



## Self-aggregation of ionic liquid–cationic surfactant mixed micelles in water and in diethylene glycol–water mixtures: Conductometric, tensiometric, and spectroscopic studies



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### ABSTRACT

Interaction of imidazolium based surface-active ionic liquid (SAIL), 1-decyl-3-methylimidazolium chloride [C<sub>10</sub>mim][Cl], with cationic surfactant cetrimide (CET) has been studied by using conductometric, tensiometric, and spectroscopic methods in pure water and in presence of diethylene glycol (DEG)–water binary mixtures. Addition of DEG has marked effect on the thermodynamic and aggregation behavior of these studied systems. From conductometric approach various parameters have been calculated such as critical micelle concentration, (*cmc*), micellar mole fraction, *X<sub>1</sub>*, of component 1 (CET), micellar interaction parameter,  $\beta$ , activity coefficients *f<sub>1</sub>* and *f<sub>2</sub>* of component 1 and component 2 (SAIL), standard Gibbs energy of micellization ( $\Delta G_m^\circ$ ), and degree of counter ion dissociation (*g*). Rubingh's non-ideal solution theory confirms the attractive and non-ideal behavior among the surfactant molecules in the mixed micelles. From the tensiometric studies different parameters such as surface tension reduction efficiency (*pC<sub>20</sub>*), maximum surface excess concentration (*Γ<sub>max</sub>*), minimum area per surfactant molecule (*A<sub>min</sub>*) and standard Gibbs free energy of adsorption  $\Delta G_{ad}^\circ$  at the interface were evaluated. The packing parameters of amphiphiles in the micelles, *P*, volume contribution of the hydrophobic chain, *v*, and its effective length, *l<sub>c</sub>* have also been evaluated for the pure and mixed systems. The micelles/mixed micelles formed have spherical geometry. Cresol red, an anionic dye, was used as a probe for UV–visible spectra of pure and mixed systems, which supports the role of SAIL in the mixed micellization process.

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### 1. Introduction

Ionic liquids, especially room temperature ionic liquids are now a day's receiving tremendous attention because of many unique properties that includes negligible vapor pressure, as an alternative and environment friendly replacements for toxic solvents, electrochemistry and are also used as a reaction medium in chemical industries [1,2]. Ionic liquids particularly surface active ionic liquids (SAILs) are amphiphilic in nature as they possess both hydrophilic as well as hydrophobic moieties in their molecules and as a result they exhibit good surface/interface activity and micelle formation. In a number of studies conventional surfactants are mixed with ionic liquids and the aggregation of the surfactants in these ionic liquids takes place in a way which is analogous to that in water, but having some differences. The first difference is that the surface tension of most of the pure ionic liquids are lower than the surface tension of pure water. The second difference is that

the *cmc* of surfactants in the ionic liquids is greater than the *cmc* in pure water and the reason may be due to lower solvophobic interaction between the surfactants in the ionic liquids as compared to hydrophobic interaction of the surfactants in the pure water [3–6]. In a few studies aqueous ionic liquids were used as a solvent for the surfactant solution [7–13]. In most of the studies, the *cmc* of surfactant depends upon the concentration of ionic liquids. It was also observed that at low concentration of ionic liquids the *cmc* showed a decreasing trend, while as at higher concentrations the *cmc* exhibit an increasing behavior [8–9]. The toxicity of 1-alkyl-3-methylimidazolium bromide ionic liquids and antioxidant defense system activity on *Daphnia magna* was recently reported and attributed mainly to high concentration of the ionic liquid [14] and its effect in oxidative stress and DNA damage in zebrafish [15]. Likewise the subchronic toxicity in rats was also studied [16] but there are only few studies which report the toxic effect.

Cetrimide, a cationic surfactant is a combination of three cationic surfactants, dodecyl-, tetradecyl-, and hexadecyltrimethylammonium bromides, out of these tetradecyltrimethylammonium bromide forms the major constituent of the mixture by weight and behaves as a single surfactant. Cetrimide has a wide range of applications, the most

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