CHAPTER XII

Concluding Remarks

In this thesis I investigated the formation of host-guest inclusion complexes of various bio-molecules with α and *β*-cyclodextrins exploring particularly towards their formation, stabilization, carrying and controlled release without chemical modification by different dependable methods like ^{1}H NMR spectroscopy, 2D ROESY, FTIR spectroscopy, UV-visible spectroscopy, high resolution mass spectrometry, isothermal titration calorimetry, surface tension study, conductivity study, pH study, solution density, viscosity, refractive index, ultrasonic speed study, which primarily focus on the encapsulation of the bio-molecules into the cavity of cyclodextrins. The stoichiometry, association constants and thermodynamic parameters for the inclusion complexes have been determined to communicate a quantitative data regarding the encapsulation of the bio-molecules inside into α and *β*-cyclodextrins.

This thesis also includes the specific interactions between few very important ionic liquids with the macrocyclic polyethers leading to complexation in acetonitrile. The transport properties support the association, while the mathematical programme reveals quantitative data of the complexation process. The specific interactions in molecular level have been illuminated with the help of FT-IR and ^{1}H NMR spectroscopic studies. These studies offer excellent ideas for fabrication of crown ether based host-guest materials.

The findings are discussed chapter wise as follows:

Chapter IV explains that nicotinic acid and ascorbic acid form ICs with *β*-CD in aqueous medium, which can be used as regulatory releaser of the above two vitamins. 2D ROESY NMR study confirms the inclusion phenomenon and its mechanism. Surface tension and conductivity studies also show that the ICs have been formed, the stoichiometry of which were confirmed as 1:1 by Job plots. The association constants and thermodynamic parameters have been estimated for both the ICs by reliable spectroscopic and calorimetric

techniques with high accuracy, which inform that ascorbic acid-*β*-CD has higher order of association than that of nicotinic acid-*β*-CD. Thus, this work communicates both qualitative and quantitative idea about the formation of ICs of *β*-CD with above two vitamins suggesting their potential applications in pharmaceutical industries and medical sciences.

In chapter V molecular recognition of the three important NTs by *β*-CD has been shown, which may find its use as potential drug delivery system in pharmacological science. The molecular assemblies, *i.e.*, formation of ICs have been explained qualitatively as well as quantitatively so as to make it dependable in its field of application. *β*-CD has long been used as a carrier for its unique structural features, which is further explored in the present work, confirming that *β*-CD forms 1:1 ICs with DH, TH and EH, established by reliable physicochemical techniques. The association constants are found highest for EH, then DH and then TH for the ICs with *β*-CD. Hence, this exclusive study describes that the ICs in aqueous medium can be used as controlled delivery systems in the field of modern biomedical sciences.

Chapter VI illustrates that host-guest inclusion phenomenon is accomplished through molecular recognition of the guest by the host molecule. There also must be dimensional suitability between the two species. One of the driving forces for the formation of IC was the release of the water molecules from the hydrophobic cavity of CD to the bulk of water thereby increasing the entropy of the system. The ICs were stabilized by both hydrophobic and H-bonding interactions. Here, formations of 1:1 ICs were established and the ICs were characterized by various techniques in aqueous medium as well as in solid state. The ICs stabilize SS from chemical modification, photo sensitization and act as regulatory releaser at the targeted site for a specified period of time reducing the overdose. Thus, the present study conveys a new approach over the already known versatile use of SS by applying α and β-CD in bio-medical sciences and pharmaceutical industries.

Chapter VII highlights toward the specific interactions between three very important ionic liquids with the macrocyclic polyether leading to complexation in acetonitrile in a range of temperature. The conductivity study support the association of the ILs with CE in 1:1 stoichiometric ratio, while the mathematical programme elucidates

quantitative data of the complexation process. Thermodynamic properties of the processes have also been evaluated for improved understanding about complexation. The specific interactions in molecular level have been illuminated with the help of FT-IR and ^{1}H NMR spectroscopic studies, which describe the H-bond type interactions as the main operating force in imidazolium and pyridinium complex, while the weak ion-dipolar attraction exists in pyrrolidinium complex. The association among the species lowers the entropy of the system, but the spontaneity of the process is attributable to higher stabilization effect of change in enthalpy. This study provides significant information about supramolecular complexation of 18-C-6 with ILs, as well as offers excellent comparison among similarly substituted imidazolium, pyridinium and pyrrolidinium ions for fabrication of crown ether based host-guest materials.

Chapter VIII explains the formation of inclusion complexes of three α-amino acids in the apolar cavity of both α and β-cyclodextrins. Surface tension study confirms that 1 : 1 inclusion complex was formed. All the derived parameters obtained from the supplementary data of density, viscosity and refractive index strongly support the formation of the inclusion complex as well as solute–solvent interaction taking place in the studied solution systems. The order of interaction for selected α-amino acid inside into α and β-CD is as follows: L-Glu < L-Lys < L-Phe. Hence, the findings discussed and explained in this paper illustrate the advancement of the work and demonstrate the suitability for diverse applications.

Chapter IX emphasizes to the definite interactions between cetylpyridinium chloride and three similar macrocyclic polyethers toward complexation in acetonitrile in a range of temperature. Here, conductivity measurement helps to ascertain the association of CPCl with the three CEs in 1:1 stoichiometry, whereas the programmed mathematical treatment reveals quantitative data for complexation processes. Thermodynamic parameters have also been estimated for better perceptive about the complexations. The detailed interactions in molecular level have been elucidated by FT-IR and ^{1}H NMR spectroscopy that explains dipolar attractions due to H-bonding is the major operating force in the three complexes. During complexation the entropy of the system is decreased,

but lowering of enthalpy has greater effect that makes the complexation spontaneous. This study not only presents remarkable information about supramolecular complexation of CPCl with the three analogous CEs, but also suggests admirable comparison among the studied CEs for construction of various types of CE-IL host-guest materials.

Chapter X gives details of a unique behavior of aqueous cyclodextrin-nucleoside system. It establishes the possibility of formation of host-guest inclusion complex between cyclodextrin and RNA nucleosides by physicochemical as well as spectroscopic methods. Surface tension measurement and pH study support that α-cyclodextrin forms inclusion complex with only pyrimidine based nucleosides, whereas β-cyclodextrin forms with both purine and pyrimidine based nucleosides, as well as the ratio of host : guest is found to be 1:1 by Job's method. The measured parameters, *e.g.*, density, viscosity, acoustic data, refractive index data support the order of interaction among different nucleosides and cyclodextrin systems, while NMR data confirms the inclusion phenomenon. The determination of association constants and various thermodynamic parameters quantitatively explain the significance of the work. Hence, this exclusive study has diverse applications in the broad field of biology and chemistry.

Chapter XI elucidates that the two essential amino acids, namely, L-Arg and L-His form host-guest inclusion complexes with α and β-CD. NMR study confirms the inclusion phenomenon while surface tension and conductivity studies reveal that 1:1 inclusion complexes have been formed. Density, viscosity and refractive index measurements are used to characterize the formed inclusion complexes by determining the group contributions of the limiting apparent molar volume and viscosity-B coefficient, as well as solvation number and limiting molar refraction. All the findings support the formation of the inclusion complexes and thus the current work describes its appropriateness towards miscellaneous applications as controlled delivery system in the field of modern bio-medical sciences.

These elaborate studies explain the formation of host-guest inclusion complexes, which may be applied to construct various complex systems. In recent years macrocyclic host molecules are of immense importance in inclusion complexes as the cyclized and

constrained conformation offer the benefit of molecular selectivity. The cyclodextrins are exclusively interesting in this regard, due to their amphiphilic nature. The interest in amphiphiles comes up from their self-assembly in aqueous systems to form well defined structures, such as micelles, nanotubes, nanorods, nanosheets and vesicles, which can be applied in several grounds ranging from nano-devices, drug delivery and cell imaging. Various sophisticated probes have been designed for this purpose for their applications in the manufacture of molecular switches, molecular machines, supramolecular polymers, chemosensors, transmembrane channels, molecule-based logic gates and other interesting host–guest systems.

In near future I plan to study intricate host-guest systems for advanced applications in delivery systems.