Name : **Ummer Farooq**
Supervisor: **Prof. Anwar Ali**
Faculty: **Natural Sciences**
Department: **Chemistry**
Title: **Study of Interactions of Ionic Liquids with Antidepressant Drugs and Surfactants in Aqueous Medium**

ABSTRACT

The present research work deals with the study of interactions of ionic liquids with antidepressant drugs and surfactants in aqueous medium. The thesis comprises of seven chapters.

CHAPTER 1. This is the introductory chapter, which covers the scope and objective of the proposed work. Various aspects of the work have been explained. An up to date literature survey has been presented to illustrate the work being carried out in this field.

CHAPTER 2. Materials and experimental techniques, which have been used in the present investigations, are presented in this chapter. Conductometry, tensiometry, fluorescence, dynamic light scattering, and UV-Visible spectroscopy studies were used to investigate the interactions taking place between ionic liquid and antidepressant drugs and ionic liquid and surfactant systems. The standard operating procedures for the apparatus and instruments used have been explained in detail.

CHAPTER3. The changes in the micellar behaviour of cationic surfactants cetylpyridinium chloride (CPC) and cetylpyridinium bromide (CPB) have been investigated in the presence of SAIL 1-decyl-3-methylimidazolium chloride [C_{10}mim][Cl] employing conductometric and tensiometric methods.Physicochemical properties of aqueous surfactant solutions can be suitably modified by the addition of room temperature surface-active ionic liquids (SAILs). As green solvents, these SAILs are used as the ideal additives for modifying the aqueous surfactant properties. Such mixed surfactant + SAIL systems in aqueous solutions find enormous applications in several technological fields. Micellar and interfacial parameters such as critical micelle concentration, cmc, micellar mole fraction, $X_{1,}$ of component 1 (CPC/CPB), micellar interaction parameter, β, activity coefficients f_1 and f_2 of component 1 and component 2 (SAIL) in the mixed micelles, excess Gibbs free energy of micellization, ΔG_{ex}^{0}, standard Gibbs free energy, $\Delta G_{m,}^{0}$ enthalpy, $\Delta H_{m,}^{0}$ and entropy, ΔS_{m}^{0} of micellization, surface excess concentration, Γ_{max}, minimum surface area per molecule, A_{min}, and standard Gibbs free energy of adsorption ΔG_{ad}^{0} at the interface were evaluated. In addition, packing parameters of amphiphiles in the micelles, P, volume contribution of the hydrophobic chain, v, and its effective length, l_C have also been evaluated for the pure and mixed systems. The interactions between CPC/CPB and SAIL in the mixtures are found to be non-ideal and synergestic, and that mixed micelles are richer in CPC/CPB monomers of the several interactive interactions, hydrophobic interaction seems to be dominant between the components of the mixed systems. Adsorption of SAIL molecules at air-solution interface is found to be richer in SAIL than CPC/CPB molecules, which is also supported by the higher negative ΔG_{ad}^{0} values than ΔG_{m}^{0} values. The micelles/ mixed micelles formed have spherical geometry.

CHAPTER 4. In this paper, we have worked on the changes in the physicochemical properties of a cationic surfactant cetyldimethylethylammonium bromide (CDEAB), upon the addition of two ionic liquids namely 1-butyl-3-methylimidazolium dicyanamide [C_4mim][dca] and 1-octyl-3-methylimidazolium chloride [C_8mim][Cl]. Our main objective was to see the effect of two different ILs having different alkyl chain lengths and different anions on the physicochemical properties of aqueous solution of CDEAB. At lower concentration both ILs show somehow same trend in modifying the properties of aqueous CDEAB, however, at higher concentration both ILs modify the properties of aqueous CDEAB in entirely different way. Different techniques which include conductivity method, fluorometry method, DLS studies, and UV-Visible spectroscopy have been employed in order to determine various properties like cmc, aggregation number, peak diameter of aggregate micelles, and interaction parameters. In case of [C_8mim][Cl] the presence of octyl chain length allows it to align with the long cetyl chain length of CDEAB, whereas in case of [C_4mim][dca] this does not happen because of absence of long alkyl chain length and therefore cannot align with the alkyl chain length of

CDEAB. It is therefore proposed that the presence of different alkyl chain length of the two ILs is responsible for the different behaviour towards micellization in aqueous cationic surfactant CDEAB.

CHAPTER 5. The interactions of cationic surfactants, namely dodecyltrimethyl ammonium bromide (DTAB) and Cetrimide (CET) with tricyclic antidepressant drug, nortryptyline hydrochloride (NOT) were studied employing conductometric and tensiometric techniques. From these techniques, various micellar and interfacial parameters such as critical micelle concentration, cmc, micellar mole fraction, X_1, micellar interaction parameter, β, activity coefficients f_1 and f_2 in the mixed micelles, excess Gibbs free energy of micellization, ΔG_{ex}^0, standard Gibbs free energy, $\Delta G_{m,}^0$ surface excess concentration, Γ_{max}, minimum surface area per molecule, A_{min}, and standard Gibbs free energy of adsorption ΔG_{ad}^0 at the interface were evaluated. In addition to this, various other parameters such as, packing parameters of amphiphiles in the micelles, P, volume contribution of the hydrophobic chain, v, and its effective length, l_C have also been calculated for pure and mixed systems. From packing parameters it was confirmed the micelle/mixed micelles to be spherical. The ΔG_m^0 and ΔG_{ad}^0 values for all studied systems were found to be negative and this shows that both micellization as well as adsorption processes are energetically favourable. Furthermore, the values of ΔG_{ad}^0 were more negative than their corresponding ΔG_m^0, showing that work is done in transferring the amphiphilic monomers from interface to the micellar stage across the aqueous solution to form micelles. The interaction parameters, β, calculated by using regular solution theory were also observed to be negative suggesting synergistic interaction for the proposed mixed systems.

CHAPTER 6. In this chapter we have studied the interaction of imidazolium based ionic liquid, 1-decyl-3-methylimidazolium chloride [C_{10}mim][Cl] with cationic surfactant cetrimide (CET) by employing conductometric, tensiometric, and spectroscopic methods in pure water and in presence of different volume percentage of diethylene glycol (DEG)-water (WR) binary mixtures at T = 298.15K. Addition of DEG has marked effect on the thermodynamic and aggregation behaviour of these studied systems. From conductometric approach various parameters have been calculated such as the mixed critical micellar concentration (cmc), standard Gibbs energy of micellization (ΔG_m^0), degree of counter ion dissociation (g), interaction parameter (β), micellar mole fraction of surfactant (X_1), ideal micellar mole fraction (X_{ideal}), and activity coefficients of surfactant (f_1) and ionic liquid (f_2). Rubing's non-ideal solution theory confirms the attractive and non-ideal behaviour among the surfactant molecules in the mixed micelles. From the tensiometric studies different parameters such as surface tension reduction efficiency (pC_{20}), maximum surface excess concentration (Γ_{max}), and minimum area per surfactant molecule (A_{min}) were also computed for the mixed systems. The packing parameters were also calculated for the pure as well as for the mixed systems and the values for all the systems are less than 0.33 i.e. $p < 0.33$ which confirms their spherical shape. Cresol red, an anionic dye, was used as a probe for UV- Visible spectra for pure surfactant as well as for IL/CET mixtures, which also supports the role of IL in the mixed micellization process.

CHAPTER 7. In this paper we have studied the interaction of surface active ionic liquid, 1-decyl-3-methylimidazolium chloride [C_{10}mim][Cl] with tricyclic antidepressant drug viz., nortryptyline hydrochloride (NOT), keeping in view that a lot of work has been done on the drug binding ability of surfactants. Various micellization as well as interfacial properties of [C_{10}mim][Cl] in presence of NOT have been investigated from conductivity and surface tension measurements. Further spectroscopic studies such as fluorescence and UV-Visible give us more detailed information regarding the nature of interaction between [C_{10}mim][Cl] and NOT. The increase in aggregation number obtained from fluorescence quenching method, along with increase in micellar size obtained from dynamic light scaterring (DLS) indicate the existence of hydrophobic as well as π-π interactions between the imidazolium ring of IL and the aromatic rings of drug molecules. Conductivity, surface tension, and spectroscopy studies provide information regarding the location of adsorption of drug molecules in [C_{10}mim][Cl] micelles. The decrease in absorption intensity and the red shift confirm the new complex formation between the reacting species. The binding constant, K, obtained by using Benesi-Hildebrand equation shows considerable binding affinity of [C_{10}mim][Cl] towards NOT. The negative value of ΔG_K further shows that the complexation process is a spontaneous process.