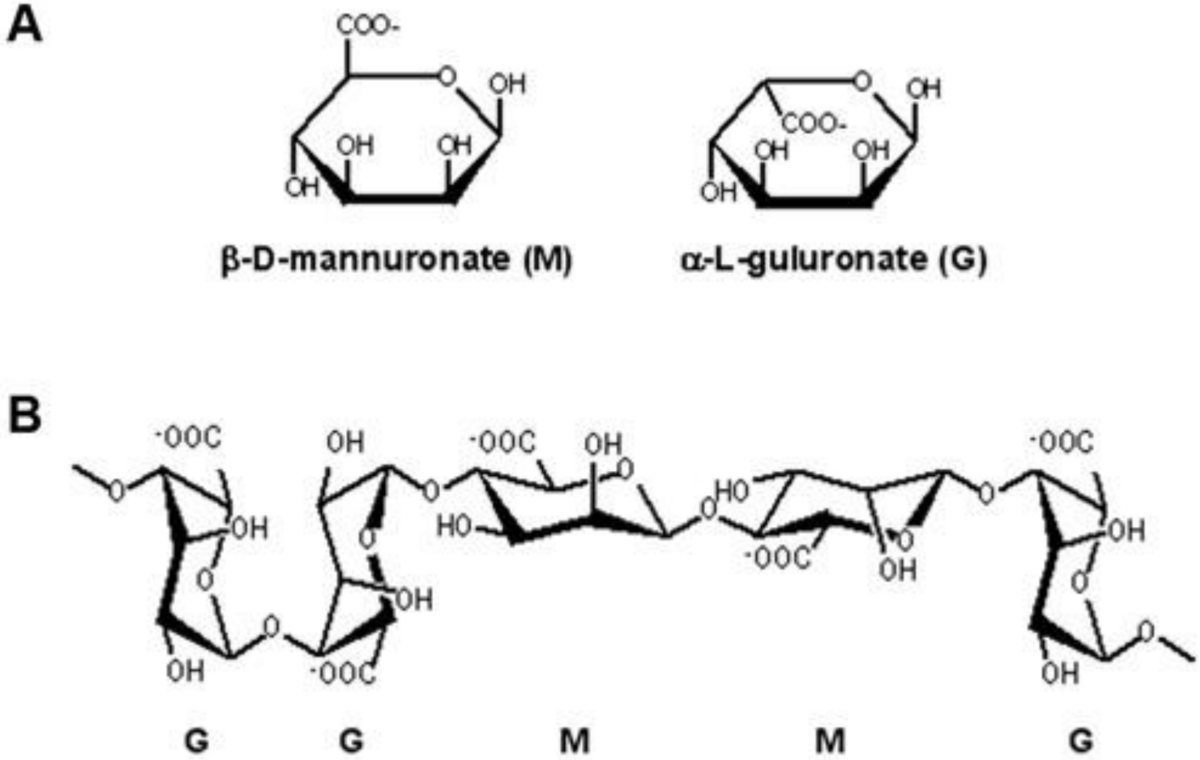



10micron
Multilamellar Veiscle
Aqueous
Phase
Bilayers
Non polar tails
Polar head group
72A
79A
WITHOUT DRUG
WITH DRUG

Trapping micelles in biopolymer gels

System investigated : Alginate + triton X100

A natural polysaccharide



Ca^{2+} induced gelation

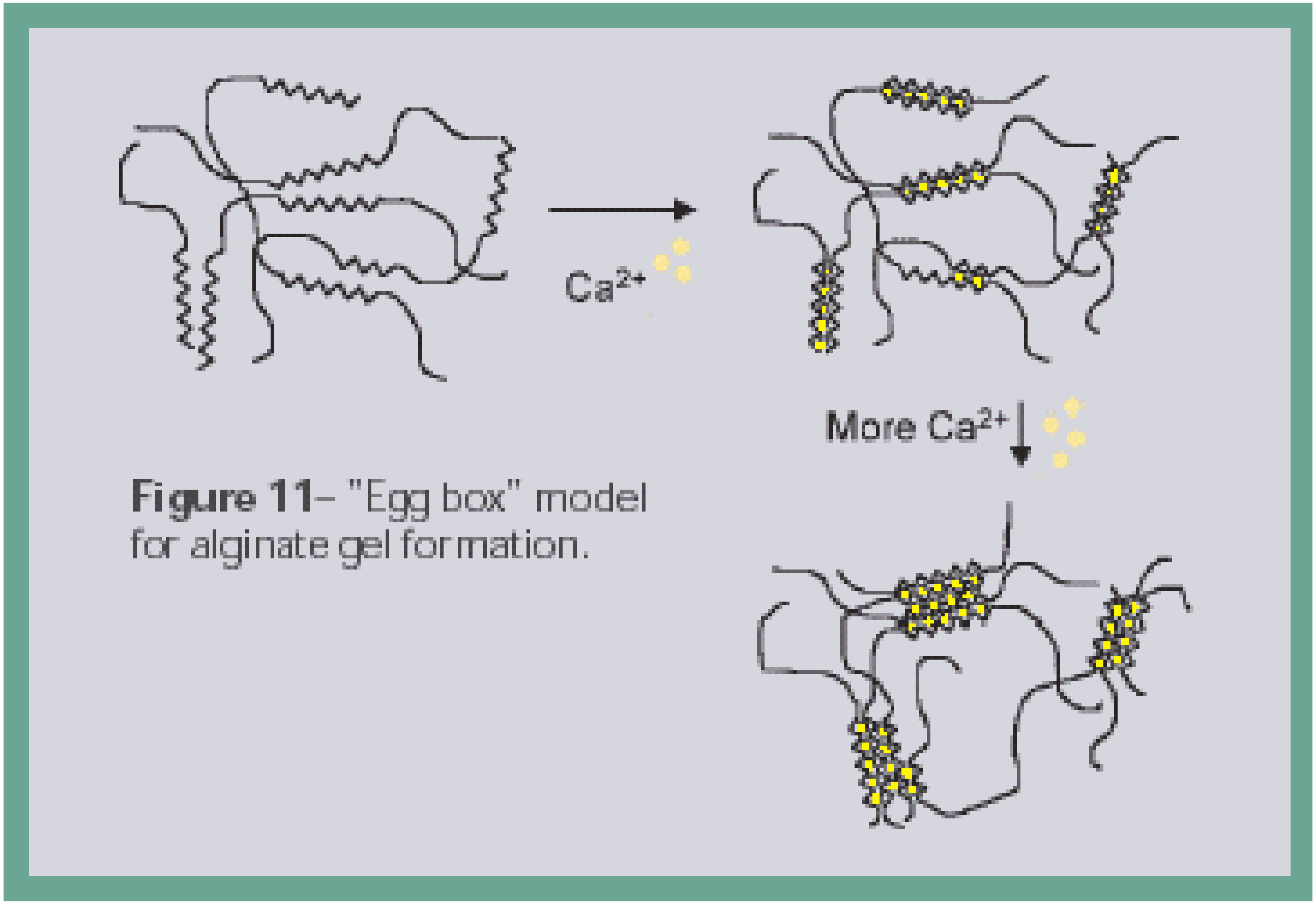
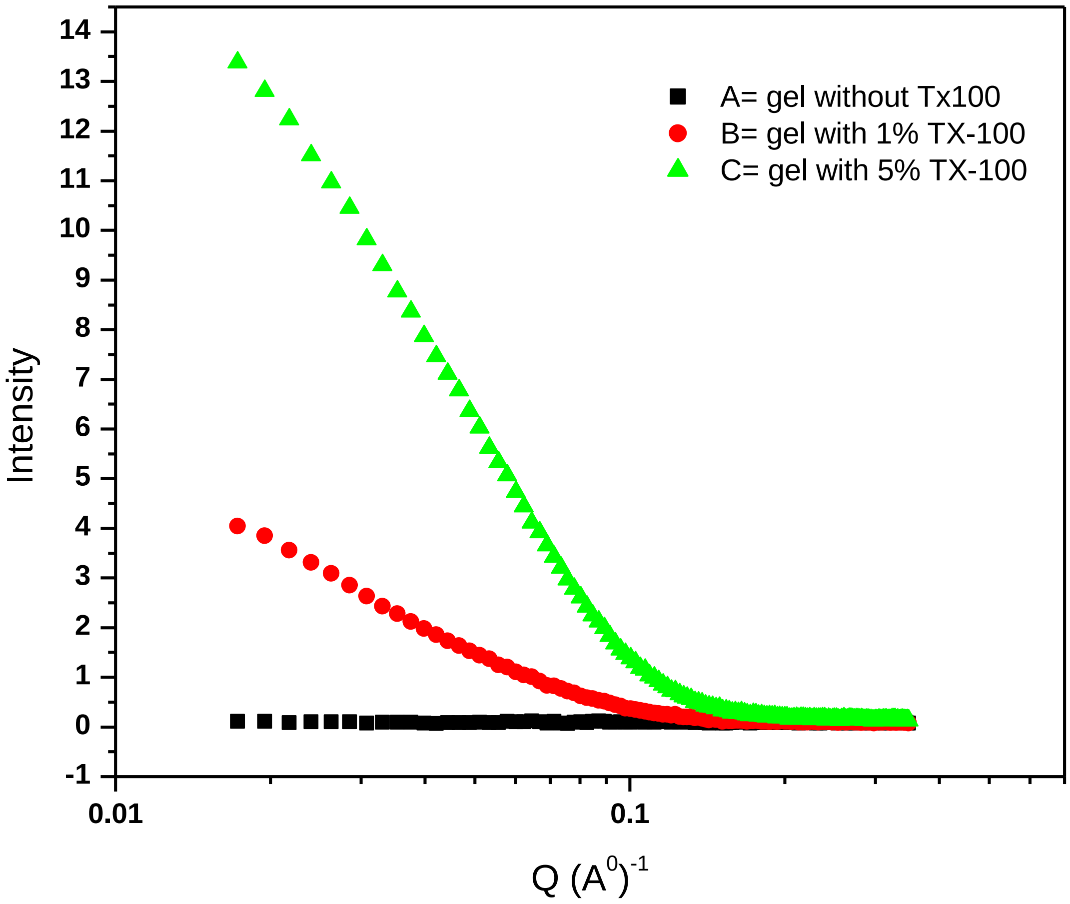


Figure 11– "Egg box" model for alginate gel formation.

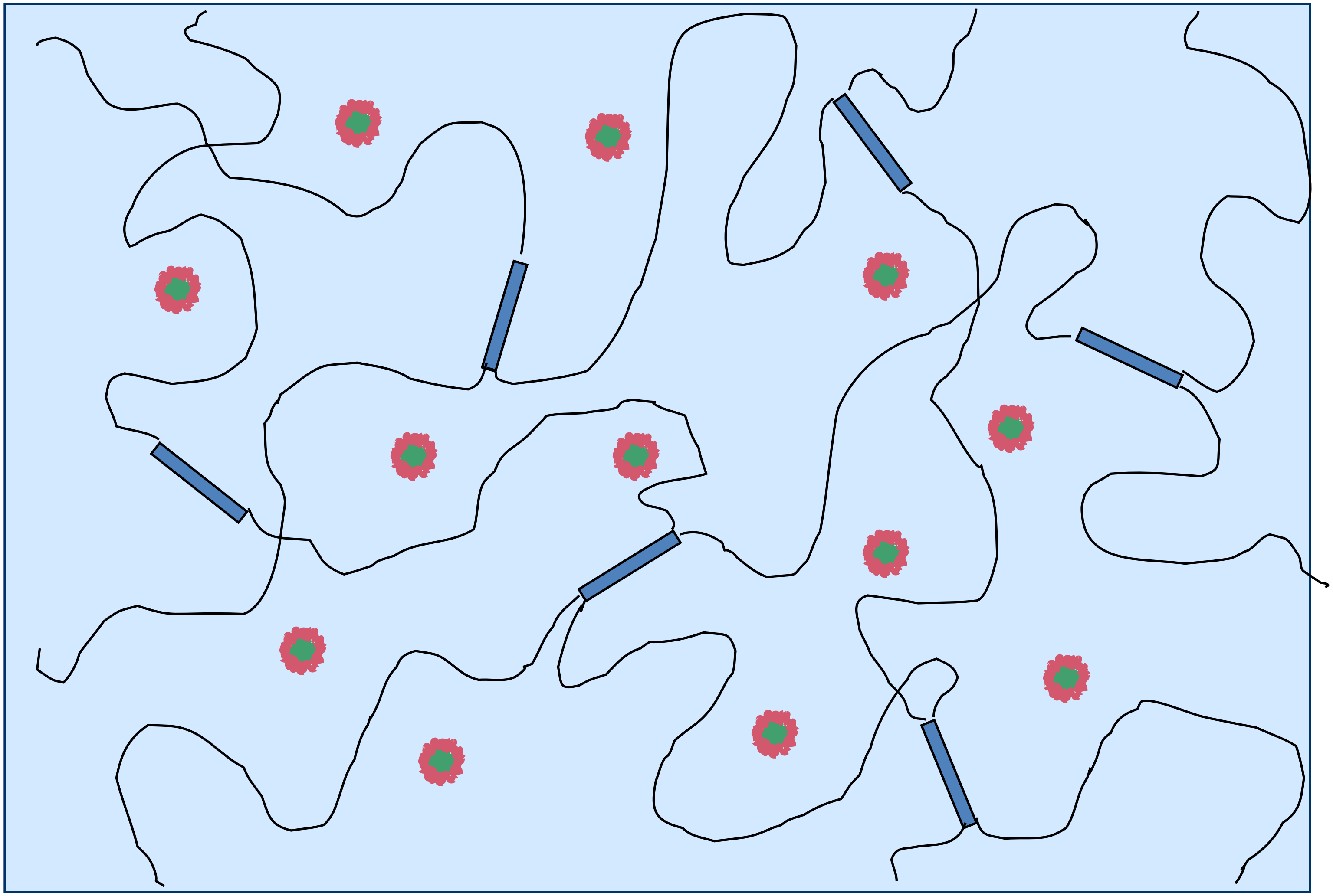
Courtesy: FMC Biopolymer

SANS

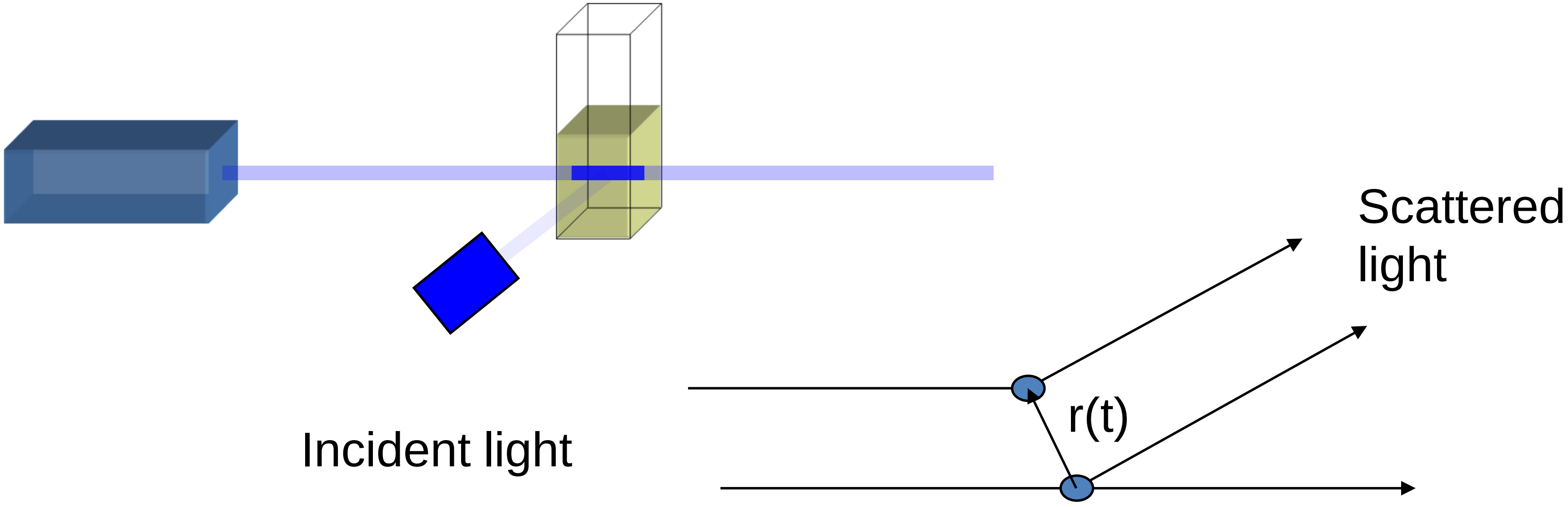
Concentration of Alginate =0.5 %



Micelle in a hydrogel



Light scattering under motion



Distance between particles changes with time due to motion

The interference of scattered light changes with time. Net intensity of light fluctuates with time

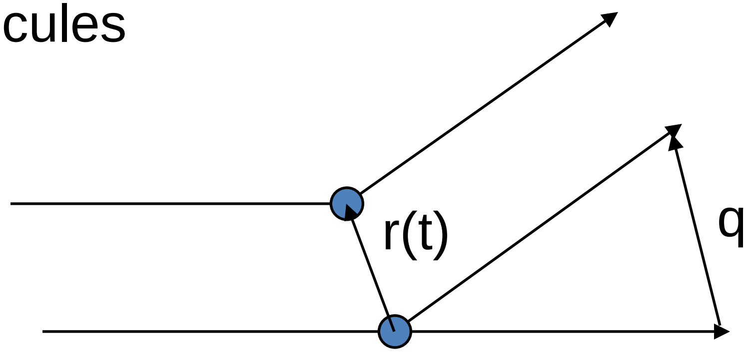
Dynamic Light Scattering

Static light scattering – unable to probe micelles

Option – Look for the motion of scatterers (dynamic)

Time dependence of scattered intensity is measured

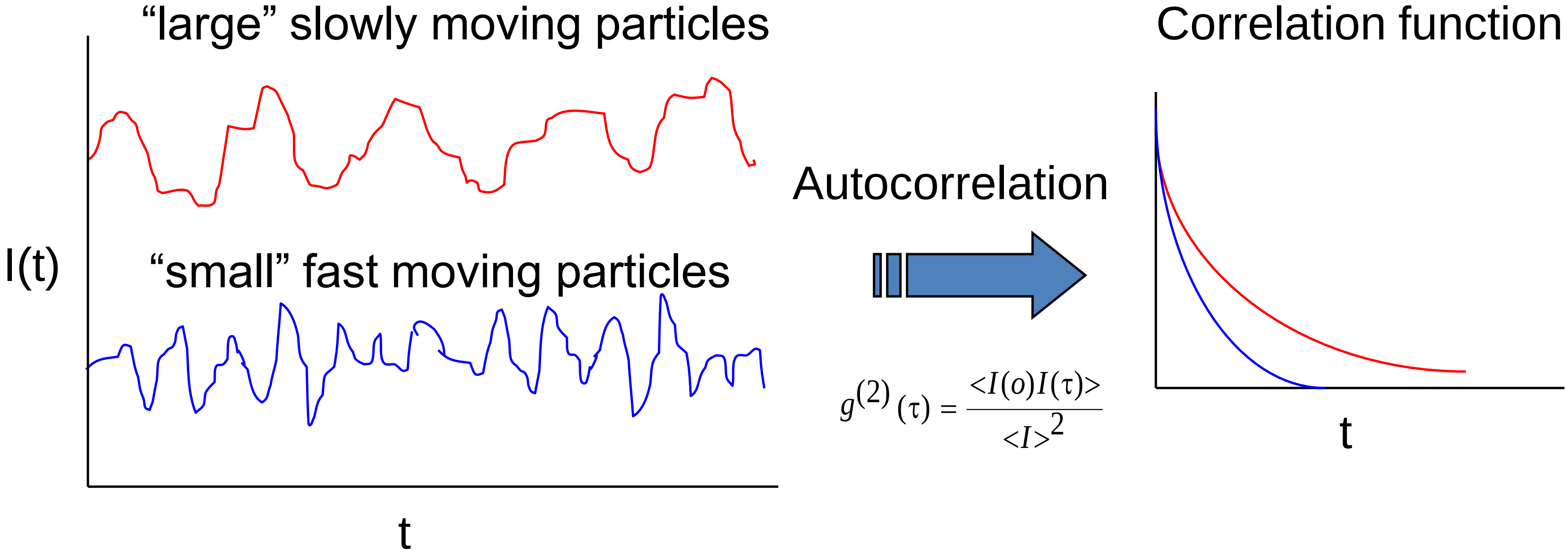
Brownian motion of colloidal particles due to collision with solvent molecules



Measures dynamic structure factor

Brownian motion depends on size, viscosity and temperature

Timescale of intensity fluctuation



“large” slowly moving particles

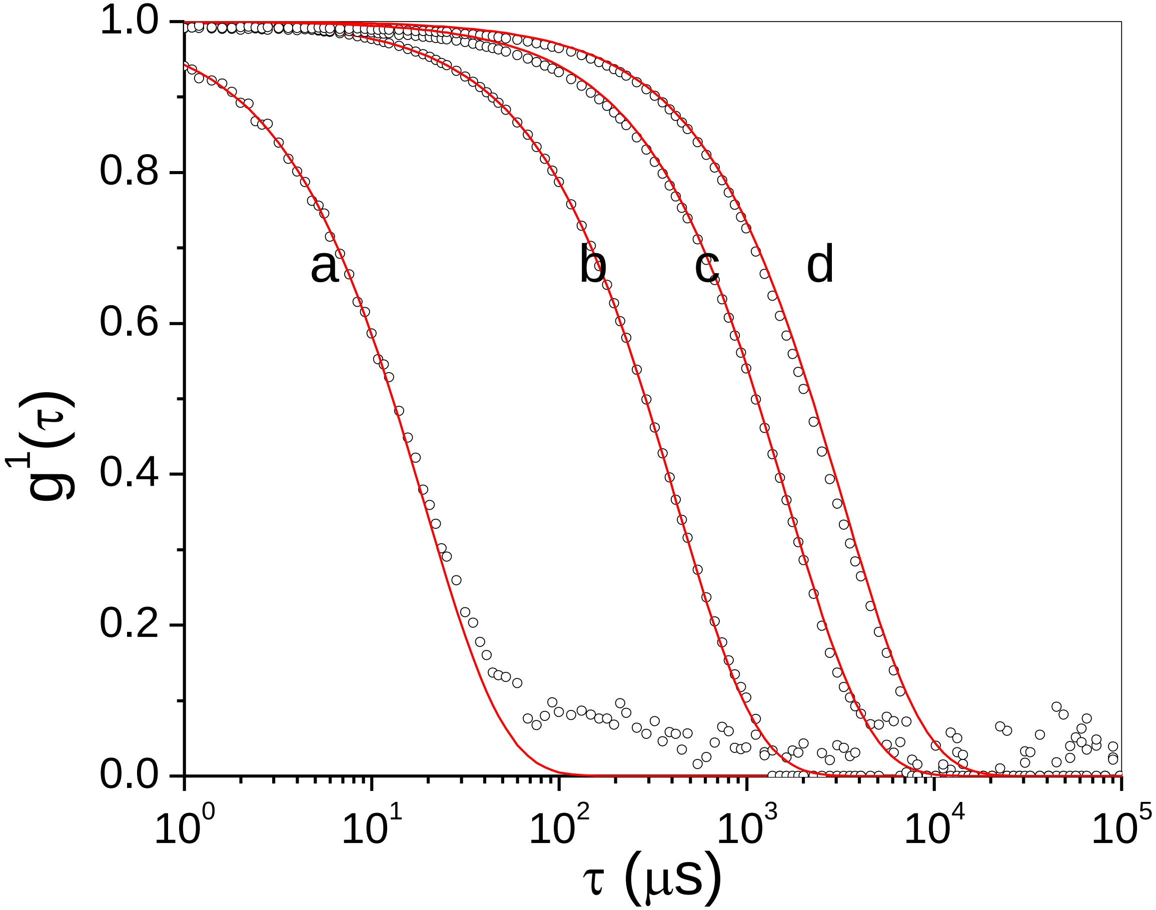
“small” fast moving particles

Autocorrelation

$$g^{(2)}(\tau) = \frac{<I(o)I(\tau)>}{<I>^2}$$

Correlation function

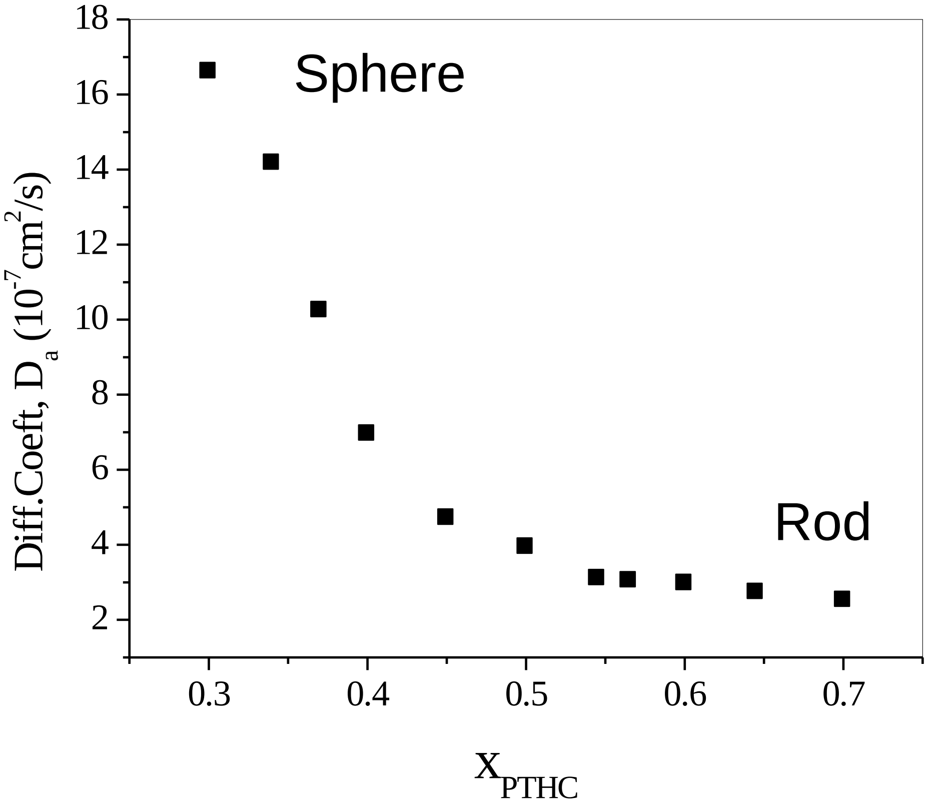
Particle size by Dynamic scattering



Spheres
with radius
a) 2.5 nm
b) 54 nm
c) 214 nm
d) 422 nm

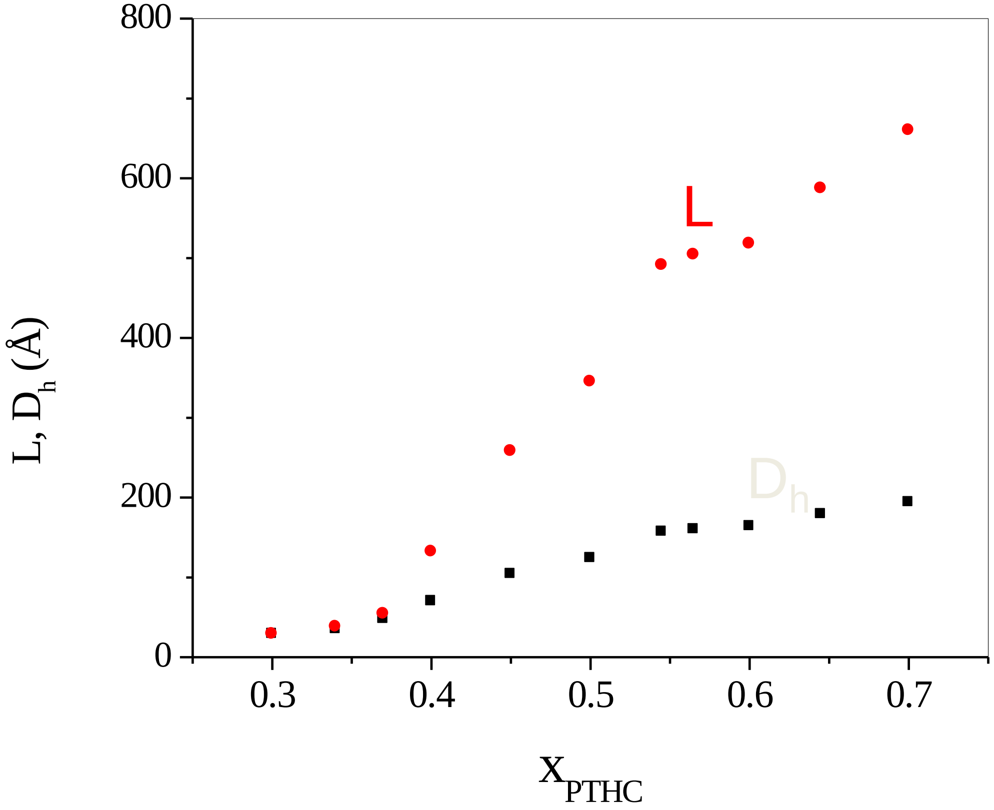
As size increases, motion become slower and the decay time increases

Micellar growth probed by DLS



Decreases the apparent diffusion coefficient of the micelles

Micelle length from DLS



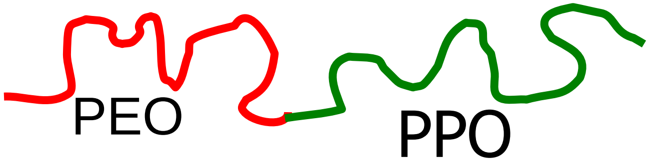
L = length assuming a rod

D_h = diameter assuming a sphere

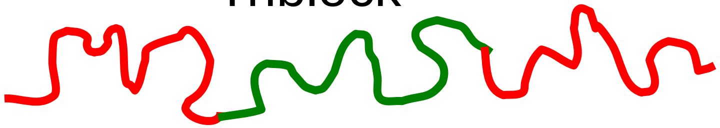
Block copolymers

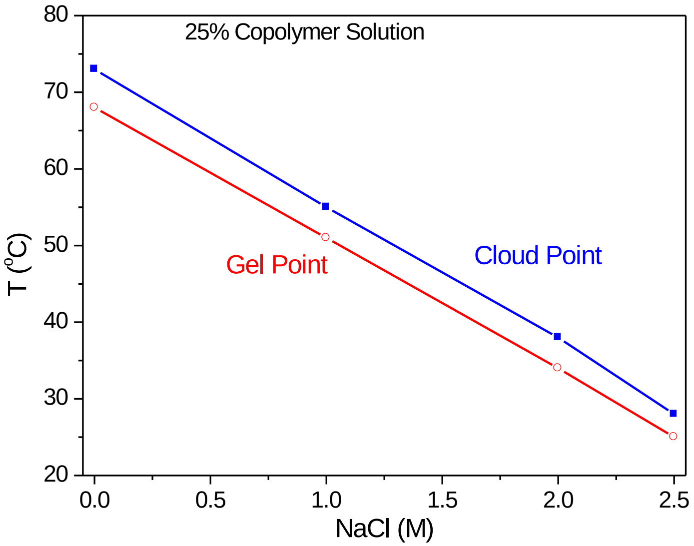
Surfactants for “macro” micelles

Diblock

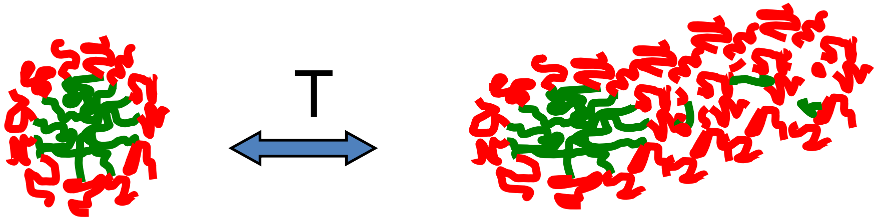


Triblock





Sphere to rod transition induced by temperature

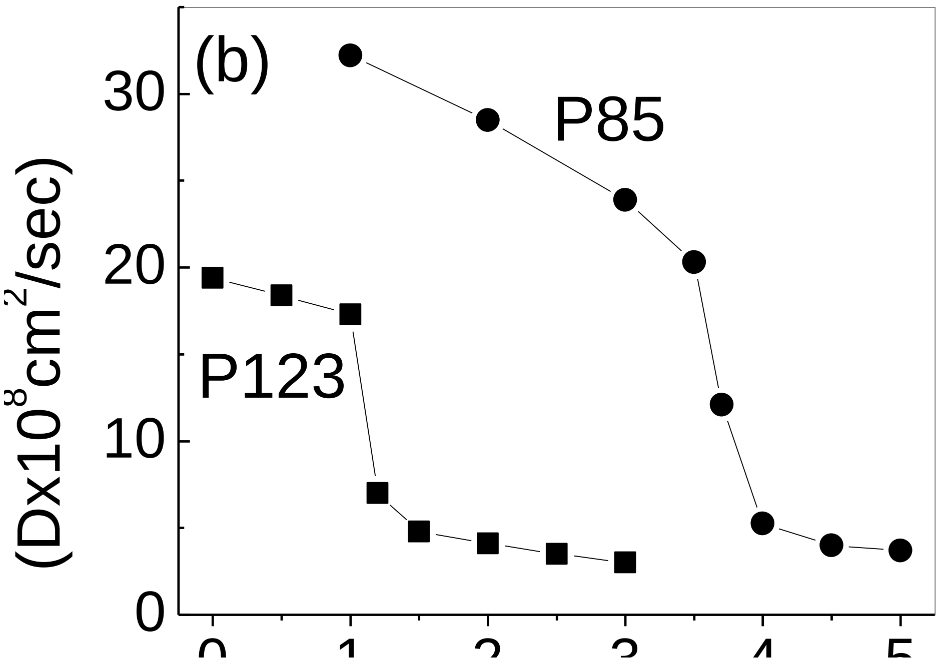


Thermoreversible gels in block copolymer micelles

J. Phys. Chem. B, **2005**, 109, 5653

J. Phys. Chem. B **2006**, 110, 9843

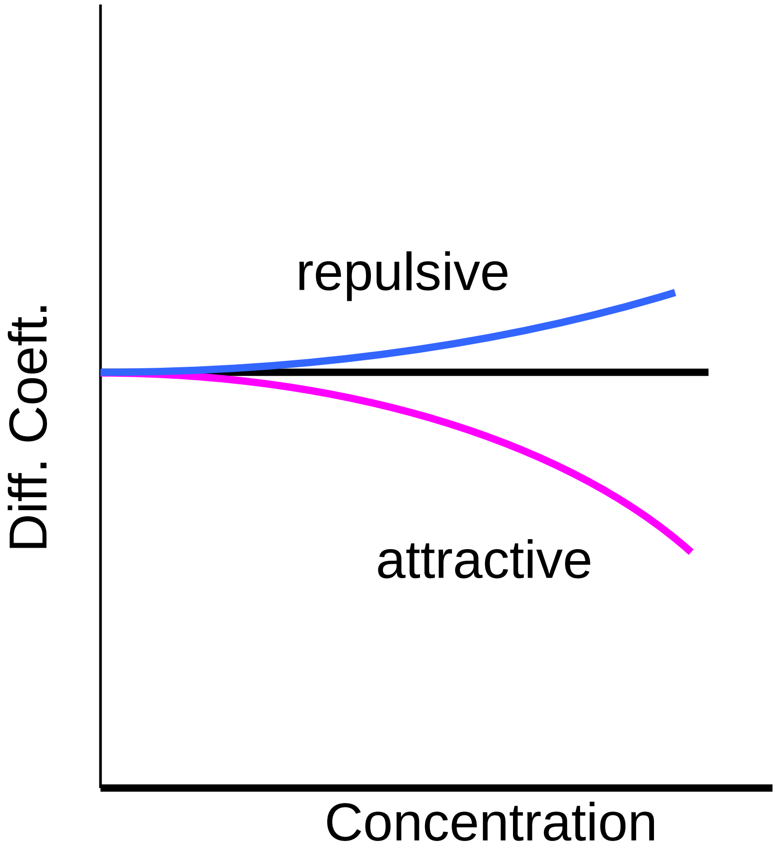
Effect of PPO block length



Particle Interactions

$D = D_0\ (1 + k_dC)$

Thermodynamic + hydrodynamic



Small q limit
No hydrodynamics,

$D = D_0/S(0)$

For repulsive $S(0) < 1$,
D increases

With hydrodynamics,

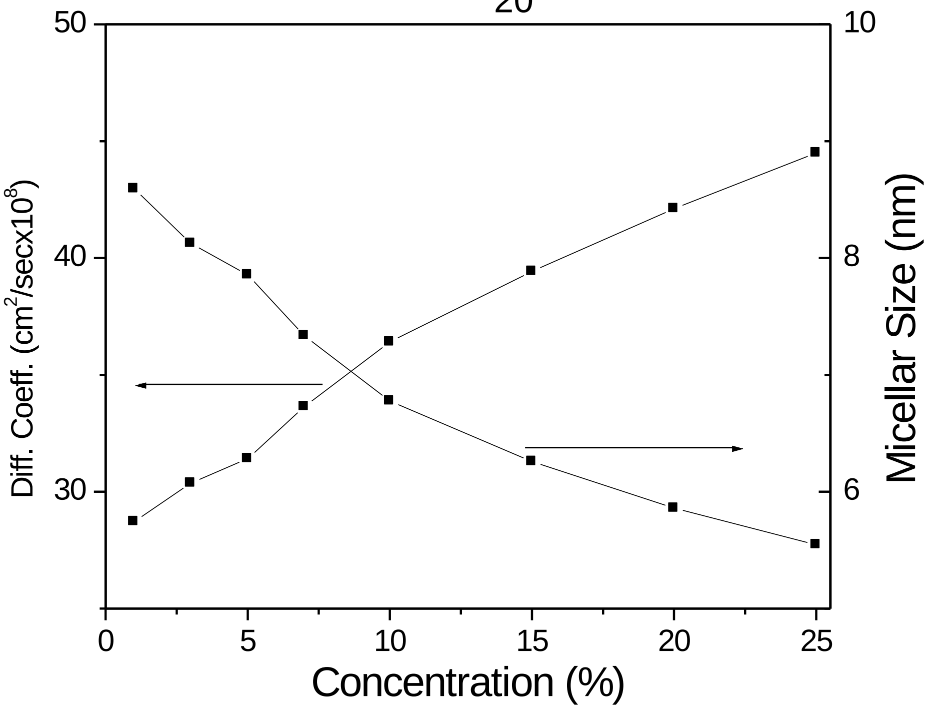
$D = D_0H(0)/S(0)$

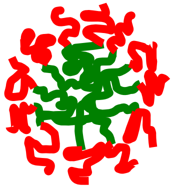
Measuring interparticle interaction

For hard spheres, in the absence of hydrodynamic interaction

$D = D_0 (1 + k_D f)$

Eg: Block copolymer micelles $(PEO)_{20}(PPO)_{70}(PEO)_{20}$ micelles



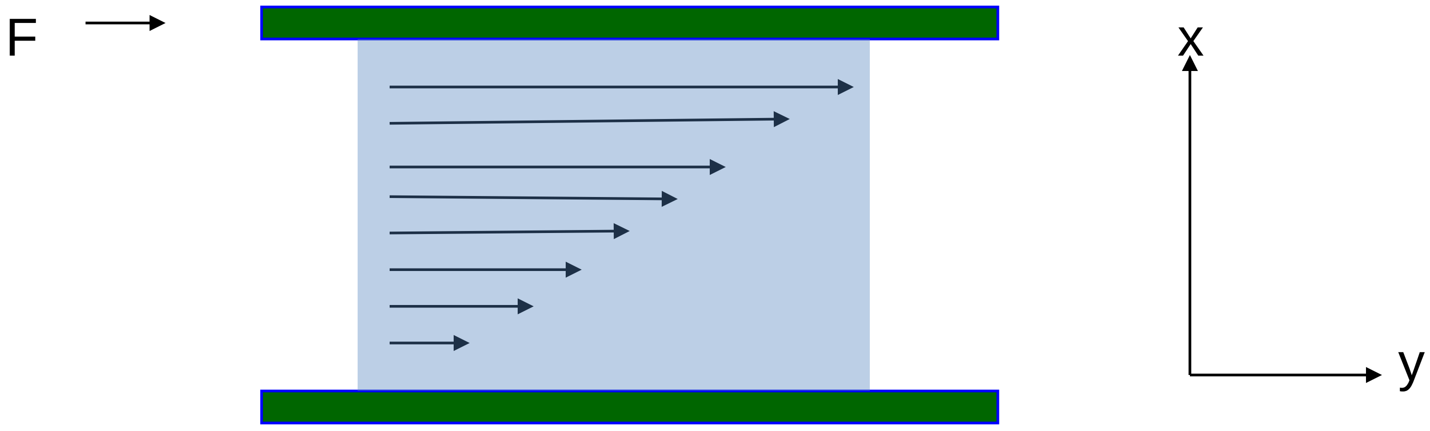


$k_D = 2.5$

Rheology

Rheology - Study of flow and deformation of matter
Microstructure can alter the flow behavior- soft materials

Shear modulus (G) – a measure of softness



Solids vs liquids

Shear stress, **s** (force/area) = F/A

Shear strain, **g** (deformation) = dy/dx

Solid are elastic

$$\sigma = G\gamma$$

Hooke's law

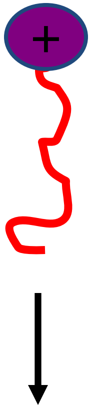
Liquids are viscous

$$\sigma = \eta\dot{\gamma}$$

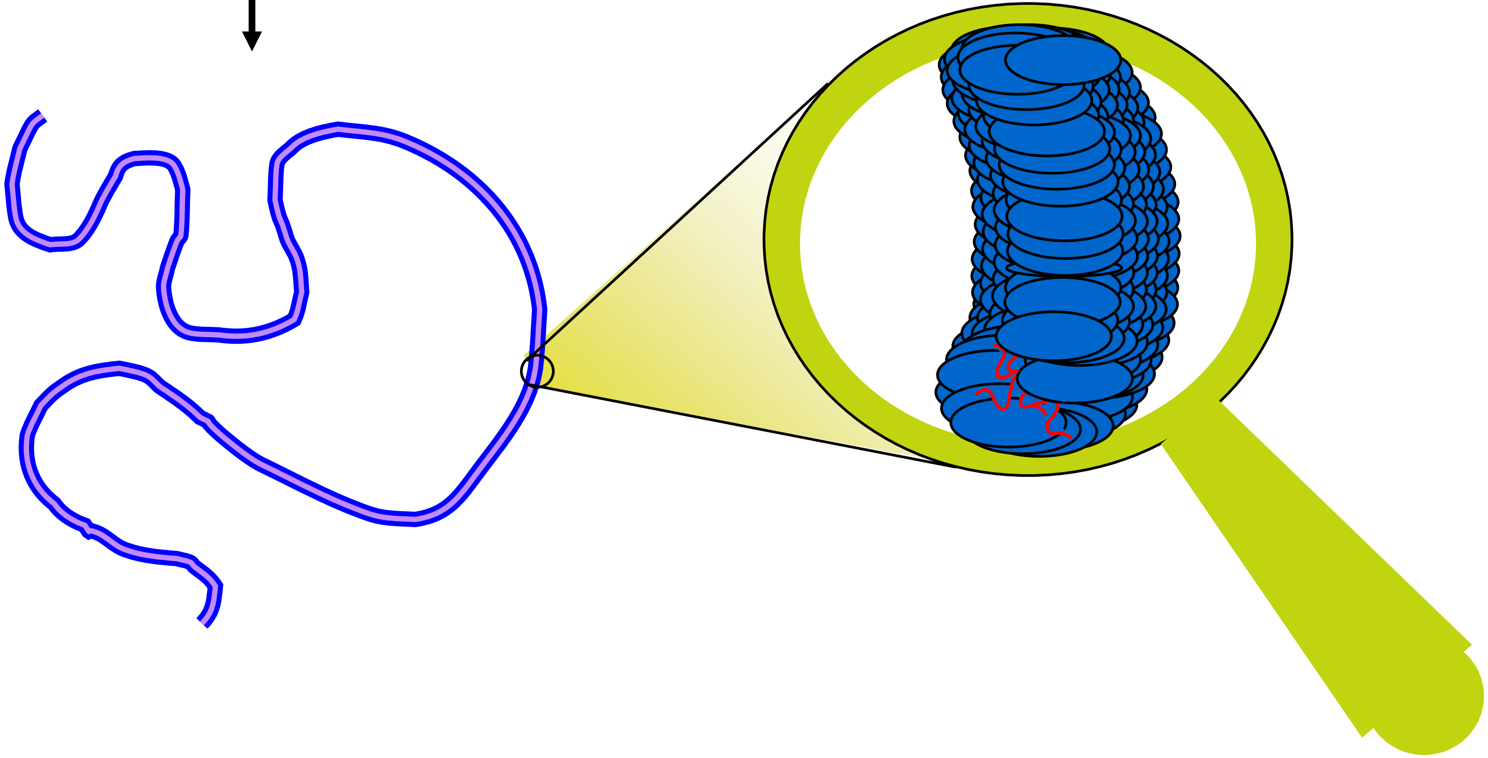
Newton's law

Soft materials are viscoelastic

Self assembled polymers



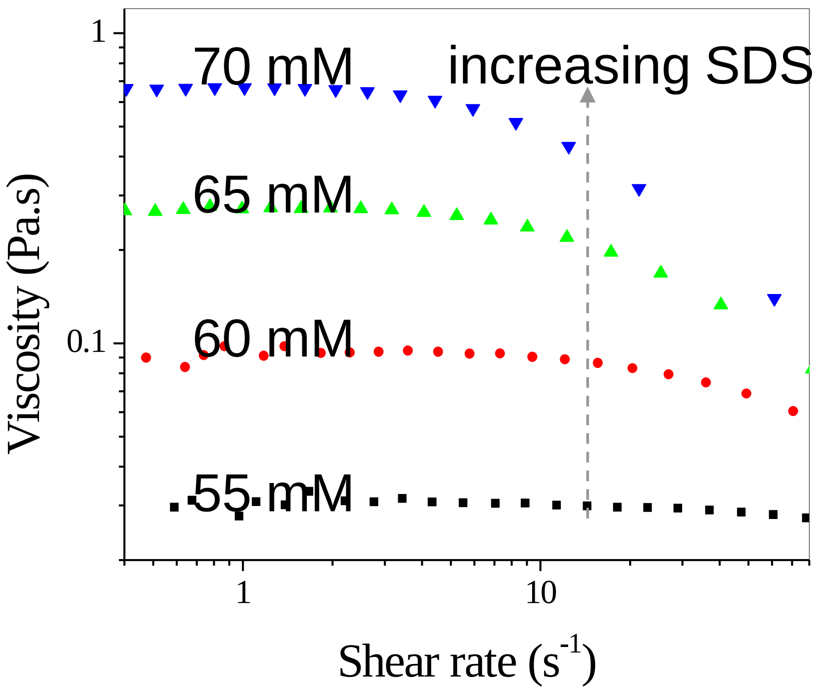
- Monomers joined together through weak forces
- Break and recombine with change in temperature
  Equilibrium polymers (living polymers)
- Thickness of chain ~ 20 – 50 Å

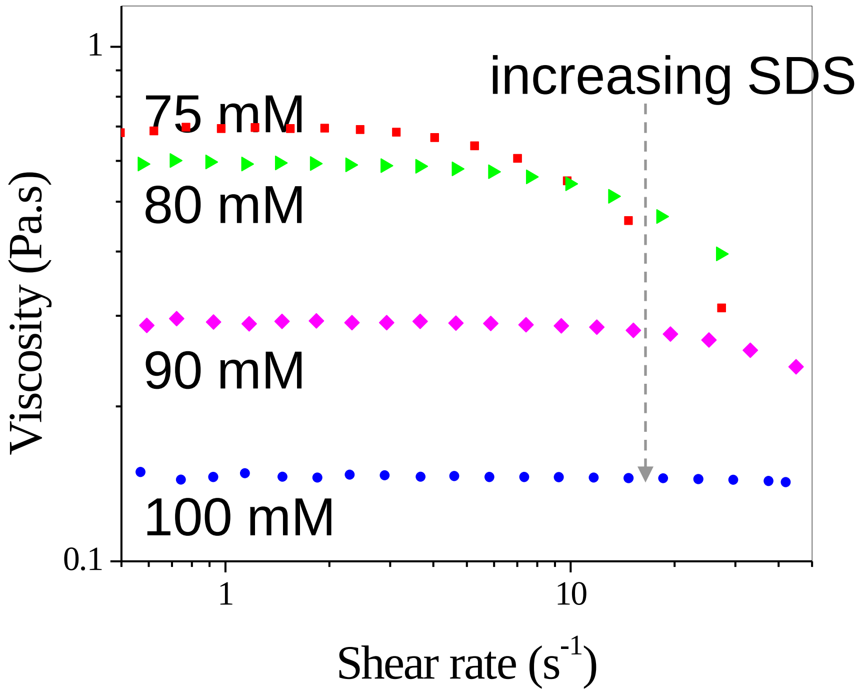


Practical Examples

Foods, Pharmaceuticals, Personal care products, Life science etc.

Polymer-like micelles as rheology modifier





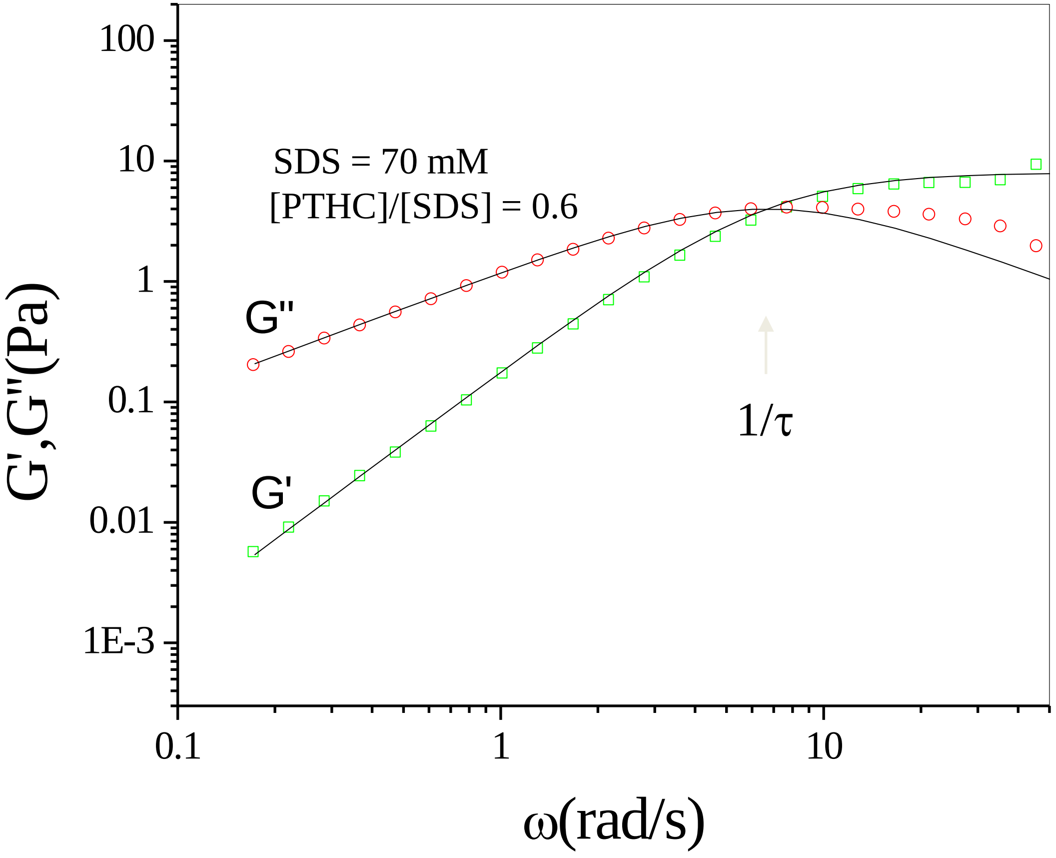
Low SDS:
increasing h_0, t

High SDS:
decreasing h_0, t

Viscosity increase and shear thinning

[PTHC]/[SDS] = 0.6

Viscoelastic behavior



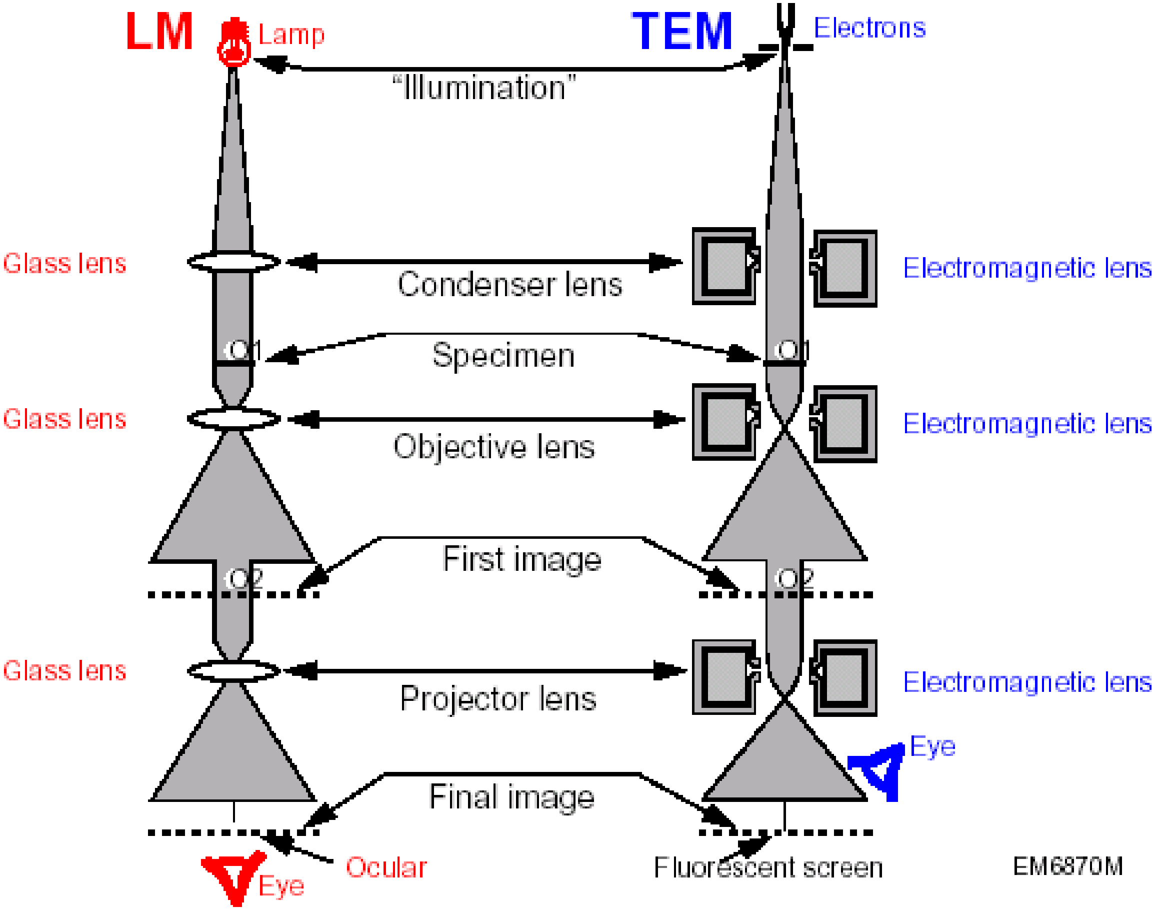
Maxwell Fluid:

$$G'(\omega) = \frac{G_0 \omega^2 \tau^2}{1 + \omega^2 \tau^2}$$

$$G''(\omega) = \frac{G_0 \omega \tau}{1 + \omega^2 \tau^2}$$

Langmuir **2002**, 18, 2543.

Microscopy


LM
Lamp
TEM
Electrons
"Illumination"
Glass lens
Condenser lens
Electromagnetic lens
O1
Specimen
O1
Glass lens
Objective lens
Electromagnetic lens
First image
O2
O2
Glass lens
Projector lens
Electromagnetic lens
Eye
Final image
Ocular
Eye
Fluorescent screen
EM6870M

Why electrons?

Resolving power

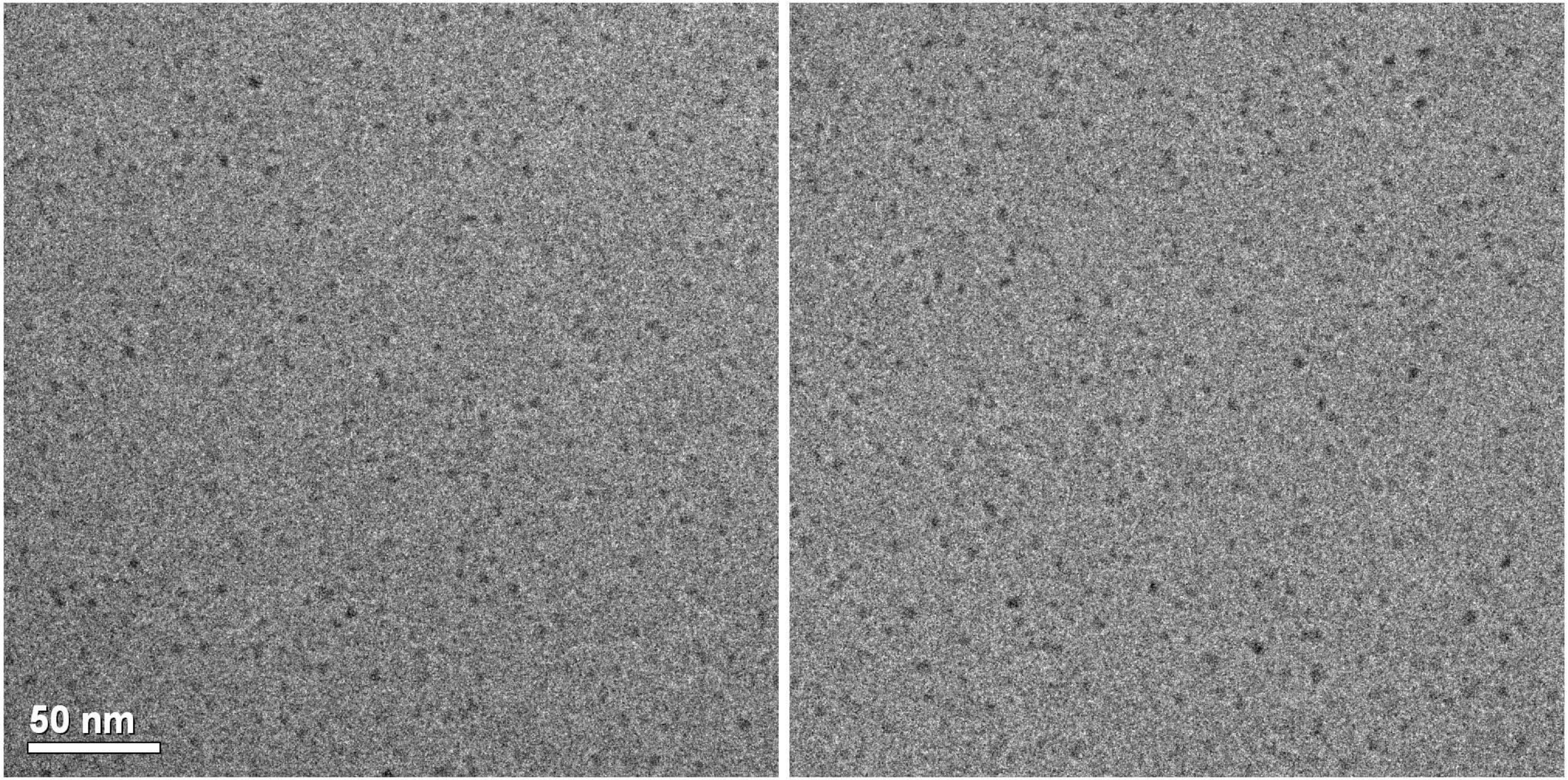
$$db = \frac{1.22 \times \lambda}{2n \times \sin \alpha} \quad \text{or} \quad db = \frac{1.22 \times \lambda}{2 \times N.A}$$

Charged particle – focused by electric or magnetic fields
Small mass- accelerated and thus energy can be changed,
de Broglie wavelength ~ Å
Visible on a fluorescent screen – detection
Availability of sources

Drawback - Needs vacuum – cryo fixation of samples!

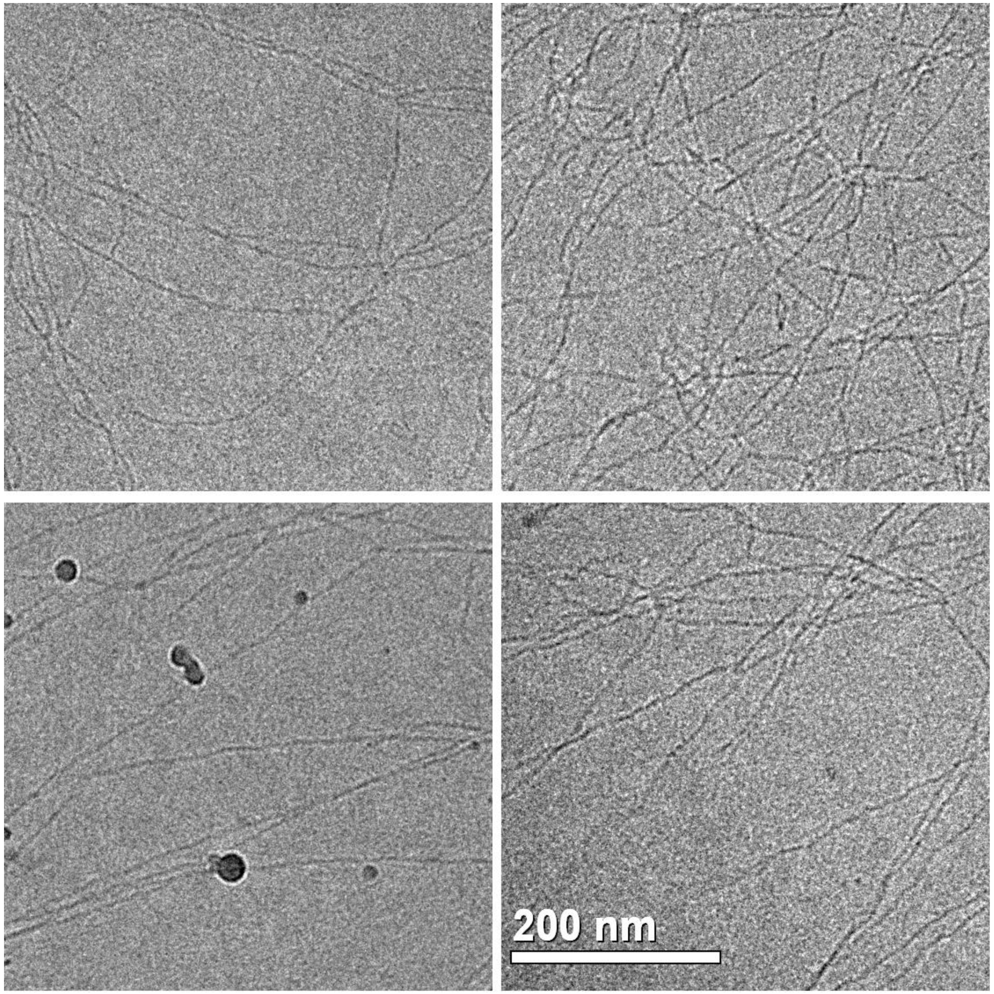
Cryo-TEM Spherical micelles

CTAB 0.01M and $NaNO_3$ 0.01M, 30ºC



3 - 4 nm spheres – (viscosity similar to that of water)

Polymer-like micelles



Length ~ microns

Viscoelastic fluid

1000 times more viscous than water

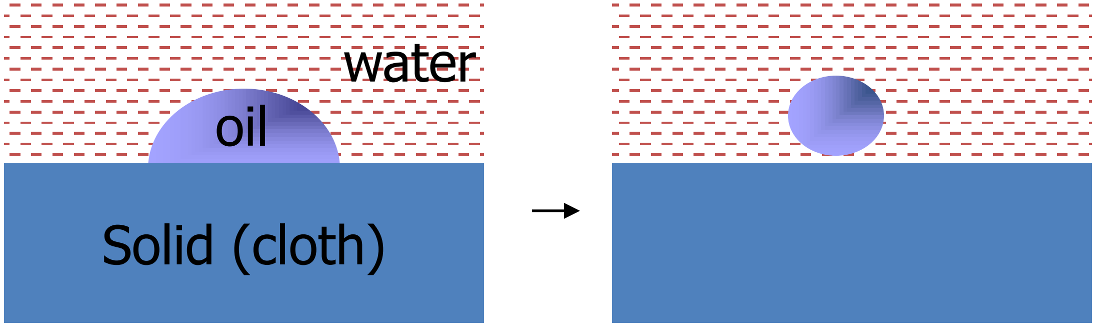
CTAB 0.01M and $NaNO_3$ 0. 5M, 30ºC

Applications in Industry

Soaps and Detergents

All household and industrial cleaners contain surfactant.

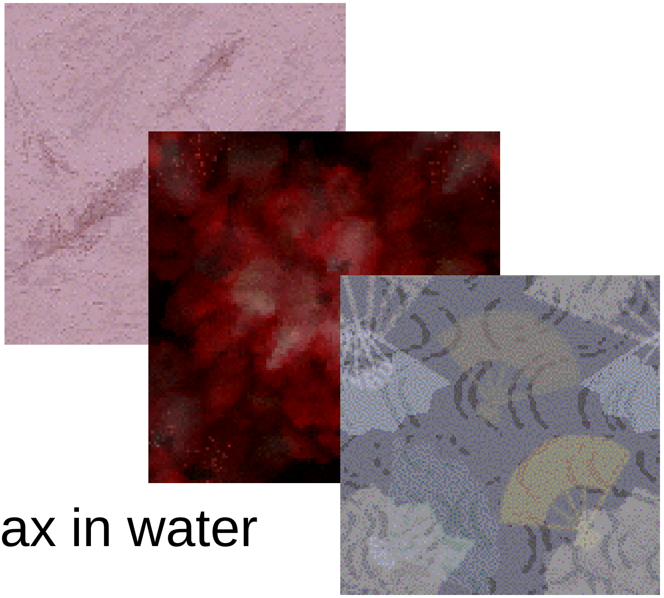
Cleaning – a three phase system



To detach a drop of oil from cloth fiber, capillary action, wetting and contact angle are important. Surfactant formulations are made to do that job

Textiles finish

Synthetic fiber yarns need “spin finish” liquids to modify the surface



Abrasion protection during weaving
Lubrication- enhances the speed of weaving

Typically an emulsion of polymers and wax in water are used as spin finish liquid

Surfactant is used as an emulsifier and as a coating material

A contact angle 20- 40^{o} with water is prefered for fibers

Surfactant as a wetting agent

Dyeing of fabrics:

Printing of polymers (polyolefin – packaging material)
Highly hydrophobic - difficult to wet with water based inks
Surfactants help to improve wetting

Other applications include:

Flux cleaning in electronic circuit boards
Lubricants in watch industry

Cell adhesion enhancement of culture cells in pathology
Removal of bubbles in electroplating industry
Tertiary oil recovery in oil fields

Pesticide formulations

Pesticides are organic compounds – insoluble in water

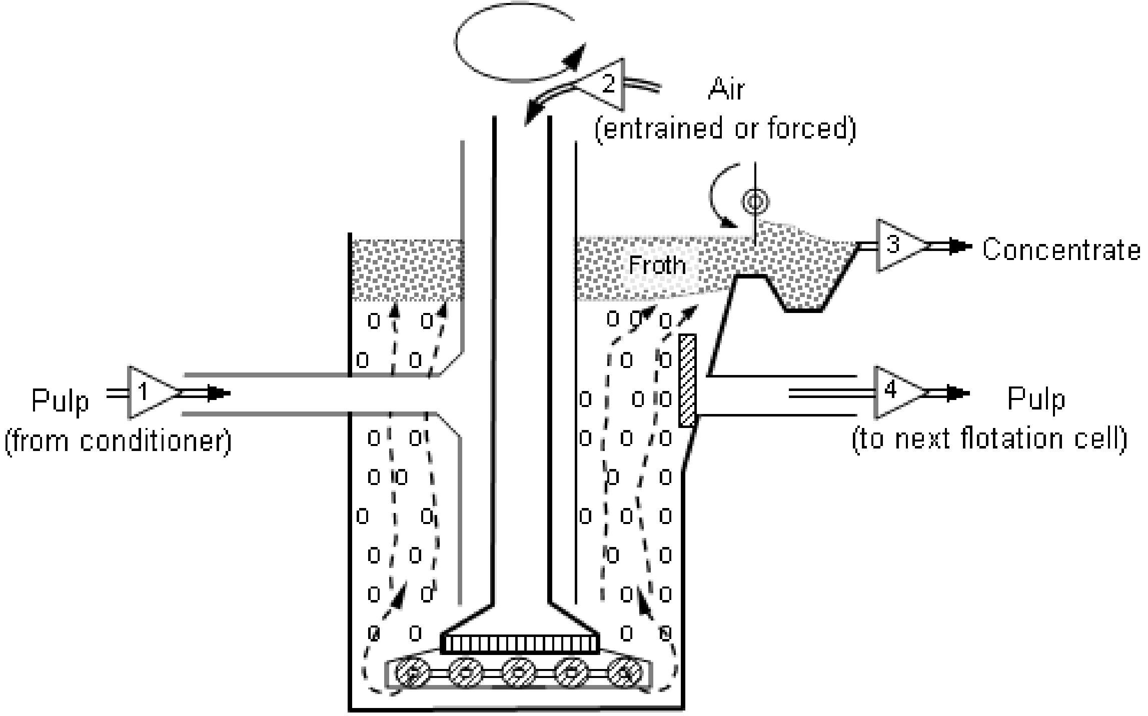
Emulsifiable concentrates
A mixture of surfactant and active ingredient in hydrocarbon - forms emulsion when mixed with water

Droplets should not fly off from leaves – good wetting

Wettable or water dispersible powders – contain surfactant as dispersing agent and stabilizer

Mineral processing

Froth floatation



Surfactants are used as collector (to make the ore hydrophobic) and foamer (stabilize the foam)

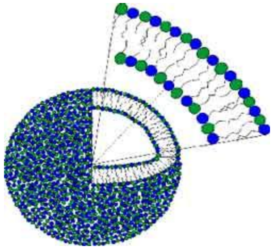
Pharmaceutical formulations

Many drugs are hydrophobic in nature

They can be solubilized and administered using surfactants

Typical formulations include:
Emulsions
Microemulsions
Micelles
Vesicles (liposomes) – uni and multi lamellar

Vesicles can incorporate both hydrophilic and hydrophobic drugs



Miscellaneous applications

Personal Care products - Looking good and feeling good

Shampoos – quarternary amine surfactants
Skin creams – emulsion and gels

Thickeners (viscosity modifier)Enhanced absorption through skin Stability of particles

Foam
Fire fighting – fluorocarbon and polymeric surfactants are used.
Mainly used for oil fire – foam act as a mask for O_2

Foam stability – depends on interfacial tension, viscosity (bulk and surface), film drainage, surface charge etc.