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Original Research Article

Effect of Sodium Chloride on the Micellization of Sodium Dodecyl Sulphate in Water and Methanol-Water systems

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Abstract

Precise measurements of the conductivity of sodium dodecyl sulphate (SDS) in the presence and absence of NaCl in water and methanol-water systems at 318.15 K are reported. The SDS concentration was varied from 0.001 to 0.035 $molL^{-1}$. A sharp increase in conductivity occurred with increase in SDS concentration and the addition of NaCl. The conductivity of SDS in methanol-water medium decreased with increase in methanol concentration regardless of NaCl. The critical micelle concentration of SDS increased with increase in methanol concentration in methanol-water system, while it decreased with the presence of salt in water and methanol-water systems.

Keywords: conductivity, sodium dodecyl sulphate, critical micelle concentration, mixed solvent media

Introduction

Surfactants are very important for our daily life, environment and industries (Li, 2011). The term surfactant comes by blending of surface and active agent. Surfactants are organic compounds which lower surface tension between two liquids or between a liquid and a solid at relatively low concentration, it means they show surface activity (Schramm et al., 2003). Each surfactant molecule is composed of a hydrophilic moiety (water-loving) head group and hydrophobic moiety (water-hating) tail group, it means they have an amphiphilic structure (Tang et al., 2013) as shown in Figure. 1.

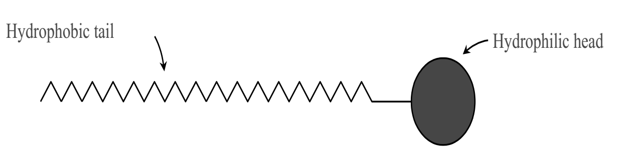

Figure1: Representative structure of a surfactant molecule, showing hydrophilic and hydrophobic groups

The hydrophobic moiety contains nonpolar tail group and is generally insoluble in water but soluble in the oil phase while the hydrophilic moiety contains polar functional head group and it is soluble in the water phase (Tadros, 2002). In aqueous solution hydrocarbon chain or alkyl group is called hydrophobic because it dislikes water and the polar or nonpolar head group is called hydrophilic because it likes water (Teegarden, 2004). One of the important properties of surfactants is their self-association which organizes molecular structures such as micelles (Khan and Shah, 2008). When surfactants are dissolved in water or any other polar solvents and reached to a certain value of concentration, ions or molecules of surfactants come closer and start to associate forming a complex unit called micelle (Salager, 1994) as shown in figure. 2.

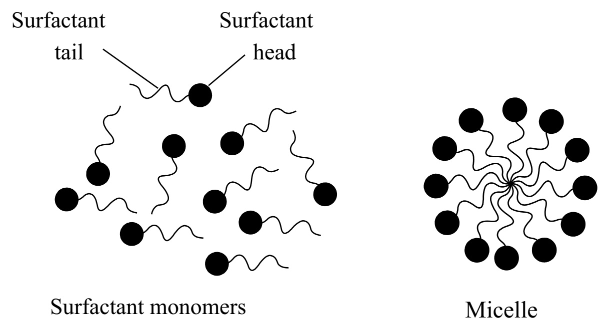

Figure 2: Representation of surfactant monomers and surfactant micelle

There are mainly three types of surfactants, viz., cationic, anionic and zwitter ionic (amphoteric) (Li, 2011). Sodium dodecyl sulphate (SDS) is one of the most important and highly studied anionic surfactants known to Science (Warra, 2013). Anionic surfactants are mainly used as cleansing agent in many detergent formulations (Yangxin, et. al., 2008). Sodium dodecyl sulphate is also known as sodium lauryl sulphate etc.

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The physical properties of surfactants, viz., specific conductance, surface tension etc., change with concentration, presence of other ions, nature of alkyl (hydrophobic) groups, and solvent. Such a change in physical properties with increase in concentration occurs slowly and then abruptly at a certain concentration called critical micelle concentration (CMC) (Tadros, 2002). Due to the effect of counter ion on the micelle, the aggregation behavior of ionic surfactants is affected by electrolytes. NaCl significantly influences on the micellization of SDS in aqueous solution, where Na^+ (counter ion) plays an important role but not chloride ion as acetate ion, propionate ion etc. (Umlong and Ismail, 2006). The values of conductance as well as CMC of SDS change with the addition of methanol in water in the presence and absence of NaCl. Methanol changes the properties of water in methanol-water system by lowering the dielectric constant of water (Arscott, et. al., 1995).

In the present study, the conductance of SDS in water and methanol-water systems with and without the addition of NaCl was determined at 318.15 K. The critical micelle concentration was also calculated.

Materials and Methods

Methanol (Merck, India) was distilled with phosphorous pentoxide and then redistilled over calcium hydride. The purified solvent had a density of 0.77723±0.00004 g/cm^3 at 308.15 K which was measured by the use of an Ostwald-Sprengel type pycnometer of 25 cm^3 capacity (Niraula et. al., 2012). The solvent was transfused into the pycnometer by using a medical syringe. The pycnometer was then tightly fixed in a thermostat at the experimental temperatures within 0.005 K. After thermal equilibrium was attained, the mass of the pycnometer with methanol and with distilled water were measured using an electronic balance (Afcoset, ER-200A, India), and the density was calculated. Density measurements were within 0.00005 g cm^{-3}, which was satisfactory for our purpose.

Preparation of methanol-water mixed solvents

Distilled water (double distilled) with a specific conductance less than 10^{-6} S cm^{-1} was used for the preparation of mixed solvents containing 0.1, 0.2, 0.3 and 0.4 volume fraction of methanol.

Preparation of sodium dodecyl sulphate (SDS)solution

Sodium dodecyl sulphate (Merck Specialties Pvt. Ltd., Mumbai, India) was dried in an electric oven at 333.15 K for 1 h and used to prepare 0.05 M SDS solutions in water and in methanol-water mixed solvents at 318.15 K.

Preparation of NaCl solution

Sodium chloride (A.R. grade, Ranbaxy chemical company, Mumbai, India) was dried in an electric oven at 333.15 K for 1 h and used for the preparation of 0.1 and 0.01M solutions in water and in methanol-water mixed solvents at 318.15 K.

Measurement of conductance

Conductance was measuredwith a Labtronics ISO 9001:2000 certified conductivity meter at a frequency of 2000 Hz using a dip-type cell with a cell constant of 1.15 cm^{-1} and an uncertainty of 0.01%. The cell was calibrated by the method of Lind and co-worker (Lind et al., 1959) using 0.1 M aqueous potassium chloride solution. The measurementwas made in a water bath maintained at 318.15±0.005 K.

Several independent solutions were prepared and experimental runs were performed to ensure the reproducibility of the results. A due correction was made for the specific conductance of the solvent by subtracting the specific conductance of the relevant solvent medium from those of the electrolyte solutions. In all cases, the experiments were performed in triplicates.

The conductance of sodium dodecyl sulphate in water and in methanol-water mixed solvents both in the presence and absence of NaClwere measured at 318.15 K. After taking conductance of the prepared solutions, the solutions were diluted by internal dilution method (5 mL of the solution was taken out and 5 mL of the solvent was added using separate pipettes of 5mL capacity) and the conductance of each of the diluted solutions were measured. The specific conductance (κ) was plotted against the concentration (C) of the solution.

Results and Discussion

The specific conductivities of sodium dodecyl sulphate in water and in 0.10 volume fraction of methanol systems in the presence and absence of 0.01M NaCl at 318.15 K are represented in Figures 3 and 4.

It was found that specific conductance increased with increase in the concentration of SDS and decreased with increase in the volume fraction of methanol in methanol-water mixed solvent regardless of NaCl (Figures 3-4). Similar result was also reported by Khanand Shah (2008). The increase in specific conductance with the increase in SDS concentration is due to increase in a number of ions {current carrying species (Na+ and $C_{12}H_{25}SO_4^-$)}. Effect of methanol concentration in water-methanol system on the specific conductance of SDS is shown in Figure 5. Specific conductance decreased with increasing methanol concentration for all concentrations of SDS solutions. The decline in the specific conductance was reported to be due to decrease in dielectric constant of solvent (Sonkar et al., 2012). It means that with the increase in methanol, the polarity of solvent or ionizing power of solvent decreases and a number of ions of both Na^+ and $C_{12}H_{25}SO_4^-$ decreases resulting in the decrease in specific conductance. It was also found that the specific conductance of SDS increased with the addition of 0.01M NaCl in water and methanol-water mixtures. Such phenomenon can be explained due to increase in the number of current carrying species i.e. counter ions (Na^+ and Cl^-) with Na^+ and $C_{12}H_{25}SO_4^-$ for carrying current.

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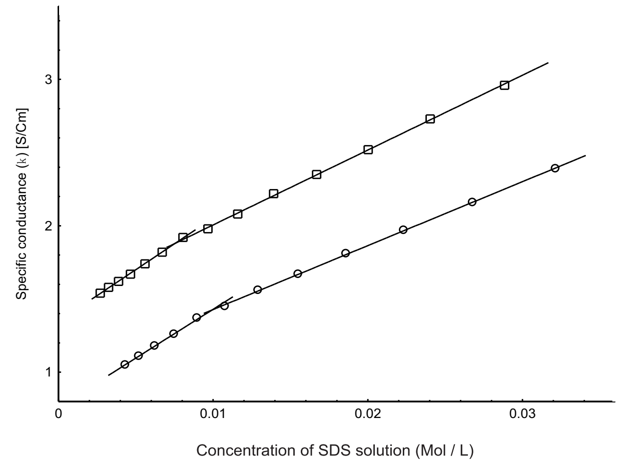

Figure 3: Conductance of sodium dodecyl sulphate in water in the presence (squares) and absence (circles) of NaCl at 318.15 K.

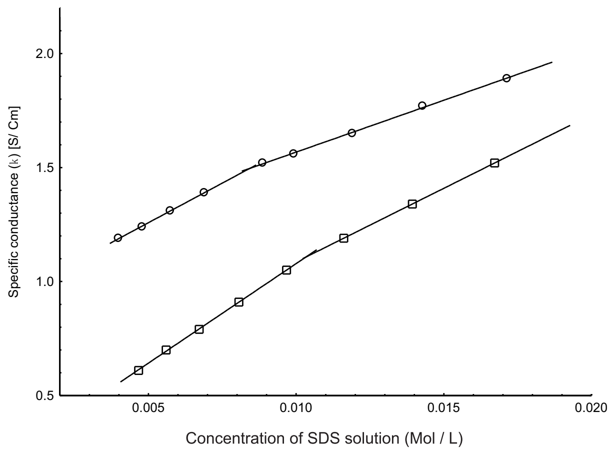

Figure 4: Conductance of sodium dodecyl sulphate in 0.1% (v/v) methanol in the presence(circles) and absence(squares) of NaCl at 318.15 K.

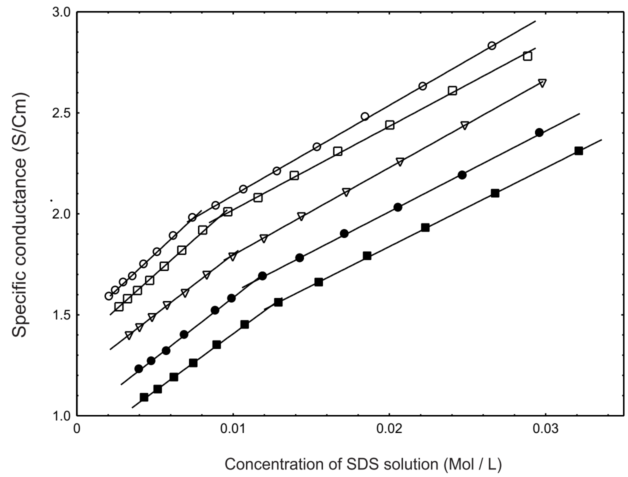

Figure 5: Conductance of sodium dodecyl sulphate in water, 0.1, 0.2, 0.3 and 0.4 methanol in the Presence of NaCl at 318.15 K. Open circles, open squares, triangles, close circles and close squares represent water, 0.1, 0.2, 0.3 and 0.4 methanol.

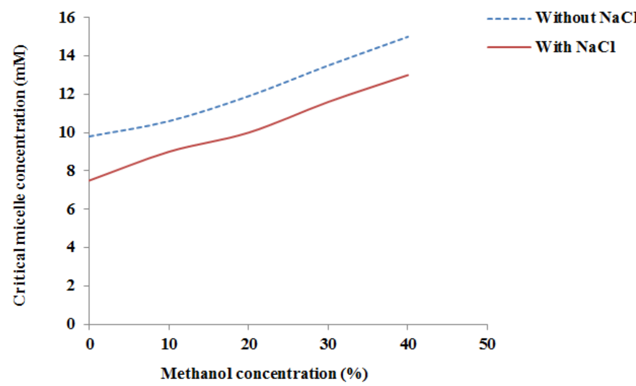

Figure 6.Effect of NaCl on critical micelle concentration of SDS in water-methanol system.

The results of critical micelle concentration (CMC) of SDS in water and in methanol-water systems with or without the addition of 0.01M NaCl solution at 318.15 K are given Figure 6. The conductance of aqueous solution of sodium dodecyl sulfate increases with increase in SDS concentration and addition of NaCl in both distilled water and methanol-water mixed solvents while it decreases with increase in the concentration of methanol in methanol-water mixed solvent. The critical micelle concentration of sodium dodecyl sulfate in methanol-water mixed solvent was higher than that in distilled water. The CMC increased with increase in methanol concentration whereas it decreased with the addition of NaCl in both distilled water and methanol-water systems.

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