IX

DETERMINATION OF CRITICAL MICELLE CONCENTRATION VIA CONDUCTIVITY MEASUREMENT

I. Aim of experiment

The aim of the study is experimental determination of critical micelle concentration (CMC) by conducitivity measurements of the surfactants solutions.

II. Introductory issues

1. Surface tension of liquids.
2. Surface active agents structure and behaviour:
   a) characterization of the hydrophilic and hydrophobic groups,
   b) localization of the hydrophilic groups in the particle.
3. Surface active agents classification based on their chemical character:
   a) ionic surfactants:
   - cationic,
   - anionic,
   - amphoteric,
   b) nonionic surfactants.
4. Properties of the surface active agent solutions.
5. Methods of critical micelle concentration determination.
6. Surface active agents application:

a) hydrophile–lipophile balance - HLB,
b) commercial and industrial application of surfactants.
7. Technological properties of the surface active agents:
a) solubilization,
b) foams,
c) wetting,
d) emulsification,
e) detergency.

References:

1. J. Ościk, *Adsorption*, PWN Warszawa, 1982.
2. A. W. Adamson, A. P. Gast, *Physical Chemistry of Surfaces*, John Wiley & Sons, Inc., 1997.
3. M. J. Rosen, *Surfactants and Interfacial Phenomena*, John Wiley & Sons, Inc., 2004.

III. Theoretical part

III. 1. Adsorption at the liguid/gas interface

Cohesive forces between molecules are unbalanced at a phase boundary. In the case of the liquid/gas interface, this is because attractive interactions of molecules at the surface with those in the interior of the liquid are greater than those with the widely separated molecules in the gas phase (Fig. 1).

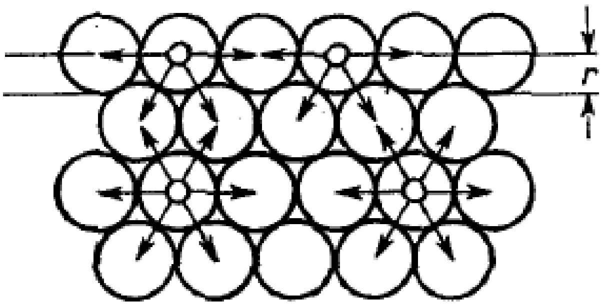


Fig. 1. Surface layer at the liquid/gas interface (r – the radius of intermolecular interaction).

The molecules at the surface of a liquid have potential energies greater than those of similar molecules in the interior of the liquid and therefore are drawn into the liquid phase, whose surface area tends to diminish. Because the potential energies of molecules at the surface are greater than those in the interior of the phase, an amount of work equal to this difference in the potential energy must be expanded to bring a molecule from the interior to the surface to expand it by unit area. **Surface tension** (denoted by γ or σ) is the minimum amount of work required to form unit area of new surface or equivalently the increase of Gibbs free energy corresponding to the formation of unit area of surface. Surface tension is also often conceptualized as a force per unit length at a right angle to the force required to pull apart the surface molecules in order to permit expansion of the surface by movement of molecules into it from the phase underneath it. The units of surface tension are N/m or J/m^2.

Among many liquids, water posses large surface pressure, larger than organic solvents. For solutions there are three possibilities of surface tension changes that depend on the properties and concentration of dissolved substances:

1. the solute has no effect on the surface tension of the solution, then

$$\left(\frac{\delta\gamma}{\delta c_2}\right)_A = 0 \text{ and } \Gamma_2^{(1)} = 0 \tag{1}$$

when the concentration in the surface phase is the same as in the remaining volume of the solution and no adsorption is observed.

2. if increasing concentration of the solute increases the surface tension of the solution, then

$$\left(\frac{\delta\gamma}{\delta c_2}\right)_A > 0 \text{ and } \Gamma_2^{(1)} < 0 \tag{2}$$

3. the solute lowers the surface tension of the solution as its concentration increases (surface active compounds) then

$$\left(\frac{\delta\gamma}{\delta c_2}\right)_A < 0 \text{ and } \Gamma_2^{(1)} > 0 \qquad (3)$$

Which means that the surface active compound accumulates in the surface phase (positive adsorption).

III. 2. Surface active agents structure and behaviour

Surfactants **(SURF*ace* ACT*ive* A*ge*NTS — SURFACTANTS)** have a characteristic molecular structure consisting of a structural group that has very little attraction for the solvent, known as a lyophobic group and a group that has strong attraction for the solvent – lyophilic group. This is known as an amphipathic structure.

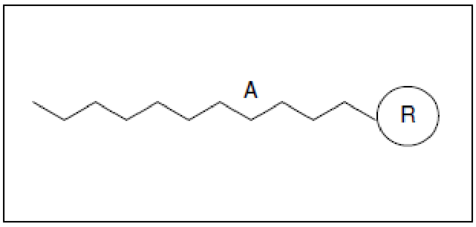


Fig. 2. Surface active agent structure: A – hydrophobic chain, R – hydrophilic group.

When a molecule with an amphipathic structure is dissolved in a solvent, the lyophobic group may distort the structure of the solvent, increasing the free energy of the system. When that occurs, the system responds in some fashion in order to minimize contact between the lyophobic group and the solvent. In the case of a surfactant dissolved in aqueous medium, the lyophobic (hydrophobic) group distorts the structure of the water (by breaking hydrogen bonds between the water molecules and by structuring the water in the vicinity of the hydrophobic group). As a result of this distortion, some of the surfactant molecules are expelled to the interfaces of the system, with their hydrophobic groups oriented so as to minimize contact with the water molecules. The surface of the water becomes covered with a single layer of surfactant molecules with their hydrophobic groups oriented predominantly toward the air. Since air molecules are essentially nonpolar in nature, as are the hydrophobic groups, this decrease in the dissimilarity of the two phases contacting each other at the surface results in a decrease in the surface tension of the water. On the other hand, the presence of the lyophilic (hydrophilic) group prevents the surfactant from being expelled completely from the solvent as a separate phase, since that would require dehydration of the hydrophilic group. The amphipathic structure of the surfactant therefore causes not only concentration of the surfactant at the surface and reduction of the surface tension of the water, but also orientation of the molecule at the surface with its hydrophilic group in the aqueous phase and its hydrophobic group oriented away from it.

The hydrophobic group is usually a long-chain hydrocarbon residue, and less often a halogenated or oxygenated hydrocarbon or siloxane chain. Differences in the nature of the hydrophobic groups are usually less pronounced than those in the nature of the hydrophilic group. Generally, they are long-chain hydrocarbon residues. However, they include such different structures as:

- Straight-chain, long alkyl groups (C8–C20),

- Branched-chain, long alkyl groups (C8–C20),
- Long-chain (C8–C15) alkylbenzene residues,
- Alkylnaphthalene residues (C3 and greater-length alkyl groups),
- High-molecular-weight propylene oxide polymers (polyoxypropylene glycol derivatives),
- Long-chain perfluoroalkyl groups,
- Polysiloxane groups,
- Lignin derivatives

The hydrophilic group is an ionic or highly polar group. The most common hydrophilic groups encountered in surfactants today are presented in Table 1.

Tab. 1. The Most Common Hydrophilic Groups in Commercially Available Surfactants

Class	General structure
Sulfonate Sulfate Carboxylate Phosphate Ammonium Quaternary ammonium Betaines Sulfobetaines Polyoxyethylene (POE) Polyols Polypeptide Polyglycidyl	$R-SO_3^-M^+$ $R-OSO_3^-M^+$ $R-COO^-M^+$ $R-OPO_3^-M^+$ $R_xH_yN^+X^-$ (x=1-3, y=4-x) $R_4N^+X^-$ $RN^+(CH_3)CH_2COO^-$ $RN^+(CH_3)CH_2CH_2SO_3^-$ $R-OCH_2CH_2(OCH_2CH_2)_nOH$ Sucrose, sorbitan, glycerol, ethylene glycol, etc $R-NH-CHR-CO-NH-CHR'-CO-...-CO_2H$ $R-(OCH_2CH[CH_2OH]CH_2)_n-...-OCH_2CH[CH_2OH]CH_2OH$

III. 3. Surface active agents classification

Depending on the nature of the hydrophilic group, surfactants are classified as:

1. **Ionic** – the surface active portion of the molecule possesses ionic charge:
   - **Anionic** - the surface-active portion of the molecule bears a negative charge, e.g. $RCOO^-Na^+$ (soap), $RC_6H_4SO_3^-Na^+$ (alkylbenzene sulfonate).
   - **Cationic** - the surface-active portion bears a positive charge, e.g. $RNH_3^+Cl^-$ (salt of a long-chain amine), $RN(CH_3)_3^+Cl^-$ (quaternary ammonium chloride).
   - **Zwitterionic** - both positive and negative charges may be present in the surface-active portion, e.g $RN^+H_2CH_2COO^-$ (long-chain aminoacid), $RN^+(CH_3)CH_2CH_2SO_3^-$ (sulfobetaine).
2. **Nonionic** - the surface-active portion bears no apparent ionic charge, for example, $RCOOCH_2CHOHCH_2OH$ (monoglyceride of long-chain fatty acid), $RC_6H_4(OC_2H_4)_xOH$ (polyoxyethylenated alkylphenol), $R(OC_2H_4)_xOH$ (polyoxyethylenated alcohol).

III. 3.1 Commercially available anionic surfactants:

1. Carboxylic Acid Salts
2. Sulfonic Acid Salts
3. Sulfuric Acid Ester Salts
4. Phosphoric and Polyphosphoric Acid Esters
5. Fluorinated Anionics

III. 3.2 Commercially available cationic surfactants:

1. Long-Chain Amines and Their Salts
2. Acylated Diamines and Polyamines and Their Salts
3. Quaternary Ammonium Salts
4. Polyoxyethylenated (POE) Long-Chain Amines
5. Quaternized POE Long-Chain Amines
6. Amine Oxides

III. 3.3 Commercially available zwitterionic surfactants:

1. pH-Sensitive Zwitterionics
    - β-N-Alkylaminopropionic Acids, $RN^+H_2CH_2CH_2COO^-$
    - N-Alkyl-β-iminodipropionic Acids,
    - Imidazoline Carboxylates,
    - N-Alkylbetaines, $RN^+(CH_3)_2CH_2COO^-$,
    - Amidoamines and Amidobetaines,
    - Amine Oxides, $RN^+(CH_3)_2O$,
2. pH-Insensitive Zwitterionics
    - Sulfobetaines, Sultaines, $RN^+(CH_3)_2(CH_2)_xSO_3^-$

III. 3.4 Commercially available nonionic surfactants:

1. POE Alkylphenols, Alkylphenol ‘‘Ethoxylates’’
2. POE Straight-Chain Alcohols, Alcohol ‘‘Ethoxylates’’
3. POE Polyoxypropylene glycols
4. POE Mercaptans
5. Long-Chain Carboxylic Acid Esters
6. Alkanolamine ‘‘Condensates,’’ Alkanolamides
7. Tertiary Acetylenic Glycols and Their ‘‘Ethoxylates’’
8. POE Silicones
9. N-Alkylpyrrolidones
10. Alkylpolyglycosides

III. 4. Properties of the surface active agent solutions.

Reduction of surface (liquid/gas) or interfacial (liquid/liquid, liquid/solid) tension is one of the most commonly measured properties of surfactants in solution. It depends directly on the replacement of molecules of solvent at the interface by molecules of surfactant, and therefore on the surface (or interfacial) excess concentration of the surfactant, as is shown by the Gibbs equation:

$$d\gamma = -\sum_i \frac{n_i^\sigma}{A} = -\sum_i \Gamma_i^\sigma d\mu_i \qquad (4)$$

where: $d\gamma$ - the change in surface or interfacial tension of the solvent,

Γ_i^σ - the surface excess concentration of any component of the system,

$d\mu_i$ - the change in chemical potential of any component of the system,

For a two-component system, when the phases in contact are gas (vapour) and solution 1+2, and assuming that solvent (component 1) is present in large excess in the solution ($\Gamma_1^\sigma = 0$) the concentration of surfactant at the interface may therefore be calculated from the surface or interfacial tension data by the use of the appropriate Gibbs equation:

$$\Gamma_2^{(1)} = -\frac{a_2}{RT}\left(\frac{\delta\gamma}{\delta a_2}\right)_{p,T} = -\frac{1}{RT}\left(\frac{\delta\gamma}{\delta \ln a_2}\right)_{p,T} \qquad (5)$$

or for dilute solutions when the activity can be replaced by concentration

$$\Gamma_2^{(1)} = -\frac{c_2}{RT}\left(\frac{\delta\gamma}{\delta c_2}\right)_{p,T} = -\frac{1}{RT}\left(\frac{\delta\gamma}{\delta \ln c_2}\right)_{p,T} \qquad (6)$$

and the surface concentration can be obtained from the slope of a plot of γ versus $\log C_1$ at constant temperature.

A typical $\gamma - \log c_1$ plot for a dilute solution of an individual surfactant is shown in Fig. 3.

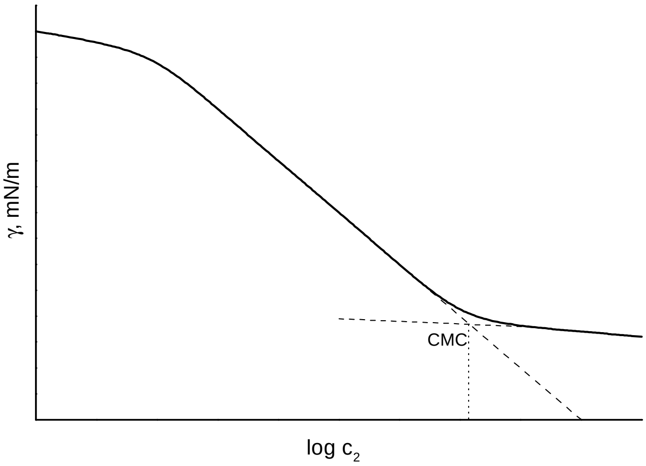


Fig. 3. Plot of surface tension versus log of the bulk phase concentraion for anaqueous solution of a surfactant.

In very dilute solution the surfactant exists in the monomeric form. The break in the curve occurs at the critical micelle concentration (CMC), the concentration at which monomers aggregate to form a surfactant cluster known as a micelle. Above this concentration the surface tension of the solution remains essentially constant because only the monomeric form contributes to the reduction of the surface or interfacial tension.

For concentrations below but near the CMC the slope of the curve is essentially constant, indicating that the surface concentration has reached a constant maximum value.

The shape of the micelle produced in aqueous media is of importance in determining various properties of the surfactant solution, such as its viscosity, capacity to solubilize water-insoluble material etc

In aqueous media, the surfactant molecules are oriented in all these structures, with their polar heads predominantly toward the aqueous phase and their hydrophobic groups away from it.

The major types of micelles appear to be:

- relatively small, spherical structures (aggregation number <100),
- elongated cylindrical,
- rodlike micelles with hemispherical ends (prolate ellipsoids),
- large, flat lamellar micelles (disklike extended oblate spheroids),
- vesicles—more or less spherical structures consisting of bilayer lamellar micelles arranged in one or more concentric spheres.

Tab 2. Effect of Hydrophilic Group on the CMCs of Surfactants with Common Hydrophobes

Hydrophobe	Hydrophile	Temperature (^{o}C)	cmc (mM)
$C_{12}H_{25}$	COOK	25	12.50
’’	$-SO_3K$	25	9.00
’’	$-SO_3Na$	25	8.10
’’	$-NH_3Cl$	30	14.00
’’	$-N(CH_3)_3Cl$	30	20.00
’’	$-N(CH_3)_3Br$	25	16.00
$C_{16}H_{23}$	$-NH_3Cl$	55	0.85
’’	$-N(CH_3)_3Cl$	30	1.30
’’	$-N(CH_3)_3Br$	60	1.00
C_8H_{17}	$-OCH_2CH_2OH$	25	4.90
’’	$-(OCH_2CH_2)_2OH$	25	5.80
C_9H1_9	$-COO(CH_2CH_2O)_9CH_3$	27	1.00
’’	$-COO(CH_2CH_2O)_{16}CH_3$	27	1.80
$C_{10}H_{21}$	$-O(CH_2CH_2O)_8CH_3$	30	0.60
’’	$-O(CH_2CH_2O)_{11}CH_3$	30	0.95
’’	$-O(CH_2CH_2O)_{12}CH_3$	29	1.10

III. 5. Methods of the critical micelle concentration determination

Many physical properties of surfactant solutions show consistent behaviour with the increasing concentration. Sharp changes in properties occur in the region of CMC. It is because in that region aggregation of the surfactants into fairly large micelles occurs. Above the CMC, additional surfactants form additional micelles leaving a concentration of single chains constant at about the CMC.

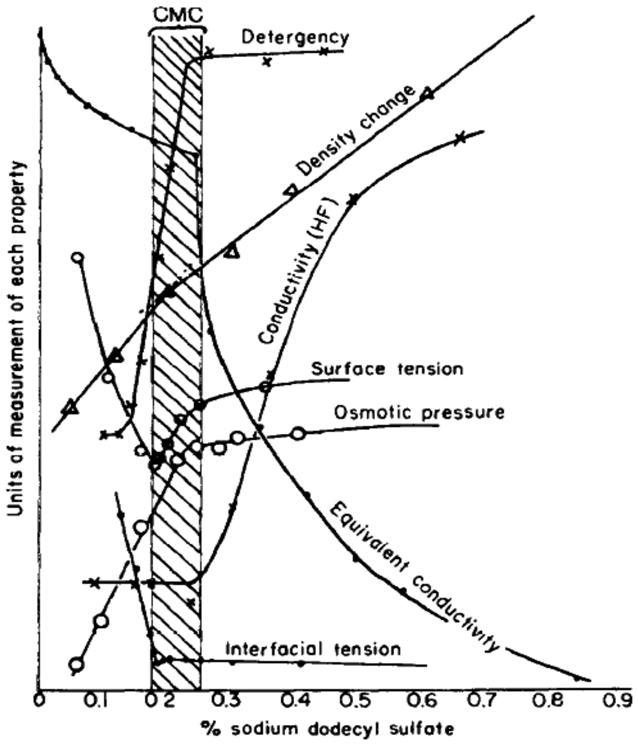


Fig. 4. Changes in properties of sodium dodecyl sulfate solution.
[W.C. Preston, *J. Phys. Coll. Chem.*, 52, 84 (1948)].

Changes in the properties of surfactant solution as a function of surface active agent concentration are used to determine its critical micelle concentration. Some of the method used are:

- surface tension measurements,
- electrical conductivity measurements,
- refractive index measurements,
- light scattering measurements,
- light absorption measurements,
- polarographic methods,
- solubilizing methods, etc.

III. 6. Surface active agents application

III. 6.1. The Hydrophile–Lipophile Balance (HLB)

It has been a long-term goal of surface science to devise a quantitative way of correlating the chemical structure of surfactant molecules with their surface activity that would facilitate the choice of material for the use in a given formulation. The first reasonably successful attempt at that aim was the HLB system (so-called hydrophile–lipophile balance (HLB) number) first developed by Griffin. He proposed to calculate the HLB number of a surfactant from its chemical structure.

For nonionic surfactants with polyoxyethylene solubilizing groups, the HLB may be calculated from the formula.

$$\mathrm{HLB} = \frac{\mathrm{mol\%hydrophilic\ group}}{5} \tag{7}$$

In such a calculation, an unsubstituted polyoxyethylene glycol would have an HLB of 20.

Surfactants based upon polyhydric alcohol fatty acid esters such as glycerol monostearate can be handled by the relationship

$$\mathrm{HLB} = 20(\frac{1-\mathrm{S}}{\mathrm{A}}) \tag{8}$$

where *S* is the saponification number of the ester and *A* is the acid number of the acid.

For materials that cannot be completely saponified, an empirical formula of the form is

$$\mathrm{HLB} = \frac{\mathrm{E}+\mathrm{P}}{5} \tag{9}$$

where E is the weight percent of polyoxyethylene chain and P is the weight percent of polyhydric alcohol (glycerol, sorbitan, etc.) in the molecule.

Davies and Rideal suggested that HLB numbers could be calculated based upon group contributions according to the formula

$$\mathrm{HLB} = 7 + \Sigma(\mathrm{hydrophilic\ group\ numbers}) - \Sigma(\mathrm{hydrophobic\ group\ numbers}) \tag{10}$$

Some typical group numbers as listed by Davies and Rideal, as well as other investigators, are listed in Table 3.

Tab. 3. Group Numbers for the Calculation of HLBs According to Davies and Rideal

Group	HLB Number	Group	HLB Number
Hydrophilic		Hydrophobic	
$-SO_4Na$	38.7	$-CH_2-$	-0.475
-COOK	21.1	$-CH_3$	-0.475
-COONa	19.1	=CH-	-0.475
-N (tertiary amine)	9.4	$-CF_2-$	-0.87
-COOH	2.1	$-CF_3$	-0.87
-OH (free)	1.9	$–CH_2–CH_2–O–$	0.330

Hydrophile-lipophile balance (HLB) is a very useful conceptual tool that allows to predict surfactants practical application.

Tab. 4. The use of HLB number

Application	HLB
antyfoaming agents	1.5 – 3
W/O emulsion	3 – 8
wetting agents	7 – 9
O/W emulsion	9 – 13
cleaning agents	13 – 15
solubilizing agents	15 - 18

III. 6.2. Commercial and industrial application of surfactants

The use of surfactants is increasing. However, it should be noticed that each application may have specific requirements that determine the utility of a particular structure. Besides economic considerations can often be almost as important as surface activity in selecting a surfactant for a given application (the least expensive material producing the desired effect will usually be chosen). To make a rational selection, without resorting to an expensive and time-consuming trial-and-error approach, there is required some knowledge of:

- the surface and interfacial phenomena that must be controlled,
- the characteristic chemical and physical properties of the available surfactant choices,
- the relationships between the structural properties of the available surfactants and their effects on the pertinent interfacial phenomena,
- any restrictions to the use of available materials, as in, for example, foods, cosmetics, or pharmaceuticals,
- economic constraints on the choice of surfactant should be taken into account.

Some of the major areas of surfactants application are listed in Tab.5.

Tab. 5. Some of the Major Modern Applications of Surfactants

Industrial	Consumer
Agricultural crop applications	Adhesives
Building materials	Cleaning fluids
Cement additives	Cosmetics
Coal fluidization	Disinfectants
Coating and levelling additives	Foods and beverages
Electroplating	Household cleaning and laundering
Emulsion polymerization	Paints
Graphic arts	Pharmaceuticals
Industrial cleaning	Photographic products
Leather processing	Soaps, shampoos, creams
Lubrication	Waxes and polishing agents
Mold release agents	
Ore flotation	
Paper manufacture	
Petroleum recovery	
Printing and printing inks	
Surface preparations	
Textiles	
Waterproofing	

III. 7. Technological properties of the surface active agents

Solubilization is one of the important properties of surfactants that may be defined as the spontaneous dissolving of a substance (solid, liquid, or gas) by reversible interaction with themicelles of a surfactant in a solvent to form a thermodynamically stable isotropic solution with reduced thermodynamic activity of the solubilized material. Although both solvent-soluble and solvent-insoluble materials may be dissolved by the solubilization mechanism, the importance of the phenomenon from the practical point of view is that it makes possible the dissolving of substances in solvents in which they are normally insoluble. For example, although ethylbenzene is normally insoluble in water, almost 5 g of it may be dissolved in 100 mL of a 0.3 M aqueous solution of potassium hexadecanoate to yield a clear solution.

Wetting in its most general sense is the displacement from a surface of one fluid by another. Wetting, therefore, always involves three phases, at least two of which are fluids: a gas and two immiscible liquids, or a solid and two immiscible liquids, or a gas, a liquid, and a solid, or even three immiscible liquids. Commonly, however, the term wetting is applied to the displacement of air from a liquid or solid surface by water or an aqueous solution, and we restrict our discussion for the most part to those situations. The term wetting agent is applied to any substance that increases the ability of water or an aqueous solution to displace air from a liquid or solid surface.

Foam is produced when air or some other gas is introduced beneath the surface of a liquid that expands to enclose the gas with a film of liquid. Foam has a more or less stable honeycomb structure of gas cells whose walls consist of thin liquid films with approximately plane parallel sides. These two-sided films are called the lamellae of the foam. Where three or more gas bubbles meet, the lamellae are curved, concave to the gas cells, forming what is called the Plateau border or Gibbs triangles.

Emulsions are heterogeneous mixtures of at least one immiscible liquid dispersed in another in the form of droplets, the diameters of which are, in general, greater than 0.1 μm. Such systems possess a minimal stability, generally defined rather arbitrarily by the application of some relevant reference system such as time to phase separation or some related phenomenon. Stability may be enhanced by the inclusion of additives such as surfactants that are the most widely studied and perhaps best understood class of emulsifiers and stabilizers. Because of their effectiveness at lowering interfacial tensions, they are of vital importance to most practical systems, facilitating the formation of small
droplets with a minimum of power input.

Detergency may be defined as the removal of foreign material from solid surface by surface-active agents. This definition includes liquid and solid soil removal from fabrics, metal surface etc., while excluding purely mechanical and purely chemical cleansing. Soap is the oldest detergent and its use in laundering clothes is the oldest and most familiar detergent action. Detergency is very important for both industries and consumers.

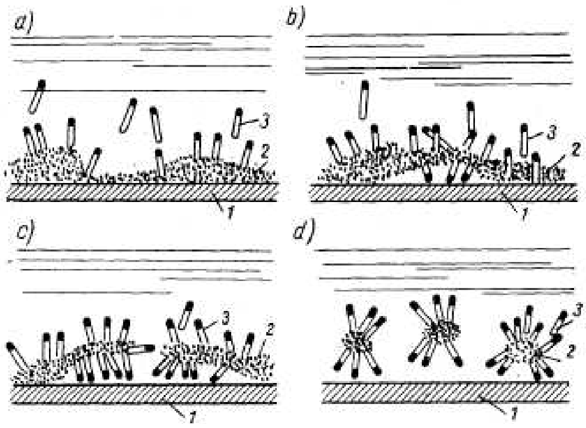


Fig. 3. Scheme of fabric cleaning using surface active agent solution.
[T. Hofmann, T. Kozłowski, *Towaroznawstwo srodków pioracych i czyszczacych*, ZW CRS, Warszawa (1973)].

IV. Experimental

A. Equipments and chemical reagents

1. Measuring apparatus: conductometer „CC-501”.
2. Equipments:
   - measurement beacker – 1 piece,
   - 50 ml volumetric flask – 1 piece,
   - 100 ml bottle – 10 pieces,
   - volumetric pipette of volume 5 and 25 ml,
3. Reagents:
   - sodium dodecyl sulfate (SDS – $C_{12}H_{25}SO_4Na$) aqueous solution of concentration $5{\cdot}10^{-2}$ M,
   - Cetyl trimethylammonium bromide (CTAB – $CH_3(CH_2)_{15}(CH_3)_3NBr$) aqueous solution of concentration $5{\cdot}10^{-3}$ M.

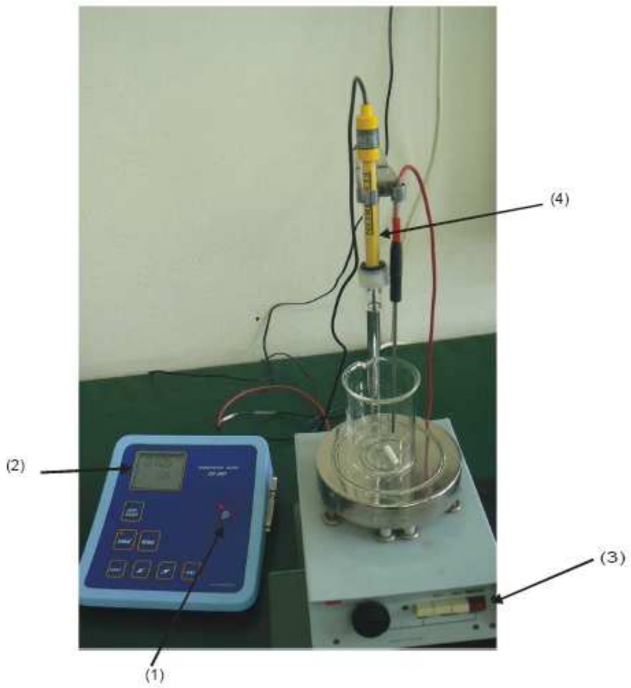
B. Scheme of experiment

1. The conductivity measurements of SDS and CTAB aqueous solutions .
2. Making the curve showing the conductivity (σ) dependence on the solution concentration $\sigma = f(\log c)$.
3. Conducting adsorption for 60 min. (mixing of bottle contents several times).
4. Determination of the critical micelle concentration based on the graphical dependence $\sigma = f(\log c)$.

C. Operation of the device

The conductivity measurements:

1. Plug in the conductometer and switch on (1).
2. Fill the measurement beaker with the measured solution, immerse the electrode (4) and the temperature sensor in the solution.
3. After the conductivity stabilization read its value from the conductometer display (2).
4. Changing the solution, rinse the measurement beaker, electrode and temperature sensor with distilled water.
5. After measurements switch off the conductometer (1).
6. Rinse the measurement beaker, electrode and temperature sensor with distilled water.
7. Put the coat with water on the electrode.



Attention!
To avoid measuring error immerse the whole electrode in the solution to the level of 1 cm from the beaker's bottom and walls.

Fig. 4. Conductometer.

D. Experimental setup

1. Adsorption

1. Take 0.6 ml of the $5 \cdot 10^{-2}$ M SDS solution (basic solution), transfer into the 50 ml volumetric flasks and add distilled water until the bottom of the meniscus touches the graduation line. Then pour the obtained solution to the bottle number 1. In a similar way prepare other solutions taking in succession: **0.8, 1, 2, 4, 6 8, 10 and 25** ml of the basic solution. Calculate molar concentrations of the prepared solutions.
2. Measure the conductivity of the basic solution and all the prepared solutions by means of the conductometer.
3. Pour out the solutions and wash the bottles with distilled water.
4. Take 2 ml of the $5 \cdot 10^{-3}$ M CTAB solution (basic solution), transfer into the 50 ml volumetric flasks and add distilled water until the bottom of the meniscus touches the graduation line. Then pour the obtained solution to the bottle number 1. In a similar way prepare other solutions taking in succession: **4, 6, 8, 10, 20 and 30** ml of the basic solution. Calculate molar concentrations of the prepared solutions.
5. Then carry out the actiones according to pp. 2 and 3.

E. Results and conclusions

1. Make the graph $\sigma = f(\log c)$.
2. Based on the obtained curve determine CMC via extrapolation of the point of intersection line above and below CMC .

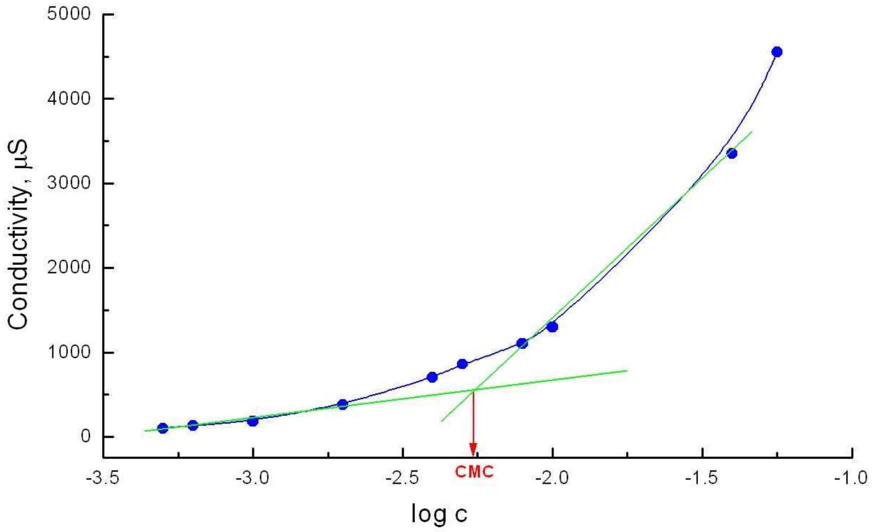


Fig. 5. Solution conductivity as a function of its concentration.

3. Compare the obtained value of CMC with those found in literature.
4. Put the obtained results in the table:

SDS		CTAB	
Concentration [mol/ml]	Conductivity [µS]	Concentration [mol/ml]	Conductivity [µS]