Available online at www.sciencedirect.com
ScienceDirect
Journal of Taibah University for Science 9 (2015) 477–489
Journal of Taibah University for Science
www.elsevier.com/locate/jtusci

Investigations of mixed surfactant systems of lauryl alcohol-based bissulfosuccinate anionic gemini surfactants with conventional surfactants: A fluorometric study

Vinayika Singh *, Rashmi Tyagi [1]

Department of Chemical Engineering, Jaypee University of Engineering and Technology, Guna 473226, Madhya Pradesh, India

Available online 20 February 2015

Abstract

In this study, fluorescence techniques have been utilized to investigate the association and aggregation properties of aqueous solutions of a pure lauryl alcohol-based bis-sulfosuccinate anionic gemini surfactant ($BSGSLA_{1,8}$) with a flexible methylene $(CH_2)_8$ spacer. In addition to the fluorescence interaction behaviour of surfactant solutions of $BSGSLA_{1,8}$ mixed with conventional surfactants, surfactant formulations using the anionic (sodium dodecyl sulphate (SDS)), cationic (cetyl trimethyl ammonium bromide (CTAB)) and non-ionic surfactants (Triton X-100) used in industrial applications were also studied. The aggregation number and micropolarity of the pure and mixed surfactant systems were investigated using steady-state fluorescence spectroscopy. The electrolyte effect of different concentrations of sodium chloride (NaCl) on the aggregation number and micropolarity was also explored for pure $BSGSLA_{1,8}$. The best synergistic behaviour of $BSGSLA_{1,8}$ was obtained with SDS compared to CTAB and Triton X-100. The maximum reduction of the pyrene intensity ratio (I_1/I_3) was observed with a $BSGSLA_{1,8}$ and SDS mixed surfactant solution. The enhanced I_1/I_3 value of the mixed gemini Triton X-100 solution showed that mixed system is not as compact as pure $BSGSLA_{1,8}$ surfactant micelles in the non-ionic surfactant.

Keywords: Bis-sulfosuccinate gemini surfactant; Aggregation number; Micropolarity; Electrolyte effect

1. Introduction

Gemini surfactants have attracted considerable attention in the field of research. They consist of two hydrophobic chains and two polar head groups that are covalently attached by a spacer group. Due to their unique structure, they show many superior features compared to conventional single-chain surfactants, such as good water solubility, low CMC, better wetting and foaming properties, and excellent surface activity in aqueous solution [1]. The gemini surfactant $BSGSLA_{1,8}$ used in our present study is the dimeric surfactant of two sulfosuccinate-type anionic surfactants attached with flexible methylene spacer, and may prove to be a high-quality industrial surfactant with excellent properties. Flexible spacers (such as methylene chains) allow to the head groups to move relative to one another and to adopt a preferred separation distance and orientation based on solvation energetic and entropic considerations

* Corresponding author. Tel.: +91 09407560721;
fax: +91 07544267011.
E-mail addresses: vinayikaradha@yahoo.co.in (V. Singh), rashmi.tyagi@juet.ac.in (R. Tyagi).
[1] Tel.: +91 09425798395.

Peer review under responsibility of Taibah University

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jtusci.2015.01.010
1658-3655

[2]. Sulfosuccinate anionic surfactants are mild compared to other anionic surfactants [3]. Sulfosuccinate surfactants have extraordinary performance properties, such as foaming, strong wetting, emulsifying, and solubilizing properties and excellent surface active properties – low critical micelle concentration, high effectiveness in reducing surface tension and biodegradability. These surfactants have industrial utilities in numerous fields, such as cosmetics, textile, polymers, paints and coating, leather, printing and agriculture [4].

There are several previous reports on the micellization behaviour of amphiphiles, most of which report either cationic–cationic or cationic–anionic interactions [5–10] using conductivity and tensiometric methods. However, the present study used fluorometric methods to detect the interaction between gemini and surfactant, which is scare in the literature. Many other researchers used mixed surfactant studies [11,12] of gemini surfactants with other conventional surfactants. Du et al. [11] have analyzed the micellization behaviour mixtures of gemini anionic surfactant (alkyl benzene sulfonate gemini surfactant) with conventional nonionic surfactants ($C_{10}F_6$) in aqueous medium. Shang et al. [12] studied the phase behaviour and microstructures of the Gemini–SDS–H_2O ternary system. In this particular paper, transmission electron microscopy (TEM) was used to investigate the phase behaviour, transition between phases and the microstructure of aqueous mixtures of cationic gemini surfactant (12-3-12, $2Br^-$) and anionic surfactant sodium dodecyl sulfate (SDS). Some other studies dealt with the mixed surfactant systems of an anionic gemini surfactant and oppositely charged conventional surfactant [13–16]. The study reported in [13] used the mixed system of gemini $(C_{10}H_{21}CHOSO_3^-\ Na^+)_2\ (CH_2OCH_2)_3$ and CTAB to analyze the cross-linking behaviour between gemini surfactants and conventional cationic and nonionic surfactants. The various factors responsible for the formation of the cross-linked structure discussed in these papers are the formation of cross-linked CTAB-rich micelles. The gemini surfactant would act as cross-linkers by having their two alkyl chains embedded in the cores of two different CTAB-rich micelles [13,15]. Longer and flexible spacers of anionic gemini surfactants are also favourable for cross-linked micelles [14–16].

The approach of present paper provides an appropriate description related to the industrial utility of surfactant formulations of mixed surfactant solutions by studying the fluorescence interactions of $BSGSLA_{1,8}$ with anionic (SDS), cationic (CTAB) surfactants and non-ionic (Triton X-100) surfactants. Fluorescence techniques were used to investigate the interactions of pure $BSGSLA_{1,8}$ as well as binary mixed surfactant solutions.

Table 1
CMC values of SDS, CTAB and Triton X 100.

Surfactant name	CMC (mM)	References
SDS	8.0–8.20	[21–24]
CTAB	0.90–1.00	[21,24–26]
Triton X 100	0.24–0.27	[22,25,27]

Fluorescent techniques are widely used in biochemical, biomedical, pharmaceutical, agriculture, forensic and environmental pollution control analysis due to their high sensitivity and great selectivity [17]. Initially, Turro and Yekta [18] recommended this approach based on the studies performed by Tachiya [19] on the kinetics of the fluorescence quenching in micellar solutions, which has been successively applied to determine the mean aggregation numbers [20]. Steady-state fluorescence spectroscopy was used to calculate the aggregation number and micropolarity [pyrene intensity ratio; i.e., the first and third vibronic ratio (I_1/I_3)]. The electrolyte effect on the micellization of a pure $BSGSLA_{1,8}$ surfactant solution was also investigated. The aggregation number and micropolarity were calculated for the pure $BSGSLA_{1,8}$ surfactant solution at different concentrations of NaCl.

$BSGSLA_{1,8}$ was synthesized and CMC investigations were performed as previously reported [1] by changing α,ω-dibromo alkanes to α,ω-dibromo octane. The CMC of $BSGSLA_{1,8}$ was 0.0030 mol/L. The values for critical micelle concentrations of anionic SDS, cationic CTAB and nonionic Triton X-100 were taken from the research papers referenced in Table 1 [21–27].

2. Experimental

2.1. Materials and methods

All of the reagents and chemicals were used without any further purification throughout these studies. Lauryl alcohol (98.0%), maleic anhydride (99.0%), ethylene glycol (99.0%), sodium bisulphite (58.0%), p-toluene sulfonic acid (98.0%), benzophenone (99.0%), chloroform (99.0–99.4%), petroleum ether (60–80 °C), sodium chloride (99.5%) and Triton X-100 (100% active) were procured from LOBA Chemie pvt. Ltd., Mumbai (India). Sodium dodecyl sulphate (SDS) (90.0%) and toluene (99%) were purchased from Merck Specialities, Pvt. Ltd., Mumbai (India). Cetyl trimethyl ammonium bromide (CTAB) (98.0%) was obtained from SD FINE-CHEM LIMITED, Mumbai (India). 1,8-Dibromo octane (98.0%) was obtained from Spectrochem Pvt. Ltd., Mumbai (India). Pyrene (98%) was