ABSTRACT

"Life" is the sum of a series of complex processes occurring in solution. The air we breathe, the liquids, beverages we drink, and the fluids in our body are all solutions. Furthermore, we are surrounded by solutions such as the air and waters (in rivers, lakes and oceans). Apart from regulating life processes occurring in human body, solutions also play a very important role in many biological processes in other organisms, and, in numerous laboratory and industrial applications of chemistry.

In the realm of chemistry, interactions are attractive or repulsive forces between molecules and between non-bonded atoms. Indeed, interactions play significant role for various systems to exist. Molecular interactions play significant role in different areas of drug designing and its liberation systems, protein folding, material science, nanotechnology, separation and origins of life. Molecular interactions are often known as non-covalent interactions.

By studying several excess thermodynamic properties one can better understand molecular interactions in solution phases. Excess thermodynamic functions can be defined as the difference between the thermodynamic functions of real solutions and the respective functions of ideal solutions. These properties give significant information towards the nature and strength of various intermolecular forces operating among mixed components. A decent idea, regarding the nature of the interactions that exist within the constituents of a solution, is obtained from the thermodynamic investigations along with the transportation behaviour of the solution.

The study of physicochemical properties of solutions provide sufficient knowledge on various thermodynamic properties of electrolytes and non-electrolytes, the effects of the variation in ionic constructions, mobility of ions along with their common ions. Evaluation of ion-solvent interactions allow chemists choosing solvents that will progress the solubility of minerals in discharging operations, the rates of chemical processes, or the reversal of the route of equilibrium reactions. Nowadays, the value and importance of Chemistry of electrolytes in mixed solvents, has paved researcher's attraction. By the determination of precise and accurate thermophysical properties of

the components in a solution, quantitative elucidation of the solvent consequences and evaluation of the nature of various interactions are possible.

Limiting molar conductance (Λ_0) gives an idea about the ion solvent interaction in the solution. A higher value of conductance of the solution is indicative of less ion-solvent interaction. Another parameter, namely, the association constant(K_A) obtained from the conductance study illustrates solvation of the ions by the solvent. The sign and magnitude of apparent molar volume(ϕ_V^0), estimated from experimental density values , provide information about the nature and extent of ion-solvent interaction. The experimental slope(S_V^*) provides information about ion-ion interactions.

Viscosity *B*-coefficients are estimated from experimental viscosity values. From experimental speed of sound values, deviation in Isentropic Compressibility (ΔK_S), limiting apparent molal isentropic compressibility($\phi°_K$) and the experimental slope S_k^* can be estimated. By studying partial molar volumes, limiting ionic conductivity as well as viscosity *B*-coefficient, ion-solvent interactions can be estimated. Approximate single-ion values are used to purify the models of ion-solvent interactions.

The idea of whatsoever happening in aqueous medium enhances interest to study the behaviour of electrolytes in aqueous and mixed solvents by investigating solute-solute and solute-solvent interactions at different circumstances. However, the behaviour of solutes in these solvents are quite different than in aqueous medium. In my research work the behaviour of various electrolytic solutions were extensively studied in aqueous, non- aqueous, and mixed solvents.

The basic aim of supramolecular chemistry is to design new functional systems of interest by combining multiple chemical entities through various non-covalent interactions. Supramolecular chemistry features phenomena like molecular self-assembly, molecular recognition, host-guest chemistry, mechanically-interlocked molecular architectures, folding of proteins etc.

The concept of host-guest chemistry has opened the way to the construction of supramolecular(inclusion) complexes with physicochemical properties superior to those of the guest molecule. Inclusion complexes play a significant role in the drug formulation and drug delivery process in pharmaceutical industries. Some other methods used to improve the solubility of drugs molecules are solid dispersion, micronization, solvent deposition etc. All the approaches are used for improving dissolution rate, miscibility and bioavailability of sparingly soluble drugs. But each method has some boundaries and advantages. Inclusion complexation with cyclodextrin is the most efficient method to improve the solubility of weakly soluble drugs. Cyclodextrin by the formation of Inclusion complex are capable to modify the physicochemical properties of drugs, such as solubility, particle size, thermal behavior and thus providing a highly water miscible amorphous forms. The CDs are not only capable of enhancing the dissolution rate but also bio-availability of the sparingly soluble drugs. The permeation of drugs through various biological membranes can also be improved by formation of drug-cyclodextrin inclusion compounds.

The formation of inclusion complex can be characterized by various spectroscopical techniques such as NMR, FT-IR, UV-Vis spectroscopies as well as physicochemical techniques such as surface tension, conductance, refractive index, density and viscosity studies. In ^{1}H NMR, the considerable chemical shifts of H3 and H5 protons of cyclodextrins and the protons of hydrophobic part of the guest molecule may be regarded as the formation of inclusion complexes. The mechanism of formation of inclusion complex may be explained using ^{1}H NMR and 2D ROESY NMR spectroscopies. The significant shift of different groups of ICs from the host and guest molecules are observed in FT-IR spectra which is also the proof of formation inclusion complexes. The surface tension and conductance study are some reliable techniques for characterization and evaluation of stoichiometry of inclusion complex. The stoichiometries of the inclusion complexes were also estimated from Job's plot of UV-visible spectroscopy. The association constants of various host-guest systems were calculated from Benesi-Hildebrand equation.

SUMMARY OF WORKS DONE

Chapter I: This chapter comprises in detail the object of the research work, their scope and applications in the contemporary science. The reason of choosing the biomolecules, drugs, electrolytes including ionic liquids, cyclodextrins and various solvent systems, have also been discussed.

Chapter II: This chapter contains the review of the earlier works in this field of research done by various scientists and researchers across the world. This chapter covers the general introduction of the thesis and forms the background of the present work. The basic of molecular interactions in aqueous and non-aqueous electrolytic solutions, as well as, the supramolecular "Host-Guest" inclusion complexation in terms of various physicochemical and spectroscopic parameters have been included. The underlying theory of UV-Visible spectroscopy, FTIR spectroscopy, ^{1}H NMR, 2D ROESY, Fluorescence spectroscopy, Scanning Electron microscopy, High Resolution Mass Spectroscopy, Surface tension, Conductivity, Density, Viscosity, Refractive index have been discussed thoroughly alongwith their significant uses in the research work.

Chapter III: The experimental section relevant to this thesis have been included here. This chapter highlights the name, source, structure, physical properties, method of purification and applications of biomolecules, drugs, various electrolytes, ionic liquids, cyclodextrins and different solvents used in this research work. It also deals with the experimental methods, the descriptions and use of the instruments involved in the research work.

Chapter IV: In this chapter, triple-ion formation of Tetrabutylphosphonium Methanesulfonate [$Bu_4PCH_3SO_3$] in methylamine solution has been reported quantitatively by conductometric study, and the observation is evident from the qualitative analysis of FT-IR spectroscopy. The ionic liquid exists as triple-ion state in low dielectric constant solution (methylamine solution having $\varepsilon_r < 10$). Thus, the conductance data have been analysed using the Fuoss-Kraus theory of triple-ion formation. After that, the results have been discussed in terms of driving forces *i.e.,* H-bond formation, dipole-dipole interactions, and structural aspects (functional group) of the ionic liquid and methylamine molecules. Shifting of the stretching frequency of functional group of the solvent in presence and absence of the ionic liquid has been taken into account in FTIR spectroscopic study, and then the solvation consequences have been manifested by the change of the intensity.

Chapter V: Here, the properties of material, like densities and viscosities of some selected lithium salts (namely, lithium nitrate, lithium iodide and lithium acetate) have been measured in acetonitrile-water binary mixed solvents at the temperature 298.15K.

Apparent molar volumes (ϕ_V) and viscosity *B*-coefficients of these salts are obtained from these data supplemented with their densities and viscosities, respectively. Limiting apparent molar volumes (ϕ_V°) and experimental slopes (S_V*) derived from density date using Masson equation have been interpreted in terms of ion-solvent and ion-ion interactions, respectively. The viscosity data have been analyzed using Jones-Dole equation, and derived parameters *B* and *A* have also been interpreted in terms of ion-solvent, ion-ion interactions, respectively. It has been observed from the both derived parameters that ion-solvent interaction is predominant than interaction of ions (ion-ion) itself. Furthermore, the structure making/breaking capacities of aforementioned salts investigated and have been discussed in terms of the rearrangement with symmetrically of the interacting ions. Another two parameters, refractive index and conductivity have been taken into account to give explanation and confirming the results obtained in the studied solutions system.

Chapter VI: This chapter deals with the non-covalent interactions occurring between ionic liquid namely 1-ethyl-3-methylimidazolium chloride-aluminum chloride and pure alcohols (*e.g.,* methanol, ethanol, 1-propanol, and 1-butanol). For that limiting apparent molar volume, molar refraction, and limiting apparent molar isentropic compressibility of the binary systems *viz.,* {([EMIm]Cl/$AlCl_3$)+methanol}, {([EMIm]Cl/$AlCl_3$)+ethanol}, {([EMIm]Cl/$AlCl_3$)+1-propanol}, and {([EMIm]Cl/$AlCl_3$)+1-butanol} have been calculated using physicochemical properties *i.e.,.* density, refractive index, and speed of sound respectively within the temperature range *T*=293.15K-318.15K (with 5K interval). Here, the ionic liquid strongly interacts with 1-butanol than other chosen primary alcohol at a higher temperature (318.15K). The outcomes have been discussed in terms of intermolecular forces and non-covalent interactions like hydrogen bond, ion-dipole, electrostriction, hydrophobic interactions, and structural configurations.

Chapter VII: This chapter contains the study of formation and investigation of host–guest inclusion complexes of 4-chloro-1-napthol insight into α- and β-cyclodextrin in 50% aqueous ethanol media by various physicochemical and spectroscopic methods. Job's plots have been drawn by UV-visible spectra and confirm 1:1 stoichiometry of the complex. Surface tension data also support 1:1 stoichiometry of the complexes. ^{1}H NMR, FTIR and ESI MS studies ensure the inclusion phenomenon once again. Association constants have been calculated by UV-Visible spectroscopy on the basis of the Benesi-

Hildebrand method and non-linear programme, and the thermodynamic parameters have been estimated with the help of Van't Hoff equation. The higher binding constant values and calculated values of thermodynamic parameters such as Gibb's free energy, enthalpy and entropy supported the high stability and feasibility of formation of the inclusion complex. The formations of inclusions have been elucidated by H-bonding interactions, hydrophobic effects, structural effects, and electrostatic interaction.

Chapter VIII: In this chapter, surface tension and ultraviolet spectroscopic methods have been employed to study the dimensional fit molecular encapsulation of hydrazinophthalazine hydrochloride insight into the cavity of β-cyclodextrin in aqueous media. Analysis of the surface tension plot against reciprocal of concentration and Job's plot drawn from UV-Vis data yields the equilibrium constant for 1:1 stoichiometry. The binding constants computed from tensiometric and spectroscopic method are 59.91μM^{-1} and (12.02 – 96.58)μM^{-1} respectively, that return the comfort zone of the results. The noteworthy upshot has also come out from standard Gibbs energy for inclusion complex formation, which is more negative than for adsorption by 6.11 kJ mol^{-1}. It seem sensible that the driving force in formation of inclusion complex inside the bucket-like cavity of β-cyclodextrin is a combination of hydrophobic effect and reduction of the surface energy, while in adsorption is only hydrophilic effect.

Chapter IX: Inclusion complex forms by encapsulation of apolar part of N,N-dimethyl-4-phenylenediamine dihydrochloride insight into the hydrophobic cavity of β-cyclodextrin. The complex has been prepared in aqueous medium and characterize by employing several physicochemical and spectroscopic techniques. The origination of (DMPD+β-CD) inclusion complex was established by UV-Visible Job's plot. 1H NMR, FT-IR and SEM studies also account for the inclusion phenomenon. Appraisement of both conductivity as well as surface tension data implies 1 : 1 stoichiometry of the inclusion complex. Association constant and free energy change is 23600 M^{-1} and -24.54 kJ M^{-1} respectively. The formation of the inclusion complex has further accomplished by hydrophobic effects, structural effects, electrostatic forces and H-bonding interactions.

Chapter X: This chapter includes the concluding remarks about the research works done in this thesis.