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DETERMINATION OF CRITICAL MICELLE CONCENTRATION OF SODIUM DODECYL SULFATE IN DISTILLED WATER AT 298.15K BY SURFACE TENSION MEASUREMENTS

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Abstract:

Surfactants are chemicals that adsorb to the interface between a solution and another phase (gases or solids) and self-assemble molecular clusters known as micelles in a solution (water or oil phase). Measurements of the surface tension of sodium dodecyl sulfate (SDS) in distilled water at 298.15K are reported. The increase of concentration of sodium dodecyl sulfate (SDS) in distilled water then decreased in surface tension at 298.15K. Critical micelle concentration (CMC) decreased with a decrease in surface tension. The graphs of surface tension versus concentration were made to determine the CMC of the solution.

Keywords: surface tension, sodium dodecyl sulfate (SDS), distilled water, temperature, critical micelle concentration (CMC)

Introduction:

A surfactant is an organic compound containing two different groups of molecule solvent-loving group called lyophilic (hydrophilic/polar group) and the solvent hating/fearing group is called lyophobic (hydrophobic /non polar group) (Burlatsky et al., 2013)cmc. They self aggregate in aqueous solution and aggregated form is called micelle due to the polar and non polar group present in their structure (Chakraborty et al., 2011).

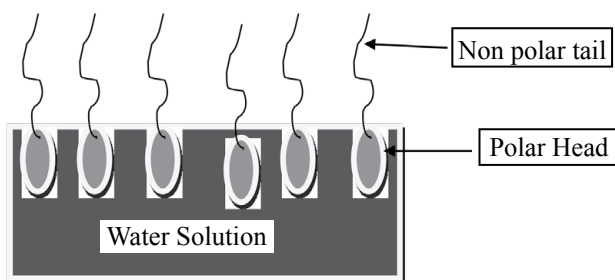


Fig 1: surfactants in water

Surface tension is a measure of the free energy of the surface per unit area. -When it is present in the liquid or solvent then it alters the surface properties of the liquid/solvent. As it contains two opposing groups, the hydrophilic portion of surfactants orient itself within the solution and hydrophobic group orient itself away from the solution. This orientation of the surfactant reduces the free energy of the surface, thus decreasing surface tension and increasing surface viscosity (Jha et al., 2013).

Surfactants lessen the force required to produce a smallest possible surface area. When surfactants are present, the solution's surface tension decreases (Sharma et al., 2016). Surface tension is reduced compared to the pure solvent state as surfactant is added. The critical micelle concentration is the limiting value of surfactant concentration that results in a drop in surface tension (Sachin et al., 2019).

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Additionally, only at high surfactant concentrations is a steeper reduction in surface tension has been seen. Since the hydrogen bond—a relatively weak bond—is the primary mechanism for association between two molecules when the temperature rises, the molecular interactions between liquid molecules become weaker. This results in a drop in surface tension. It has been reported that the surface tension reduces with rising temperatures (Shah et al., 1970). The increased surface activity at the higher temperatures is responsible for this drop, and the adsorption of contaminants in the system was proposed as the cause of this anomaly. In this study, a surface tension technique analysis of the aggregation of SDS at 298.15K in aqueous.

The force, which is responsible for the tension at the surface of the liquid is called surface tension. It is defined as force in dynes acting upon the line of unit length on the surface of the liquid. The surface tension is denoted by γ and its units are dynes/cm in CGS unit. In SI unit Newton/meter the two units are related as $1 \text{ Nm}^{-1} = 10^3 \text{ dynes cm}^{-1}$.

More about surface tension: (referenced from Wikipedia) Surface tension is an effect within the surface layer of a liquid that causes that layer to behave as an elastic sheet. It allows insects, such as the water strider to walk on water. It allows small metal objects such as needles, razor blades, or foil fragments to float on the surface of water, and it is the cause of capillary action. The physical and chemical behavior of liquids cannot be understood without taking surface tension into account. It governs the shape that small masses of liquid can assume and the degree of contact a liquid can make with another substance. Surface tension is caused by the attraction between the molecules of the liquid by various intermolecular forces. In the bulk of the liquid each molecule is pulled equally in all directions by neighboring liquid molecules, resulting in a net force of zero. At the surface of the liquid, the molecules are pulled inwards by other molecules deeper inside the liquid and are not attracted as intensely by the molecules in the neighboring medium (e.g., vacuum, air or another liquid). Therefore all of the molecules at the surface are subject to an inward force of molecular attraction which can be balanced only by the resistance of the liquid to compression. This inward pull tends to diminish the surface area, and in this respect a liquid surface resembles a stretched elastic membrane. Thus the liquid squeezes itself together until it has the locally lowest surface area possible.

Some surfactant molecules move to the water's surface when a surfactant is added to a liquid like water. As a result, this water/surfactant compound develops a layer of weakly attracted molecules on its surface. Compared to if it were only water, this liquid has less surface tension. The surfactant lowers the surface tension of water by adhering at the liquid-gas interface. They also reduce the friction between oil and water by adsorbing at the liquid-liquid contact.

The meaning of surface tension is a chemical phenomenon that happens at the surface of a liquid where the liquid becomes denser than the rest. The presence of dissolved solute or impurities on the surface affects the surface tension of the liquid. When highly soluble substances are present, water or any other solvent becomes more viscous, whereas sparingly soluble substances lower the surface tension of water or any other solvent. As the temperature rises, the surface tension of the liquid drops (de Castro et al., 1998).

Surfactant lowers inter-facial tension and alters how easily water or oil will wet a solid surface by adhering to it. A decrease in water-wetting and an increase in oil-wetting will occur when the orientation of the adsorbed surfactant is such that its hydrophobic tail groups point away from the surface or along the surface (Schramm et al., 2003). (Bhattarai et al., 2013) the surface-active agent, which is the main ingredient in synthetic detergents, is supported in its cleaning agent function by the builders used (sometimes called built detergents). Construction materials like phosphates, metasilicates, and carbonates help emulsify and suspend soil in aqueous solutions. The molecules of

the compounds that serve as surface-active agents have two groups, one of which is hydrophobic and the other hydrophilic. At this point, it is important to clarify that hydrophilic refers to a preference for water whereas hydrophobic denotes a preference for oil or a dislike of water. Therefore, when a surface-active agent has two groups present, it possesses surface-active qualities, or the capacity to alter the interfacial interaction between two dissimilar substances like oil and water.

Classification of surfactants

After discussing and defining a surface-active agent and other terminologies associated with these compounds, it is time to organize them into the three classes that are most familiar to the industrial world: anionics, cationics, and nonionics.

Anionic surfactants

The reaction of an organic substance, such as a high molecular weight acid or alcohol, and an inorganic substance, such as sodium hydroxide or sulfuric acid, results in an anionic surface-active agent. In the end result of this reaction, the sodium ion-containing water-soluble portion of the molecule has a positive charge, while the organic portion of the molecule have -ve charge. example are ammonium lauryl sulfate, sodium laureth sulfate.

Cationic surfactants

In reactions involving primary, secondary, or tertiary fatty amines and alkyl halides, cationics are produced. It is called a cationic surface-active agent because the water-soluble portion of the molecule is negatively charged and the water-insoluble portion of the molecule is positively charged in this case.

In acid media, wetting agents made of cationic surface-active substances are employed to lower surface tension. The lack of detergent activity when mixed into an alkaline solution is a drawback of cationic surface-active agents. Example are cetyltrimethylammonium bromide (cetrimide), benzethonium chloride and benzalkonium chloride.

Non ionic surfactants

Since all of the surface-active compounds produced by Texaco Chemical Company fall under this category, it is this group of surface-active agents that we are most interested in. The hydrophobic/hydrophilic balance of nonionic surface-active chemicals, which results in neither a positive nor a negative charge in any half of the molecule, is what gives them their nonionic name. The benefit of these surface-active substances is that they are not impacted by As anionic and cationic surfactants are affected by water hardness or pH variations, it is frequently advantageous that they are regarded as medium- to low-foaming agents. When a very low foaming surface-active agent is required, it is very advantageous. The diagram below provides an illustration of the chemical composition of a nonionic surface-active agent.(Niraula et al., 2018)

A surface-active agent's hydrophil/lipophil balance is also gauged by a cloud point. A surfactant is a water soluble surface active agent if it can have its cloud point run in an aqueous solution; otherwise, it is either water dispersible or oil soluble in nature when its cloud point must be run in an aqueous/solvent mixture. Nonionic surface-active agents have a cloud point that changes depending on the nonionic surface-active agent's hydrophil/lipophil balance because they are less soluble in aqueous solutions at high temperatures.

As you can see, we've categorized nonionic surface-active agents into three groups depending on how well they dissolve in water. We've also provided two methods for classifying a surfactant, including computing the hydrophil/lipophil balance and measuring this balance using a cloud point. example are monoglyceride of long-chain fatty acids, polyoxyethylenated alkylphenol.

Amphoteric surfactants

Surface-active compounds with both acidic and alkaline properties are known as amphoteric surfactants. Sodium stearate is a good example of a surfactant. It is the most common surfactant in soap. Another common surfactant is 4-(5-dodecyl)benzenesulfonate. Other examples include docusate (dioctyl sodium sulfosuccinate), alkyl ether phosphates, benzalkonium chloride (BAC), and perfluorooctanesulfonate (PFOS).

Methodology:

Material and Methods:

The anionic surfactant SDS was purchased from Loba Chemie Private Limited (Mumbai, India). SDS was highly pure (99.0%) and used after drying it for 1 h.

All solutions were prepared in triply distilled water. 2.88gm of SDS was dissolved in 100 ml volumetric flask to obtain a stock solution. This stock solution was used to make a series of solutions in distilled water as given below. The surface tension measurement was carried at a constant temperature of 298.15 K using a thermostat in the Chemistry laboratory of Dhankuta multiple campus.

Preparation of samples of research work in distilled water:-

- (1) 1ml SDS solution +14 ml distilled water =15ml
- (2) 2ml SDS solution +13 ml distilled water =15ml
- (3) 3ml SDS solution +12 ml distilled water =15ml
- (4) 4ml SDS solution +11 ml distilled water =15ml
- (5) 5ml SDS solution +10ml distilled water =15ml
- (6) 6ml SDS solution +9ml distilled water =15ml
- (7) 7ml SDS solution +8 ml distilled water =15ml
- (8) 8ml SDS solution +7 ml distilled water =15ml
- (9) 9ml SDS solution +6 ml distilled water =15ml

Surface tension was measured using a stalagmometer by a drop count method.

Surface tension of given liquid can be calculated by following expression,

$$\gamma_2 = \frac{n_1}{n_2} \cdot \frac{d_2}{d_1} \times \gamma_1$$

Where,

γ_1 - Surface tension of water

γ_2 - Surface tension of given liquid.

d_1 - Density of water

d_2 - Density of given liquid

n_1 : Number of drops of water

n_2 : Number of drops of given liquid

$d = M/V$

d = density of liquid, M = mass of liquid, V =volume of solution

Results and Discussions:

The experimental data of surface tension of various solutions of SDS in distilled taken at 298.15K using stalagmometer is tabulated in table 1 and plotted in Fig. 2.

S.N	Concentration(M)	Density) (gm/cm ³)	Surface tension γ (N/m)
1.	0.0066	0.972	21.556
2.	0.0133	0.973	20.073
3.	0.0200	0.976	18.384

4.	0.0266	0.980	17.335
5.	0.0333	0.992	16.217
6.	0.0400	0.999	15.18
7.	0.0466	1.0077	14.78
8.	0.0533	1.0166	14.43
9.	0.0600	1.0198	13.59

Surface Tension of SDS in distilled water at 298.15K is shown in Graphically

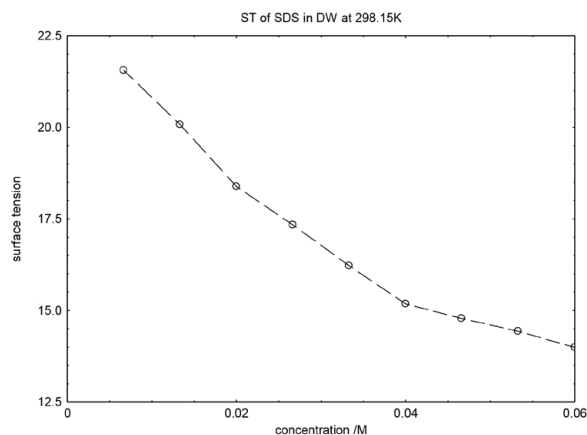


Fig 2: Surface tension of SDS in Distilled water at 298 K.

In the Fig. 2, a linear decrease in surface tension can be seen with the increase in surfactant (SDS) concentration. From the plot, the Critical Micellar Concentration (cmc) was obtained at the intersection of lines of different slopes.

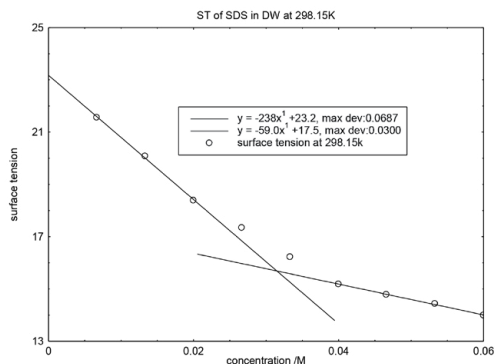


Fig 3: CMC of SDS in Distilled water at 298.15K

The cmc was the threshold surfactant concentrations required to saturate the air/solution interface and were obtained from the sharp breaks in the surface tension versus surfactant concentration. It is observed that in a given the cmc of SDS is 0.03184M obtained by solving the equation

$$\text{Straight line, } y = -238x + 23.2$$

$$\text{Straight line, } y = -59.0x + 17.5$$

Two factors must be considered to explain this significant influence of the cmc value of SDS:

(a) the presence of surfactants increases the cohesive energy density, or the solubility parameter, of water, thus decreases the solubility of the surfactant and hence decreasing the cmc.

(b) the co-solvent causes an increment in the relative permittivity of the aqueous phase, favouring the mutual attraction of the ionic heads in the micelle, thus supporting micellisation and decreasing the cmc

Critical micelle concentration (CMC), the minimum concentration at which the formation of a micelle begins, of SDS in distilled water at 298.15 K was determined to be 0.03184M. The CMC is determined by locating the break in the plot of the surface tension versus the concentration of surfactant solution at a given temperature, as shown in **Figs. 3**. This micellization can be explained on the basis of hydrophobic interaction between tails and electrostatic repulsion between ionic heads (Niraula et al., 2018). Hydrophobic interaction depends on the dielectric constant of the medium. Water has higher dielectric constant.

Conclusions:

From the above results, it is concluded that a decrease in surface tension of sodium dodecyl sulphate with concentration is observed. The CMC of sodium dodecyl sulphate (SDS) in distilled water at 298.5 K is found to 0.03184M.

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