Chapter – I

General Introduction

and

Review of Literature
The study of polyols is of great interest [1] because they can be studied as a function of the number of functional groups and their stereo chemical conformation. Polyhydroxy compounds are of biological importance in life process, they are implicated in recognition phenomenon between cells and various component of the immune system. Thus recent times have witnessed renewed interests in detail of solute-solute interactions and hydration of these compounds in aqueous solution [1-4]. The behavior of the bifunctional compounds appeared to be very complex, the purpose of study is to contribute to further elucidation of their hydration properties.

Solution chemistry deals with liquid solutions in such fields as physical chemistry, chemical physics, molecular biology, statistical mechanics, biochemistry and biophysics. Water treatment, waste material separation and recycling of industrial wastes are some applications of solution chemistry. Important industrial processes often utilize solution chemistry. The majority of chemical processes are reactions that occur in solution. The ion-ion and ion-solvent interactions play an important role in the solution chemistry. In the study of ion solvent interactions, water has been used in mixed solvent due to its easy availability and high dielectric constant. These interactions help in better understanding of the solute and solvent i.e. whether the solute modifies or distort the structure of the solvent. The study of the electrolytes in mixed solvents enables us to know about the nature of ion-ion and ion-solvent interactions [5-6].

During the last two decades studies on solute-solvent interactions of electrolyte solutions have been subject of active interest among the physical chemist. These studies were restricted mainly to aqueous solutions in the early days of research and the solution theories have been mainly based on the results so obtained, but in recent research multi-component systems are preferably used. In the recent years, an increasing interest has been shown in the study of electrolyte in aqueous and non-aqueous mixed solutions, with a view to investigate solute-solute and solute-solvent interactions under varied conditions [7-10]. The information drawn from these studies have been related to structural aspects of the solvent in terms of the ion-solvent and solvent-solvent interactions and structure making or breaking capacity of various electrolytes [11-17]. These multi-component systems contain some organic solvents miscible in water, aqua-organic systems or some solid solutes dissolved in water, aqua-inorganic systems. Solvent systems that contain one or more solid
component dissolved in water and are similar to the bio-fluids in their composition are of most interest to the researchers. It has been realized that ion-solvation can be better understood in mixed solvents as nature of water can be modified by a co-solvent in such a way that the electrostatic effects, arising from dielectric constant, remain almost the same, then the chemical effects of the co-solvent play an important role in influencing the ion-ion interactions. Moreover, mixed binary aqueous solvent systems behave in an unexpected manner as compared to the non-aqueous system. These observations have given a new impetus to the detailed study of structure of electrolytic aqueous mixtures.

The thermodynamic and transport properties of very dilute electrolytic solution has always been a major area of research in solution chemistry and has been proven a powerful tool in elucidating the specific interactions and structural features supporting the liquid structure in solutions. The nature of solute-solute and solute-solvent interactions has been deduced mainly from the transport properties such as viscous flow and electric conductance, thermodynamic properties such as free energy transfer parameter and partial molar volume and ultrasonic properties such as relative association, adiabatic compressibility etc. The volumetric and viscosity of solutes in solution provide information regarding solute-solute and solute-solvent interactions. At infinite dilution, partial molar volumes are, by definition, independent of solute-solute interactions, and thus can be used to examine solute-solvent interactions.

All the biological reactions occur in the solutions that is bio-fluids. Water, sodium chloride, potassium chloride, carbohydrates and ascorbic acid are the main components of living organism. Ascorbic acid is found in plants, animals and single cell organism. All animals either makes it, eat it, or die from scurvy due to lack of it. Ascorbic acid and its sodium and potassium salts are commonly used as oxidant food additives. It is needed to synthesize carnitine, important in transfer of energy to the cell mitochondria. It neutralizes potentially harmful reaction in the watery parts of the body, such as blood and the fluid inside the surrounding cells. Ascorbic acid and compounds containing ascorbic acid were found to show anti-tumor and anticancer properties [18-20]. These interesting biological properties of ascorbic acid made it an important system for research. Carbohydrates act as vital energy source in living being. Sodium and potassium perform a very important function in our body as sodium potassium exchange pump in plasma membrane. This pump transfer sodium
and potassium ions against their electrochemical gradient. Thus it would be worthy studying systems comparable to bio-fluids. So solutions containing some bio-fluids like water, carbohydrates, sodium chloride, potassium chloride and ascorbic acid were studied to know the of processes occurring in bio-systems in laboratory. A wide range of concentrations for ascorbic acid (0.01-0.12 m) was chosen for this investigation. Temperatures used for this study (303.15, 308.15, 313.15 and 318.15 K) were also in wide range and is important as it covers the temperature range of human body. In this work density, viscosity, molar conductance and ultrasonic velocities were obtained and these quantities were used to calculate various thermodynamic and transport parameters.

REVIEW OF THERMODYNAMIC AND TRANSPORT PROPERTIES IN SOLUTIONS

Conductometric measurements on octahedral Co(III) complexes have been reported in water and water+ethanol mixtures at 5-40°C [21]. The limiting equivalent conductance \( \Lambda_e \) and the ion-association constants (\( K_A \)) for the complex salts in these mixtures have been evaluated using Shedlovsky equation. Based on the composition dependence of the Walden product, the influence of the mixed solvent composition on the solvation of ions has been discussed. Temperature variation of the association constant has also been studied to evaluate the thermodynamic parameters. The results have been discussed in terms of ion-ion, ion-solvent and solvent-solvent interactions.

The density and ultrasonic velocities of lithium tetrafluoroborate (LiBF\(_4\)), sodium tetrafluoroborate (NaBF\(_4\)), tetraphenylphosphonium chloride (Ph\(_4\)PCl), tetraphenylphosphonium bromide (Ph\(_4\)PBr), and tetraphenylarsonium chloride (Ph\(_4\)AsCl) in 2-methoxyethanol (ME) have been measured at 15, 25, and 35\(^0\)C [22]. Apparent molar isentropic compressibilities \( \kappa_\varphi \) of these electrolytes were derived from these data supplemented with their densities. The partial molar compressibilities \( \kappa_\varphi^0 \) were obtained at infinite dilution by extrapolation from the plot of \( \kappa_\varphi \) vs. the square root of the molarity. The \( \kappa_\varphi^0 \) values of the electrolytes were split into approximate limiting ionic compressibilities \( \kappa_\varphi^{\pm} \) on the basis of the assumption that \( \kappa_\varphi^0 (BF_4^-) = 0 \). The results have been interpreted in terms of specific constitutional and structural factors of the solvent molecules and of solute ions.
Viscosities and speeds of sound of aqueous and methanolic calcium chloride solutions were measured as functions of concentration ($0.0040 \leq m/(\text{mol kg}^{-1}) \leq 7.151$ and $0.1903 \leq m/(\text{mol kg}^{-1}) \leq 3.252$ for aqueous and methanolic calcium chloride solutions, respectively) and temperature (273.15 \leq T/K \leq 323.15) [23]. Isentropic compressibility isotherms of aqueous calcium chloride solutions converge at 5.1 mol kg$^{-1}$. In the case of methanolic calcium chloride solutions, isentropic compressibility isotherms vary smoothly with the increase in concentration and converge at 5.66 mol kg$^{-1}$ on extrapolation. Total solvation numbers of calcium chloride in water and methanol media were estimated to be 10.9 and 5.5, respectively.

The linear attenuation coefficients in aqueous solutions of some chlorides and sulphates, viz. MgCl$_2$.6H$_2$O, CaCl$_2$, SrCl$_2$.6H$_2$O, BaCl$_2$.2H$_2$O, Na$_2$SO$_4$, K$_2$SO$_4$ and MgSO$_4$.7H$_2$O were determined at 81, 356, 511, 662, 1173 and 1332 keV by the $\gamma$-ray transmission method in a good geometry setup [24]. From the precision measured densities of these solutions, mass attenuation coefficients were then obtained which varied systematically with the corresponding changes in the concentrations ($\text{g/cm}^3$) of these solutions. A comparison between experimental and theoretical values of attenuation coefficients has shown that the study has potential application for the determination of attenuation coefficients of solid solutes from their solutions without obtaining them in pure crystalline form.

Ultrasonic velocities and densities were measured, and isentropic compressibility coefficients calculated for solutions of anhydrous and hydrated CeCl$_3$ and PrCl$_3$ in ethanol and $n$-propanol at 258 °C [25]. The solvation numbers were calculated. The results were interpreted in terms of inner-sphere coordination of chloride anions by lanthanide cations, as well as changing dissociation degree of the solutes with concentration. The steric effect of the solvent molecules on modelling the structure and co-ordination number of metal ions was considered and compared with the X-ray diffraction of solid solvates. The above studies were correlated with our earlier optical investigations.

Various acoustical properties such as isentropic compressibility, specific impedance, molar sound velocity, molar compressibility, van der Waals constant, intermolecular free length, excess molar volume ($V^E$), excess viscosity, excess adiabatic compressibility, Gibb’s free energy of activation for viscous flow etc. have been calculated in three binary systems: anisole + methanol, anisole + chloroform and
anisole + dimethyl formamide from sound velocity (2 MHz), density and viscosity measurements at 30 °C. The results are interpreted in terms of molecular interactions [26].

The apparent and partial molar volumes, the apparent and partial molar compressibilities and viscosity B-coefficient are useful to understand ion-ion and ion-solvent interactions [27-31].

Densities of glycine, L-analine and L-serine in aqueous glucose solutions have been measured at 298.15 K by oscillating tube densimeter [32]. Apparent molar volumes and limiting partial molar volumes of each amino acid have been calculated. The trends of transfer volumes have been interpreted by the co-sphere overlap model.

Densities of glycine in glucose-water and sucrose-water mixed solvents have been measured at 298.15 K by an oscillating-tube densimeter [33]. Apparent molar volumes and limiting partial molar volumes and number of hydration of glycine have been calculated. The transfer volumes from water to sugar-water mixtures have been obtained and discussed in terms of structural hydration interaction model. The results obtained have been compared with that in glycerol-water and ethylene glycol-water mixtures. It has been concluded that the magnitude of enhancement effect on volume is related to the number of -OH groups.

The temperature and concentration dependences of the molar adiabatic compressibility in aqueous solutions of HCl, NaOH, and NaCl are analyzed in terms of the Onori approach and concept of overlap of ion hydration spheres with increasing electrolyte concentration [34]. The structural characteristics of the hydration complexes of the ions are determined. The influence of the temperature and electrolyte concentration on the features of hydration of HCl, NaOH, and NaCl is discussed.

Ultrasonic velocity, density and viscosity of solutions of some derivatives of sulphonamides in dimethylformamide (DMF) were measured at 35 °C [35]. From these experimental data, various acoustical properties such as specific impedance (Z), isentropic compressibility (K_s), Rao’s molar sound function (R_m), the Van der Waals constant (b), molar compressibility (W), intermolecular free length (L_f), relaxation strength (r), free volume (V_f), relative association (R_A), internal pressure (π), apparent molar volume (ρ), apparent molar compressibility (ρK), etc. were
calculated. The results are interpreted in terms of molecular interactions occurring in the solutions.

The densities, viscosities and ultrasonic velocities of some mineral salts viz; ammonium nitrate \([\text{NH}_4\text{NO}_3]\), potassium nitrate \([\text{KNO}_3]\); magnesium nitrate \([\text{Mg} (\text{NO}_3)_2]\) and calcium nitrate \([\text{Ca} (\text{NO}_3)_2]\) in 30% (w/w) tetrahydrofuran + water mixtures have been measured at temperatures 303, 308, 313, 318 and 323K [36]. Apparent molar volumes \((\tilde{\phi})\), viscosity B-coefficient, and adiabatic compressibility \((\beta)\) of these electrolytes were derived, from the data supplemented with their densities, viscosities and ultrasonic velocities respectively. The limiting apparent molar volume \((\tilde{\phi}^0)\) and experimental slopes \((S^*_x)\) obtained from 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. The results show that these electrolytes have structure-making capacities in this solvent mixture. The compressibility data also indicate the electrostriction of solvent molecules around the metal ions.

Partial molar volumes for a homologous series of amino acids and peptides have been measured in 1m aqueous solution of sodium acetate, sodium, thiocyanate and sodium sulphate at 25°C [37]. These data have been utilized in conjunction with the data in water to deduce partial molar volumes of transfer \((\Delta \tilde{\phi}^o)\) from water to these aqueous salt solutions. The volumes of transfer for the amino acids and peptides are found to be positive. The interpretation is that this result arises from the dominant interaction of the sodium salts with the charged centers of amino acids and peptides. Thermal denaturation of the structurally homologous proteins lysozyme and \(\alpha\) -lactalbumin has observed in the presence of sodium acetate and sodium sulphate. However, thermal stabilization observed for \(\alpha\) -lactalbumin is very small in the presence of these salts and the sodium thiocyanate leads to a lowering of its thermal denaturation temperature. The rise in the surface tension of aqueous salt solutions with salt concentration has been correlated with the calorimetric and volumetric measurements. The results show that \((\Delta \phi^o)\) depends less on the type of electrolyte than on the ionic strength of the solutions, indicating significant role of surface tension in interactions of amino acids, peptides or protein with the salts.
Complex formation in ternary liquid mixtures of dimethylsulfoxide (DMSO) with phenol and o-cresol in carbontetrachloride has been studied by measuring ultrasonic velocity at 2 MHz, in the concentration range of 0.019-0.162 (in mole fraction of DMSO) at varying temperatures of 20, 30 and 40 °C [38]. Using measured values of ultrasonic velocity, other parameters such as adiabatic compressibility, intermolecular free length, molar sound velocity, molar compressibility, specific acoustic impedance and molar volume have been evaluated. These parameters have been utilized to study the solute-solute interactions in these systems. The ultrasonic velocity shows a maxima and adiabatic compressibility a corresponding minima as a function of concentration for these mixtures. The results indicate the occurrence of complex formation between unlike molecules through intermolecular hydrogen bonding between oxygen atom of DMSO molecule and hydrogen atom of phenol and o-cresol molecules. The excess values of adiabatic compressibility and intermolecular free length have also been evaluated. The variation of both these parameters with concentration also indicates the possibility of the complex formation in these systems.

Further, to investigate the presence of O-H-O bond complexes and the strength of molecular association with concentrations, the infrared spectra of both the systems, DMSO-phenol and DMSO-o-cresol, have been recorded for various concentrations at room temperature (20 °C). The results obtained using infrared spectroscopy for both the systems also support the occurrence of complex formation through intermolecular hydrogen bonding in these ternary liquid mixtures.

Densities of solutions of NaBF₄ in water have been determined at 20°C over the concentration range 0.05 to 9.0 molal (0 to 50 wt %) NaBF₄. The results are represented by $d(\text{g/ml, } 20 \text{ °C}) = 9.726 \times 10^{-5} \text{m}^3 - 3.2157 \times 10^{-3} \text{m}^2 + 6.7447 \times 10^{-2} \text{m} + 0.99843$, where $d$ is density and $m$ is the molality [39]. This equation has been used to derive concentrative properties for NaBF₄ solutions. The raw density data have been used to derive partial molal volumes. The partial molal volume at infinite dilution is $37.6 \pm 2.7 \text{ ml/mol at } 20\text{°C}$. The partial molal volume at 20°C is represented by

$$\bar{v}_2 = 37.5 + 9.22 m^{1/2} - 2.92 m \text{ from 0 to 2.5 m NaBF}_4$$

and

$$\bar{v}_2 = 44.6 + 0.081 m \text{ from 2.5 to 9m NaBF}_4.$$

Densities and viscosities of ternary systems involving maltose, alkali metal
halides (NaCl, KCl, KBr and KI) and water have been determined at temperatures 293.15, 303.15 and 313.15 K [40]. From density data the values of limiting apparent molar volumes \( \bar{v}_m^0 \) of maltose in purely aqueous solutions and also in the presence of NaCl, KCl, KBr and KI have been obtained to determine the partial molar volume of transfer \( \bar{v}_{2, tr}^0 \) of maltose from water to aqueous solutions of NaCl, KCl, KBr and KI. The viscosity data of alkali metal halides in purely aqueous solutions and in the presence of maltose have been analyzed by applying Jones-Dole equation. The structure making and structure breaking capacities of NaCl, KCl, KBr and KI in purely aqueous solution and in the presence of maltose have been ascertained from the temperature dependence of \( \phi_v^0 \).

Various acoustic parameters such as isentropic compressibility (\( \beta_s \)), intermolecular free length (\( L_f \)), apparent molar volume (\( \phi_v \)), apparent molar compressibility (\( \phi_s \)), molar compressibility (\( \omega \)), molar sound velocity (\( R \)), acoustic impedance (\( Z \)) of KI in 10,20 and 30% dioxane-water at 303.15K have been determined from ultrasonic velocity (\( V \)), density (\( \rho \)) and relative viscosity (\( \eta_r \)) of the solution [41]. These parameters have been related with the molar concentration of the solution and reflect the distortion of the structure of the solvent i.e, dioxane-water when solute is added to it.

Experimental results for partial molar volumes and viscosities of aqueous solutions of \( \alpha \)-dl-aminobutyric acid, dl-norvaline and dl-norleucine at 288.15, 293.14, 298.15 and 303.15K have been reported [42]. The thermodynamic behavior of aqueous amino acid solutions has been compared with that reported for glycine and \( \alpha \)-alanine in water is discussed in terms of group additivity and electrostriction. The temperature dependence of the infinite dilution partial molar volumes and the B-coefficients are interpreted in terms of amino acid hydration. According to the usual hydrophobicity criteria, the amino acids considered do not have a hydrophobic character and their behavior is dominated by the polar groups.

Densities and viscosities for the solutions of \( \alpha \)-amino acids in aqueous calcium chloride (3.0 mol kg\(^{-1}\)) have been determined 278.15, 288.15, 298.15 and 308.15K [43]. These data have been used to calculate apparent molar volumes and viscosity B-coefficients of the amino acids. The standard partial molar volumes \( \bar{v}_{2,1}^0 \)
and hydration number of the amino acids have been determined at different temperatures. Free energies of activation \( \Delta \mu_{2}^{\text{at}} \) for viscous flow of solutions were obtained by the application of transition state theory to the B-coefficient data and the corresponding activation enthalpy \( \Delta H_{2}^{\text{at}} \) and entropy \( \Delta S_{2}^{\text{at}} \) were also given. It has been shown that \( \Delta \mu_{2}^{\text{at}} \), B-coefficients and the free energies of activation vary linearly with increasing number of carbon atoms in the alkyl chain of the amino acids and they were split into contributions from the zwitter-ionic and group \((-\text{NH}_3^+, \text{COO}^-)\) and methylene groups of the amino acids. The volumetric data have been interpreted in terms of the hydration of the hydrophobic and hydrophilic parts of the amino acids. From the viscosity data structural effects of the amino acids in the solutions have been discussed.

Apparent molar adiabatic compressibilities and viscosities of glycine, dl-\( \alpha \) -alanine, dl-\( \alpha \)-amino-n-butyric acid, l-valine, 1-valine, l-leucine and diglycine have been determined in aqueous and mixed aqueous solutions of \( m(B) = 1.0, 2.0, 3.0, 4.0 \) and 5.0 aqueous-n-propanol solutions at 298.15K [44]. From these data the partial molar adiabatic compressibilities and viscosity B-coefficient have been evaluated to calculate the corresponding transfer functions. The partial molar adiabatic compressibilities of transfer at infinite dilution \( \Delta \kappa_{\mu,2,1}^{\text{at}} \) for all the studied model compounds are positive and increase with the concentration of n-propanol. Positive and negative B-coefficients of transfer \( \Delta B_{\mu} \) have been observed for the studied amino acids in lower and in higher concentration of n-propanol, respectively. The activation energy for the viscous flow in aqueous and mixed aqueous n-propanol solutions has been calculated from B-coefficient and the partial molar volume data. Hydration numbers and the interaction coefficients have also been calculated from these data. These parameters have been discussed in terms of solute-co-solvent interactions. Thermal denaturation of lysozyme has also been studied using UV-visible spectrophotometer in aqueous and in mixed aqueous solutions of n-propanol, 1, 2-propanediol and glycerol. The thermodynamic parameters accompanying the thermal denaturation have been evaluated. The results have been explained on the basis of competing patterns of interactions of the co-solvents with the native denatured reaction. The preferential interaction parameters have been calculated from these thermodynamic data and by correlating the surface tension data of n-propanol.
and 1,2-propanediol to the surface area of the protein. Some parallelism in the patterns of interaction has been observed for the studied model compounds and proteins in the aqueous solutions of these solvents.

Ultrasonic velocity, density, refractive index and viscosity of dextrose+methionine, ZnCl₂ +dextrose, ZnCl₂ + methionine, ZnCl₂ + methionine + dextrose in water have been reported [45]. From these measured values the apparent molar volume ($\psi$), partial molar volume ($\psi^\circ$), experimental slope ($S_v$), adiabatic compressibility ($\beta$), apparent molar compressibility ($\phi$), viscosity coefficients A and B of Jones-Dole equation have been calculated at 298.15 K. The observed and calculated values have been used to explain molecular association, ion-solvent and hydrogen bonding interaction. The study may be helpful in understanding the dynamics between metal ions and bio-molecules.

Viscosities of aqueous solutions of nitrates of Na⁺, K⁺, Mg²⁺, Ca²⁺ and Sr²⁺ were determined by using thermostated Ubbelhode flow viscometer at temperatures from 20-50°C [46]. From the experimental results, ion-solvent interactions terms (B-coefficients) were calculated in the concentration range 0.1 to 4 m, by using an empirical equation. It was concluded that the viscosities of these ions in aqueous solutions could be understood in terms of hydration number, charge on ion and ionic radius. Ratio of the viscosities of the nitrates and chlorides with common cations were also calculated and interpreted in terms of hydration of cations, anions and ion-pair formation.

Structural and dynamical investigations on concentrated aqueous solutions of aluminium chloride and bromide in liquid and glassy states have been performed by means of Raman and inelastic neutron scattering spectroscopy and by x-ray diffraction [47]. Inelastic neutron scattering results for solutions of beryllium chloride in a glassy state are compared with the results for the aluminium cation solutions. Isotopic changes on going from H₂O to D₂O of the Raman spectra assigned to vibrations of water molecules in the cation hydration shells are discussed. Inelastic neutron scattering data complement and corroborate the Raman spectral study. Further structural information is obtained from x-ray diffraction experiments, and its interpretation is supported by calculations based on ad hoc molecular models. The
existence of a liquid-type quasi-close packing is suggested for concentrated aqueous solutions of aluminium halides, in agreement with previous studies.

Ultrasonic velocity and density of aqueous solutions of polypropylene glycol have been measured experimentally over the whole range of composition at temperatures \( T = (283.15 \text{ to } 313.15) \text{ K} \) and atmospheric pressure [48]. From these experimental data, the excess specific volumes, isentropic compressibility, increments of the ultrasonic velocity, and the isentropic compressibility have been determined for each composition. The results have been interpreted in light of polymer–solvent and polymer–polymer interactions. Also, the excess specific volumes, the increments of the ultrasonic velocity, and the isentropic compressibility were fitted to a variable-degree polynomial equation.

The ultrasonic velocities of tetraethylammonium bromide (Et₄NBr), tetrapropylammonium bromide (Pr₄NBr), tetrabutylammonium bromide (Bu₄NBr), tetrpentylammonium bromide (Pen₄NBr), sodium tetraphenylborate (NaBPh₄), and sodium bromide (NaBr) in N,N-dimethylacetamide + water (50\% v/v) mixture have been measured in the concentration range 0.01–0.10 mol dm⁻³ at 298.15 K [49]. Apparent molar isentropic compressibilities (\( k_\Phi \)) of these electrolytes were derived from these data supplemented with their density values. The limiting apparent molar isentropic compressibilities (\( k_\Phi^0 \)) have been obtained by the method of extrapolation from the linear plots of apparent molar isentropic compressibilities (\( k_\Phi \)) against the square root of the molal concentration. The limiting apparent molar isentropic compressibility (\( k_\Phi^0 \)) values were separated into approximate limiting ionic compressibilities (\( k_{\Phi,\text{ion}}^0 \)) on the basis of the assumption that the limiting ionic compressibility of the bromide ion is zero. The results have been interpreted in terms of electrostriction and penetration effects.

Ultrasonic velocities of tetrapropylammonium bromide (Pr₄NBr), tetrabutylammonium bromide (Bu₄NBr), tetrpentylammonium bromide (Pen₄NBr), tetrahexylammonium bromide (Hex₄NBr), tetraheptylammonium bromide (Hep₄NBr), and tetraoctylammonium bromide (Oct₄NBr) in N,N-dimethylacetamide have been measured at 298.15 K [50]. Apparent molar isentropic compressibilities \( k_\Phi \) of these electrolytes were derived from these data supplemented with their densities. The limiting apparent molar isentropic compressibilities \( k_\Phi^0 \) were obtained.
by extrapolation from the plot of $\kappa_\phi$ vs. the square root of the molality. The $\kappa_\phi^0$ values of the electrolytes were split into approximate limiting ionic compressibilities $\kappa_\phi^0\pm$ on the basis of the assumption that $\kappa_\phi^0 (\text{Br})=0$. The results have been interpreted in terms of specific constitutional and structural factors of the solvent molecules and of solute ions.

Viscosities and densities of sucrose in aqueous alkali metal halide solutions of different concentrations in the temperature range 293.15 to 313.15 K have been measured [51]. Partial molar volumes at infinite dilution ($V_2^\circ$) of sucrose determined from apparent molar volume ($\Phi_v$) have been utilized to estimate partial molar volumes of transfer ($V_2^\circ_{\text{tr}}$) for sucrose from water to alkali metal halides solutions. The viscosity data of alkali metal halides in purely aqueous solutions and in the presence of sucrose at different temperatures (293.15, 303.15 and 313.5 K) have been analyzed by the Jones-Dole equation. The nature and magnitude of solute-solute and solute-solvent interactions have been discussed in terms of the values of limiting apparent molar volume ($\Phi_v$), slope ($S_v$) and coefficients of the Jones-Dole equation. The structure-making and structure-breaking capacities of alkali metal halides in pure aqueous solutions and in the presence of sucrose have been ascertained from temperature dependence of ($\Phi_v$).

Relative viscosities for the solutions of oxalic acid and its salts viz-ammonium oxalate, sodium oxalate and potassium oxalate, at different concentrations have been determined in water and in binary aqueous mixtures of tetrahydrofuran (THF) [5, 10, 15 and 20% by weight of THF] at 298.15 K and in water and in 5% (w/w) THF + water at five different temperatures [52]. The data have evaluated using the Jones-Dole equation and the obtained parameters have been interpreted in terms of solute-solute and solute-solvent interactions. The activation parameters of viscous flow have been obtained which depicts the mechanism of viscous flow. The oxalic acid and its salts behave as structure breakers in water and in binary aqueous mixtures of THF.

Experimental values of density and viscosity for the binary mixtures of aniline with methanol, ethanol, isopropanol and butanol at four different temperatures (303.15 – 318.15 K) over the entire mole fraction range of the mixture components at atmospheric pressures have been obtained [53]. From these data, excess molar
volume and excess viscosity of the compositions have been calculated. Negative volumes of excess molar volume and viscosity are exhibited by the systems. The results suggest that various effects such as physical, chemical and geometrical interactions might be developed in the systems.

Densities (\( \rho \)) of glycine, L-alanine and L-valine in aqueous solutions of MgCl\(_2\cdot6\)H\(_2\)O (0.1 – 0.8 mol kg\(^{-1}\)) have been measured at 288.15 and 308.15 K [54]. Apparent molar volumes (\( V^\phi \)), and limiting partial molar volumes (\( V^o \)) of each amino acid have been calculated. These data were combined with the earlier reported \( V^o \) values of glycine, L-alanine, and L-valine in aqueous MgCl\(_2\cdot6\)H\(_2\)O solutions at 298.15 K in order to describe the temperature dependence behavior of partial molar quantities. Group contributions to partial molar volumes have been determined for the amino acids. The trends of transfer volumes (\( \Delta V^o \)) have been interpreted in terms of solute-cosolute interactions on the basis of a cosphere overlap model. Pair and triplet interaction coefficients have also been calculated from transfer parameters.

The densities and viscosities for the binary mixtures of acetonitrile + aromatic ketones (acetophenone, propiophenone, paramethyl acetophenone and parachloro acetophenone) at 308.15K over the entire range of composition are reported here [55]. The densities and viscosities have been used to calculate the excess molar volumes and deviations in viscosity. The excess molar volumes and deviations in viscosity are fitted to a Redlich - kister type equation. Other parameters like excess Gibbs free energy of activation of viscous flow and Grunberg – Nissan interaction constant are also utilized in the qualitative analysis to elicit the information on the nature of the bulk molecular interactions of acetonitrile + aromatic ketone binary mixtures.

Densities and viscosities of glycine have been measured at 288.15, 298.15 K and 308.15 K in aqueous sucrose solutions ranging from 5 to 25 mass % of sucrose [56]. The viscosity data have been analyzed using the Jones-Dole equation. Apparent molar volumes, limiting partial molar volume and relative viscosity have been evaluated from the density and viscosity data. Transfer volumes and limiting partial molar expansibilities have also been calculated from the temperature dependence of limiting partial molar volumes. The results have been discussed in terms of solute-solute and solute-solvent interactions and the structural changes of the solutes in solutions.
Viscosities and densities of aqueous solutions of sodium salts of monocarboxylic acids (formic, acetic, propionic, valeric, chloro acetic, trichloro acetic, glycolic, phenyl acetic) and dicarboxylic acids (oxalic, malonic, succinic, glutaric, adyptic, pimelic, dl-tartaric, dl-malic, maleic, fumaric, O-phthalic) have been measured in the concentration range 0.02 – 0.1 mol.dm$^{-3}$ at 298.15 K. The effect of hydrolysis of salts on viscometric data describing the objects under study was considered [57]. The modified Jones-Dole equation taking into account the phenomenon of hydrolysis was proposed. The viscosity B-Coefficients for these electrolytes were determined.

The thermal conductivity of three (0.239, 0.499 and 0.782 mol.kg$^{-1}$) and the viscosity of four (0.0658, 0.2055, 0.3050 and 0.4070 mol. kg$^{-1}$), binary aqueous K$_2$SO$_4$ solutions have been measured with coaxial – cylinder (steady state) and capillary – flow techniques, respectively [58]. Measurements were made at pressure up to 30MPa, and the range of temperature was 298 – 575 K. The total uncertainties of the thermal conductivity, viscosity, pressure, temperature, and composition measurements were estimated to be less than 2%, 1.6%, 0.05%, 30 mk and 0.02% respectively. The measured values of the thermal conductivity and viscosity of K$_2$SO$_4$ (aq) were compared with data and correlations reported in the literature. The reliability and accuracy of the experimental method was confirmed with measurements on pure water with well known (IAPWS Standards) thermal conductivity and viscosity values (deviations, AAD, within 0.31% and 0.52% respectively). The values of the viscosity A-, B- and D- coefficients of the extended Jones – Dole equation for the relative viscosity $(\eta/\eta_o)$ of aqueous K$_2$SO$_4$ solutions as a function of temperature were studied. The maximum of the B- coefficient near 340 K has been found. The derived values of the viscosity A- and B- coefficients were compared with results predicted by Falkenhagen – Dole theory of electrolyte solutions and calculated with the ionic B- coefficient data. The behavior of concentration dependence of the relative viscosity of aqueous K$_2$SO$_4$ solutions is discussed in terms of the modern theory of transport phenomena in electrolyte solutions.

The enthalpies of dilution of D-sorbitol and D-mannitol with water and aqueous sodium halide solutions were determined by isothermal microcalorimetry at 313.15 K [59]. Experimental enthalpies of dilution varying with the concentration of
the polylols were correlated with the virial expansion equation that was obtained with the McMillan-Mayer theory. Enthalpic interaction coefficients \( h_2, h_3, \) and \( h_4 \) in the equations have been determined, and the values of the pairwise enthalpic interaction coefficient \( (h_2) \) are discussed in terms of solute-solute and solute-solvent interactions.

Isopiestic measurements have been carried out at the temperature 298.15 K for the quinary system (water + mannitol(sat) + sodium chloride + ammonium chloride + barium chloride) saturated with mannitol and its ternary sub-systems (water + mannitol(sat) + sodium chloride), (water + mannitol(sat) + ammonium chloride) and (water + mannitol(sat) + barium chloride) [60]. Taking aqueous sodium chloride as reference solutions, osmotic coefficients of the other aqueous solutions were determined. The experimental results show that the isopiestic activities of the quinary system in relation to its ternary sub-systems are in excellent agreement with the ideal-like solution model.

Ultrasonic velocities and densities were measured in the mixtures of water with ethylene glycol (EG) and polyethylene glycol (PEG) 200, 400 in the temperature range from 291.15 to 303.15 K [61]. Adiabatic compressibilities were calculated from Laplace's equation based on the experimental results obtained. Variations of these values with concentration and temperature were studied. Structural interactions and the formation of a compact pseudostable structure at very low concentrations of ethylene glycol and polyethylene glycols were observed. The plots of the adiabatic compressibility versus the mole fraction of PEG and EG display two characteristic points at low concentrations: the intersection of the isotherms and their minimum. Such relations between adiabatic compressibility, concentration and temperature are usually attributed to the formation of pseudo-stable molecular structures. To formulate a model of local structures present in the investigated molecular systems, it is indispensable to get an insight into hydration of molecules and the formation of hydrogen bonds. Therefore, the attention was focused particularly on these problems.

The results of acoustic measurements of velocity and absorption in three pure liquids: thiophene, p-and m-xylene and their mixtures are presented [62]. The experiments for the mixtures of thiophene were carried out by Eggers' method at frequencies 0.3–5 MHz, and for pure liquids by the pulse method in the frequency range 10 MHz–10 GHz, all at 293.15 K except for thiophene (at 281 and 333 K). The absorption in thiophene shows that all vibrational degrees of freedom take part in the
observed relaxation, caused by the Kneser processes. This process can be described as a vibrational relaxation with one relaxation time. Absorption in the mixtures decreased when increasing the amount of xylenes, as predicted by theory of gases, thus suggesting that the absorption is probably due to the same phenomenon as in gases.

Ultrasonic velocities (u) in dilute solutions of water in diethylamine, triethylamine, dibutylamine and di-sec-butylamine have been determined at 298.15 K using single crystal variable path interferometer working at 3 MHz [63]. Excess ultrasonic velocities (uE) have been evaluated using thermodynamically valid expression. A distinctive non-linear variations of ultrasonic velocity and excess ultrasonic velocity with concentration (X2) of water in all the (amine + water) systems have been observed. The linear variation of u and uE upto certain optimum concentration (X2)opt, observed has been explained as due to the existence of water molecules as monomers distributed uniformly throughout the solutions. The non-linear variations of u and uE versus X2 beyond (X2)opt has been explained in the light of water-water and water-amine interactions leading to the formation of water-amine complexes.

The densities, ρ, ultrasonic speeds, u and viscosities, η of pure benzyl alcohol, 1-propanol, 2-propanol and those of their binary mixtures, with benzyl alcohol as a common component, have been measured at 298.15, 303.15, 308.15 and 313.15K over the entire composition range [64]. The excess molar volume, V^E, deviation in isentropic compressibility, Δkₛ, excess thermal expansivity, α^E, deviations in ultrasonic speed, Δu and viscosity, Δ η, partial molar volume and compressibility, V₀^φ, 2 and K₀^φ, 2 of 1-propanol/2-propanol in benzyl alcohol at infinite dilution have been evaluated from the experimental data. The results have been used to discuss the nature and strength of intermolecular interactions in these mixtures. The V^E values have also been calculated theoretically by using the Flory’s statistical theory and Prigogine–Flory–Patterson theory. The calculated V^E values were found in good agreement with the experimental V^E values. The thermal expansivity, α and isothermal compressibility, k_T have been calculated theoretically by using Flory’s theory and various hard sphere models, and were compared with experimental α and k_T values.

Densities, ρ, ultrasonic speeds, u, viscosities, η, and refractive indices, n, of
pure benzene, benzyl alcohol (BA), benzonitrile (BN), benzoyl chloride (BC), chlorobenzene (CB) and their thirty six binary mixtures, with benzene as common component, were measured at 303.15 K over the entire mole fraction range [65]. From these experimental data the values of deviations in ultrasonic speed, $\Delta u$, isentropic compressibility, $\Delta k_s$, excess acoustic impedance, $Z^E$, deviation in viscosity, $\Delta \eta$, and excess Gibbs free energy of activation of viscous flow, $G^*E$, and partial molar isentropic compressibility, $R^0_{q2}$ of BA, BN, BC and CB in benzene were computed. The variation of these derived functions with composition of the mixtures suggested the increased cohesion (molecular order) in the solution and that interaction $(A-B) > (A-A)$ or $(B-B)$. Moreover, theoretical prediction of ultrasonic speed, viscosity and refractive index of all the four binary mixtures was made on the basis of empirical and semi-empirical relations by using the experimental values of the pure components. Comparison of theoretical results with the experimental values was made in order to assess the suitability of these relations in reproducing the experimental values of $u$, $\eta$ and $n$. Also, molecular radii of pure liquids and the average molecular radii of binary mixtures were evaluated using the corresponding refractive indices of pure liquids and binary mixtures. The average molecular radii of binary mixtures were found to be additive with respect to mole fraction of the pure component.

Isentropic compressibilities, Rao’s molar sound functions, molar refractions, excess isentropic compressibilities, excess molar volumes, viscosity deviations and excess Gibbs energies of activation of viscous flow for seven binary mixtures of tetrahydrofuran (THF) with cyclohexane, methylcyclohexane, n-hexane, benzene, toluene, p-xylene and propylbenzene over the entire range of composition at 303.15 K have been derived from experimental densities, speeds of sound, refractive indices and viscosities [66]. The excess partial molar volumes of THF in different solvents have been estimated. The experimental results have been analyzed in terms of the Prigogine–Flory–Patterson theory.

Densities and ultrasound velocities for the binary mixtures of 1-bromobutane + benzene and 1,4-dimethylbenzene and of 1-bromopentane + cyclohexane and benzene have been measured at 308.15 K [67]. Adiabatic compressibilities ($\beta_{ad}$), and Wada’s constants (W) have also been evaluated as a function of composition. The ultrasound velocities decrease, attains a minimum and then increase with increase in
mole fractions of hydrocarbons in the binary mixtures except in the case of 1-bromopentane + benzene binary mixtures where the variation is just the reverse. Dependence of adiabatic compressibilities with mole fractions of hydrocarbons is sigmoid. The non-ideal behavior of the systems studied is explained on the basis of dipole-induced dipole interactions.

Viscosity as well as molar volume for binary liquid mixtures of N,N-dimethyl aniline (DMA) with methylene chloride and chloroform have been determined as a function of the composition at 303.15 K, 308.15K and 313.15 K respectively [68]. Excess Gibbs energy of activation $\Delta G^\text{*E}$ of viscous flow has been calculated as per Eyring theory of absolute reaction rates. The deviations of the viscosities from a linear dependence on the mole fraction and the values of $\Delta G^\text{*E}$ for binary mixtures have been explained in terms of molecular interactions between unlike molecules.

Densities $(\rho)$, Ultrasonic velocities $(U)$ and relative viscosity $(\eta_r)$ of manganese chloride in 20% ethanol + water mixture have been measured as a function of electrolyte concentration at 303.15K temperature [69]. The experimental values of $\rho$ and $U$ are used to calculate isentropic compressibility $(\phi_s)$, intermolecular free length $(L_\phi)$, relative association $(R_A)$, and apparent molar volume $(\phi_s)$. The derived parameters have been used to interpret the solvent-solvent, ion-solvent and solute-solvent interactions.

Densities $(\rho)$ and apparent molar volume $(V_\phi)$ of aqueous urea, N-methyl urea, N,N-dimethyl urea and 1,1,3,3-tetramethyl urea have been measured from 0.2M to 1.0M on an interval of 0.2M at 30 °C [70]. Limiting density $(\rho^o)$ and apparent molar volume $(V_{\phi}^o)$ were obtained by regression of primary data and to illustrate the solute-solvent interactions. The decrease value of $\rho^o$ and increasing value $V_{\phi}^o$ with increasing number of –CH$_3$ groups suggests some weak hydrophilic and strong hydrophobic interactions so that the structure-breaking effect decreases and structure making effect increases. It was also found that with increasing concentration the hydrophilic or hydrophobic interactions become stronger.

Fundamental properties, density $(\rho)$ and viscosity $(\eta)$ of citric acid (CA) and disodium hydrogen orthophosphate (DSP) at various strengths were obtained at
different temperatures [71]. The \( \rho \) and \( \eta \) values were used to determine apparent molal volumes and viscosity of systems. The \( \rho, V_\phi \) and \( \eta \) values were regressed against molality \( m \) for \( \rho^o, \eta^o \) and \( V_\phi^o \), the limiting constants at infinite dilution \( (m \to 0) \) for ionic and molecular interactions. The \( \rho^o \) and \( V_\phi^o \) of aqueous acids are higher than those of aqueous DSP and the viscosity of DSP is higher than that of aqueous CA. Examination of \( \rho^o \) and \( V_\phi^o \) functions indicates that mutual compositions of CA and DSP counterbalance concentration and temperature effects on pH in bioprocesses.

Density and viscosity data are presented for eight binary liquid mixtures of toluene with n-butylamine, Sec-butylamine, tert-butylamine, n-pentylamine, n-hexylamine, n-heptylamine, n-octylamine and cyclo hexylamine at 303.15 K over the whole range of composition [72]. From the experimental data, excess viscosity and excess molar Gibb’s free energy for the activation of flow have been computed and presented as function of composition. The results are attributed to the interaction between unlike molecules.

Conductance measurements for selected alkali metal chlorides, MCl (\( M^+ = \) Li, Na, K) are performed in the binary mixtures of methanol with carbon tetrachloride and 1, 4-dioxane at 298.15K [73]. The limiting equivalent conductance \( (\Lambda_e) \), the association constant \( (K_A) \), and the Walden products \( (\Lambda_e \eta_e) \) for the three salts are evaluated at all the mole fractions of the solvent mixtures using the 1978 Fuoss conductance-concentration equation. Analysis of data indicates presence of strong association of the electrolytes in the solvent mixtures studied here. The results have been discussed and interpreted in terms of ion-solvent interactions and structural changes in the mixed solvent systems.

A comprehensive mixed-solvent electrolyte model has been extended to calculate liquid–liquid equilibria in water–organic salt systems [74]. Also, it has been applied to calculate phase equilibria and speciation in strongly associating systems such as sulfuric acid/oleum (\( H_2SO_4+SO_3+H_2O \)) in the entire concentration range. The model combines an excess Gibbs energy model with detailed speciation calculations. The excess Gibbs energy model consists of a long-range interaction contribution represented by the Pitzer–Debye-Hückel expression, a short-range term expressed by
the UNIQUAC model and a middle-range term of a second-virial-coefficient type for specific ionic interactions. The model accurately represents the thermodynamic behavior of systems ranging from infinite dilution in water to pure acids and beyond, e.g. in mixtures of H\textsubscript{2}SO\textsubscript{4} and SO\textsubscript{3}. In particular, the model has been shown to predict speciation that is consistent with spectroscopic measurements for the H\textsubscript{2}SO\textsubscript{4}+H\textsubscript{2}O system. In addition, vapor-liquid and liquid-liquid equilibria can be accurately reproduced in mixtures that show complex phase behavior.

Densities, viscosities, and ultrasonic velocities of binary mixtures of chloroform with propan-1-ol and butan-1-ol have been measured over the entire range of composition, at (303.15 and 313.15) K and at atmospheric pressure. From the experimental data, excess molar volumes ($V^E$), deviations in viscosity ($\Delta\eta$), and excess isentropic compressibility ($k_s^E$) have been calculated. The excess molar volumes and isentropic compressibility for propan-1-ol and butan-1-ol are positive while deviations in viscosity are negative [75]. The results have been interpreted in terms of intermolecular interactions.

Experimental results of investigations of the specific heat and the velocity of sound in aqueous solutions of the Pluronic PE6400 copolymer have been presented [76]. Phase transitions, phase states, and possible physical mechanisms of the effects have been discussed based on these results.

Ultrasonic velocity $U$ and viscosity $\eta$ have been measured for the binary mixture of tetrahydrofuran with 1-propanol and 2-propanol at $T = 293$ K, 303K and 313K over the entire composition range [77]. Using these experimental data and previously reported values of density $\rho$, excess adiabatic compressibility $\beta_s^E$, excess viscosity $\Delta\eta$, excess energy of activation $\Delta G^E$ and excess internal pressure $\pi^E$ have been evaluated. All these excess parameters were plotted against the mole fraction of tetrahydrofuran over the whole composition range. The strength and the nature of the interactions between like and unlike molecules have been discussed.

Speed of sound and densities of the ternary mixture 2-propanol + diethyl ether + n-hexane and also the binary mixtures 2-propanol + diethyl ether and 2-propanol + n-hexane have been measured at the entire composition range at 298.15 K [78]. The excess isentropic compressibilities and the excess speed of the sound have been calculated from experimental densities and speed of sound. These excess properties of
the binary mixtures were fitted to Redlich-Kister equation, while the Cibulka's equation was used to fit the values related to the values to the ternary system. These excess properties have been used to discuss the presence of significant interactions between the component molecules in the binary mixtures and also the ternary mixtures. Speed of sound of the binary mixtures and the ternary mixture have been compared with calculated values from free length theory (FLT), collision factor theory (CFT), Nomoto's relation (NR), Van Deal's ideal mixing relation (IMR) and Junjie's relation (JR). The results are used to compare the relative merits of these theories and relations in terms of the root mean square deviation relative (RMSDr).

Densities, $\rho$, viscosities, $\eta$, and refractive indices, $nD$ of aqueous caffeine (0.5M) and of solutions of amino acids, 1-phenylalanine (Phe), 1-tyrosine (Tyr) and 1-histidine (HIS), (0.01-0.05M) in aqueous-caffeine have been measured at 298.15, 303.15, 308.15 and 313.15K [79]. From these experimental data, apparent molar volume, limiting partial molar volume, and the slope, transfer volume, Falkenhagen coefficient, A, Jones-Dole coefficients, B, free energies of activation per mole of solvent, and per mole of solute, enthalpy and entropy of activation of viscous flow, and molar refraction were calculated. The results are interpreted from the point of view of solute-solvent and solute-solute interactions in these systems. It has been observed that there exist strong solute-solvent and weak solute-solute interactions in these systems. Further, the solute-solvent interactions decrease, whereas solute-solute interaction increases with rise in temperature. It is observed that these amino acids act as structure-makers in aqueous-caffeine solvent. The thermodynamics of viscous flow have also been discussed.

The excess molar volume $\bar{V}_m^E$, ultrasonic speed ($u$), and dynamic viscosity ($\eta$) have been measured in dipropylene glycol dimethyl ether + butylamine, dibutylamine, and tributylamine across their entire composition ranges at 298.15K and atmospheric pressure [80]. The density values derived from the excess molar volumes were converted to molar volumes ($V$) which are combined with the speed of sound to obtain estimates of the product $K_s$, $m$ and their excess counterparts $K_s^E$, $m$. In all mixtures the excess molar volumes are negative and symmetric across the entire composition range. The $K_s^E$, $m$ values are positive for all mixtures. The deviation of the speed of sound $u^D$ from their ideal values $U^{id}$ in an ideal mixture was also calculated.
for all measured mole fractions. Viscosities have also been measured for mixture of dipropylene glycol, dimethyl ether and butylamine, dibutylamine or tributylamine at the same temperature. From the experimental data, the deviation in the viscosity \( \eta \) from \( \sum x_i \ln \eta_i \) and excess energies of activation for viscous flow \( (\Delta G^e) \) have been derived for all systems. The Flory theory of mixtures provides a useful basis for a quantitative interpretation of the viscosity results. The theoretical values of molar isentropic compressibility \( (K_s, m) \) and of speed of sound \( (u) \) have been estimated using the Prigogine-Flory-Patterson (PFP) theory with the Vander wads (VdW) potential energy model and results have been compared with experimental values.

Viscosities for the solutions of some bivalent transition metal nitrates viz. manganese nitrate, cobalt nitrate, nickel nitrate, copper nitrate and Zinc nitrate; and magnesium nitrate, at different concentrations have been determined in aqueous and in binary aqueous mixtures of N, N-dimethyl foramide (DMF) at 303.15 K and in aqueous and in 5\% (w/w) DMF + water at five different temperatures [81]. The data have been evaluated using the Jones-Dole equation and the obtained parameters have been interpreted in terms of ion-ion and ion-solvent interactions. The activation parameters of viscous flow have been obtained which depicts the mechanism of viscous flow. The transition metal nitrates and magnesium nitrate acts a structure breakers in aqueous and in binary aqueous mixtures of DMF.

Apparent molar volumes \( (\nu_\phi) \) of oxalic acid in water and in aqueous sucrose solutions with concentration \( \approx (0.5-2.0) \) mol kg\(^{-1} \) have been determined as a function of molality by measuring \( \approx (0.5 - 2.0) \) mol kg\(^{-1} \) have been determined as a function of molality by measuring the densities at 293.15, 303.15, 313.15 and 323.15K [82]. From these data the limiting apparent molar volume\( (\nu_\phi) \), which is equal to the partial molar volume at infinite dilution\( (\nu_T^o) \), has been obtained at different temperatures. The partial molar volumes have been used to calculate the partial molar volumes of transfer \( (\Delta \nu_T^o) \) of oxalic acid from water to aqueous sucrose solutions. The values of limiting apparent molar expansibilities \( (\phi_T^e) \) and that of \( (\partial^2 \nu_T^o / \partial T^2) \), have also been determined from temperature dependence of \( \nu_T^o \) at various concentrations of the sucrose solutions. The results have been discussed in terms of various interactions operating in oxalic acid, water and sucrose systems.
The density of two binary mixtures formed by 1-butyl-3-methylimidazolium hexafluorophosphate [bmim][PF₆] with aromatic compound (benzyl alcohol or benzaldehyde) has been determined over the full range of compositions at the temperature range from 298.15 K to 313.15 K and at atmospheric pressure using a vibrating-tube densimeter (DMA4500) [83]. Excess molar volumes (Vₘₑ) have been obtained from these experimental results, and been fitted by the fourth-order Redlich–Kister equation. Our results show Vₘₑ decreases slightly when temperature increases in the systems studied. The results have been interpreted in terms of ion–dipole interactions and structural factors of the ionic liquid and these organic molecular liquids.

Results of ultrasonic velocity studies of tetrabutylammoniumtetraphenyl boride Bu₄NB₄Ph₄, tetrapropylammoniumiodide Pr₄NI, tetrabutylammonium iodide Bu₄NI, tetrapentylammonium iodide Pen₄NI and sodium tetraphenyl boride NaB₄Ph₄ in binary mixtures of DMSO and Ac has been reported [84]. Adiabatic compressibility coefficient, β and corresponding limiting molar adiabatic compressibility, $\phi\kappa^0 (s)$ of R₄NI salts are noted to decrease with the decrease in the size of hydrophobic group. This observation is suggested to be of relevance to the reorganizing of solvent molecules at the hydrocarbon–solvent interface, and not to direct solute–solvent interaction. The variation in $\phi\kappa^0 (s)$ with solvent composition, although reflects the contribution due to intermolecular interaction, insensitivity of solvent composition dependence of limiting ionic molar compressibility $\phi\kappa^0 (i)$ and its sign for Pen₄N⁺, Bu₄N⁺, Pr₄N⁺ and Ph₄B⁻ indicate their poor solvation behavior. $\phi\kappa^0 (i)<0$ for Na⁺ and I⁻ on the contrary, is suggested to support the solvation effect of these ions.

Ultrasonic velocity (u), viscosity (η) and density (ρ) have been measured for binary mixtures of dimethyl sulphoxide (DMSO) with propanoic acid (PA) and n-butyric acid (BA) at three temperatures 293 K, 303 K and 313 K, over the entire range of composition [85]. Deviation in isentropic compressibility $\Delta\beta_s$, deviation in viscosity $\Delta\eta$ and excess free energy of activation for viscous flow $\Delta G^*E$ have been calculated using experimental values of ultrasonic velocity (u), density (ρ) and viscosity (η). Deviation in isentropic compressibility ($\Delta\beta_s$) and viscosity ($\Delta\eta$) as well as excess free energy of activation for viscous flow ($\Delta G^*E$) were plotted against the mole fraction of DMSO over the entire composition range. The values of $\Delta\beta_s$ have
been found to be negative whereas the values of $\Delta G^{\neq E}$ and $\Delta \eta$ were positive for both the mixtures over the entire composition range. The strength and the nature of interaction between the molecules of DMSO with propanoic acid and n-butyric acid have been discussed.

The density, viscosity and ultrasonic velocity (2 MHz) of pure solvents: ethanol, MEK and DMF, and BCFA solutions (0.5–4 wt%) were investigated at three different temperatures: 30, 35 and 40 °C [86]. Various acoustical parameters such as isentropic compressibility ($\kappa_s$), internal pressure ($\pi$), free volume ($V_f$), free path length ($L_f$) and solvation number ($S_n$) were determined and correlated with concentration ($C$). Fairly good to excellent linear relationships are observed at three temperatures. The linear decrease of $\kappa_s$, $\pi$ and $L_f$ with $C$ and linear increase with temperature; and linear increase of $V_f$ with $C$ and $T$ in DMF system, nonlinear increase with $C$ and $T$ in EtOH system and nonlinear decrease with $C$ and increase with $T$ in MEK system indicated strong molecular interactions in the solutions and solvophilic nature of BCFA, which is further supported by positive values of solvation number. The observed solvation trend is EtOH > MEK > DMF.

The studies of ultrasonic velocities, refractive indices and surface tension are being increasingly used as tools for investigation of the properties of pure components and the nature of intermolecular interactions between the liquid mixture constituents [87]. Refractive indices ($n_0$), ultrasonic velocities ($U$) and surface tension ($\sigma$) have been measured for the binary liquid mixture of Anisaldehyde + benzene over the entire composition range at 313.15 K. This study involves the evaluation of different thermo acoustical parameters along with the excess properties. The Redlich-Kister model was used to correlate the measured properties. It was found that in all cases, the experimental data obtained fitted with the values correlated by the corresponding models very well. The molecular interactions existing between the components were also discussed.

Apparent molar adiabatic compressibilities, $K_{s,2}^{\Phi}$, viscosities, $\eta$, of glycine, DL-$\alpha$-alanine, L-valine, L-leucine and L-phenylalanine have been determined in water and in mixed aqueous solutions of glycerol (0.5, 1.0, 2.0, 3.5, and 5.0 mB molality of glycerol in water /mol kg$^{-1}$) at 298.15K [88]. These data have been used to calculate partial molar adiabatic compressibilities at infinite dilution, $K_{s,2}^{\Phi}$, and viscosity B-coefficients, and their corresponding transfer functions. The positive
partial molar adiabatic compressibilities of transfer at infinite dilution, $\Delta nK^0_{s,2}$, have been observed for the studied amino acids (except at lower concentration up to 0.6 mB in some cases), and their magnitude increases with increase in concentration of glycerol. B-coefficient of transfer, $\Delta cB$, values are positive for these amino acids, which after passing through maxima $\sim 3.5$mB decrease at higher concentration of glycerol. The activation energy of viscous flow in aqueous and mixed aqueous glycerol solution has been calculated from B-coefficient and partial molar volume data. Hydration numbers, interaction coefficients and side chain contributions have also been calculated. These results have been discussed in terms of solute-solvent interactions, and an attempt has also been made to correlate these parameters with the stability of protein in aqueous glycerol solutions.

Viscosity and apparent molar volumes ($V_\phi$) of solutions of uni- univalent and bi-univalent electrolytes (NaCl, KCl, NH4Cl, NaNO3, KNO3, NH4NO3 and BaCl2, MgCl2, Ba(NO3)2 and Mg(NO3)2 in purely aqueous thiourea solution have been determined at $(293.15, 303.15$ and $313.15)K$ [89]. These data have been used to calculate the constant of Jones-Dole and Masson’s equations. Activation thermodynamic quantities ($\Delta\mu^0_1$, $\Delta\mu^0_2$, $\Delta S^0_2$, $\Delta H^0_2$) of viscous flow have also been obtained. From the values of these parameters conclusion regarding ion-ion and ion-solvent interactions have been obtained. It has also been found that all the electrolytes behave as structure maker in purely aqueous and thiourea solutions.

Apparent molar volume ($V_f$) have been determined for mono-and disaccharides [D(+)-glucose, D(-)-fructose and sucrose] in water and aqueous oxalic acid solutions at different concentrations in the range 0.2-1.0 mol kg$^{-1}$ by measuring the densities at $(293.15, 303.15, 313.15$ and $323.15)K$ [90]. The limiting apparent molar volume ($V_f^0$) and experimental slope ($S_v$) have been obtained in each case and their significance has been discussed briefly. The partial molar volume ($V_t^0$) has been used to calculate the partial molar volume of transfer ($\Delta V_f^0$) of mono and disaccharides from water to aqueous oxalic acid solutions at different temperatures. The values of limiting apparent molar volume expansibilities ($\bar{F}_0$) and that of $(d^2V_f^0 /dT^2)p$ have been determined from temperature dependence of $V_f^0$. It is concluded that all the saccharides behave as structure maker in water as well as in aqueous solutions of oxalic acid.
Apparent molar volumes and viscosity B-coefficient for nicotinamide in (0.00, 0.05, 0.10, and 0.15) mol dm\(^{-3}\) aqueous tetrabutylammoniumbromide (TBAB) solution have been determined from solutions density and viscosity measurements at temperature range (298.15 to 318.15) K as function of concentration of nicotinamide (NA) [91]. In the investigated temperature range, the relation: \(\varphi_v^0 = a_0 + a_1 T + a_2 T^2\), have been used to describe the temperature dependence of the standard partial molar volumes \(\varphi_v^0\). These results in conjuction with the results obtained in pure water have been used to deduce the standard volumes of transfer \(\Delta \varphi_v^0\) and viscosity B-coefficients of transfer for NA from water to aqueous TBAB solutions for rationalizing various interactions in the ternary solutions. The structure making or breaking ability of NA has been discussed in terms of sign of \(\partial^2 \varphi_v / \partial T^2\).

Apparent molar volumes and viscosities of disaccharides D- (+)-maltose monohydrate, D- (+)- lactose monohydrate, sucrose, and D- (+)- cellobiose in water and in (0.49850 and 0.99705) mol. kg\(^{-1}\) aqueous solutions of ammonium sulphate have been determined from density, \(\rho\), and efflux time, \(t\), measurements, respectively, at temperatures (288.15, 298.15, 308.15, and 318.15) K [92]. The refractive indices, \(n_D\), for these systems have also been determined. From these data, the standard partial molar volumes at infinite dilution and viscosity B-coefficients (using the Jones-Dole equation) have been determined at different temperatures. The standard partial molar volumes of transfer and B-coefficients of transfer, \(\Delta B\), have been estimated for the transfer of disaccharides from water to aqueous ammonium sulphate solutions. Partial molar expansion coefficients \((d^2 \varphi_v^0 / dT^2)_p\) and \((d^3 \varphi_v^0 / dT^3)_p\) and dB/dT coefficients have also been estimated. Gibbs free energy of activation of viscous flow has been calculated by using Feakin’s transition-state theory for the studied systems.

Apparent molar volumes for MgSO\(_4\), CuSO\(_4\), Na\(_2\)SO\(_4\), NaCl, MgCl\(_2\), and CuCl\(_2\) and viscosity B-coefficients for MgSO\(_4\)/CuSO\(_4\) in sucrose + water solutions were determined from density and viscosity measurements at 298.15 K [93]. Infinite-dilution apparent molar volumes for Na\(_2\)SO\(_4\), NaCl, MgCl\(_2\), and CuCl\(_2\) in sucrose + water solutions were evaluated. Volumetric interaction parameters were also obtained from the transfer volumes of electrolytes. Activation energies were also calculated from the viscosity B-coefficients. Results showed that the values of standard transfer volumes, viscosity B-coefficients and activation energies are positive and increases usually with increasing sucrose content.
The relation between thermodynamic, transport and structural properties of electrolyte solutions is explored for volumes and radii of ions in solutions, water structure making and breaking by ions, ion pairing and electromotive force of cells with transport, and preferential solvation of ion in mixed solvents [94].

Viscosities of ammonium sulphate, potassium sulphate, and aluminium sulphate in water and water + (5%, 10%, 15%, and 20%) N, N-dimethylformamide mixed solvent have been measured at $T = (298.15$ and $308.15) \text{ K}$ and at atmospheric pressure. A molality range has been studied between (0.0081 and 0.1000) mol kg$^{-1}$ [95]. The viscosity data have been analyzed with the Jones–Dole equation, and B-coefficients have been calculated. The results have been interpreted in terms of structure making/breaking behavior of these salts in water and water + DMF mixed solvents.

Refractive index, $n_D$, and density, $\rho$, have been measured at 298.15 K and atmospheric pressure, for the binary mixtures of toluene with methyl acetate, methyl propanoate, methyl butanoate, methyl heptanoate, or butyl acetate [96]. From these experimental data refractive index deviations, $\Delta n_D$, molar refraction, $R$, molar refraction deviation, $\Delta R$, and excess molar volume, $V^E$ were calculated. Refractive indices were compared with those predicted using several mixing rules.

Hole theory has been applied to calculate isothermal compressibility, thermal expansivity, ultrasonic velocity and internal pressure of ternary and quaternary liquid mixture [97]. The obtained calculated values are compared with experimental findings. A fairly good agreement is found. The results of calculations show that for all the systems under consideration, the calculated values of various thermodynamic parameters show the same trend as observed experimentally.

Scientific investigations in the field of ultrasound velocity measurements in electrolyte solutions and various liquid systems was reviewed by Voleišis et al [98]. Measurements were performed with a specially designed ultrasonic-laser interferometer and a pulse-echo system. The main molecular acoustic interferometric experiments were provided in aqueous solutions of nine lanthanide nitrates and six sulphates within the frequency range of 3–200 MHz. The rear earth elements from lanthanum (57) to lutecium (71) are the ideal group for investigation of the ion-ion interaction as well as influence of ion field on the solvent structure. Data of
ultrasound velocity dispersion at different temperatures and concentrations are interpreted as being due to the process of association of lanthanide (III) ions and ligands and formation of inner sphere complexes [\(\text{LnNO}_3\)aq\(^{2+}\)] and [\(\text{LnSO}_4\)aq\(^+\)]. Kinetic parameters for the formation of inner sphere complexes have been determined. Non monotonic variation of the hydration number was obtained for lanthanide nitrate solutions across the series. Measurements in the synovial and cerebrospinal fluids were provided with the aim of disease diagnostics, in blood – for coagulation studies. Water-glycol mixtures were proposed as reference media, acrylamide polymerization-as a phantom for blood clotting. Some investigations were provided for the application in the control of technological processes.

The ultrasonic velocity, density and viscosity have been measured for the ternary mixtures of benzene and N,N-dimethyl formamide with pyridine at 303, 308 and 313K [99]. From the experimental data, adiabatic compressibility (\(\beta\)), intermolecular free length (\(L_f\)), free volume (\(V_f\)), internal pressure (\(p_i\)), acoustic impedance (\(Z\)), relaxation time (\(\tau\)), and Gibbs’s free energy (\(\Delta G^*\)) have been computed. The excess values of some of the above parameters were also evaluated and discussed in the light of molecular interactions in the mixture.

The excess molar volumes (\(V_m^E\)), viscosity deviations (\(\Delta \eta\)), and excess Gibbs energies of activation (\(\Delta G^{*E}\)) of viscous flow have been investigated from densities and viscosities measurements for two ternary mixtures 1-propanol + triethylamine + cyclohexane and 1-propanol + tri-n-butylamine + cyclohexane and corresponding binaries at 303.15K and atmospheric pressure over the entire range of composition [100]. The empirical equations due to Redlich–Kister, Kohler, Rastogi et al., Jacob–Fitzner, Tsao–Smith, Lark et al., Heric–Brewer, and Singh et al., have been employed to correlate \(V_m^E\), \(\Delta \eta\) and \(\Delta G^{*E}\) of ternary mixtures with their corresponding binary parameters. The results are discussed in terms of the molecular interaction between the components of the mixture. Further, the Extended Real Associated Solution (ERAS) model has been applied to \(V_m^E\) for the present binary and ternary mixtures and the results are compared with the experimental data.

Neutron diffraction experiments were carried out on concentrated aqueous solutions of beryllium chloride at three concentrations: 1.5, 3, and 6 molal [101]. By working with a specific (“null”) mixture of heavy water (\(D_2O\)) and water (\(H_2O\)), information on the local structure around \(Be^{2+}\) ions was extracted directly. For all
three BeCl₂ solutions, the results show that the Be²⁺ ion has a well-defined 4-fold coordination shell that is dominated by oxygen atoms. There is also a relatively small probability (10-15%) that there are direct contacts between Be²⁺ and Cl⁻ at a distance of ~2.2 Å. The oxygen atoms of the highly structured Be²⁺ first hydration shell are found to be situated at 2.6 Å apart, and form a pyramidal structure, in agreement with recent MD simulation results. The Cl⁻ ions have approximately seven oxygen atoms (water molecules) in their hydration shells sited at 3.2 Å.

Thermo-acoustical parameters of liquid mixtures viz., Acetone, Methyl Iodide and Acetone+Methyl Iodide have been evaluated at different temperatures in terms of the coefficient of volume expansion, on the assumption that the Moelwyn–Hughes parameter has been utilized to establish some simple relations between the lattice Gruneisen parameter, Beyer's non-linearity parameter, the Anderson–Gruneisen parameter and the Sharma constant. A relationship among the isobaric, isothermal and isochoric microscopic (lattice) Gruneisen parameters have been studied and analyzed in the case of liquid mixtures [102]. The Sharma's parameter S₀ remains invariant with the temperature over a wide range of temperatures and retains its characteristics value i.e., 1.11±0.01 as observed in case of liquid systems. The present treatment has the distinct advantage of calculating available volume (Vₐ) and intermolecular free-length (Lₒ) through Moelwyn–Hughes parameter mainly. Analysis of such type is not found so far in literature.

Ultrasonic velocity (U), viscosity (η) and density (ρ) have been measured for three amino acids viz., L-serine, L-proline, L-histidine in aqueous 1,4-dioxane mixtures (0.6m) at 298.15K [103]. Using the experimental values, the adiabatic compressibility (β), molal hydration number (n₉₉), apparent molal compressibility (ϕ₉), apparent molal volume (ϕᵥ), limiting apparent molal compressibility (ϕ₀₉), limiting apparent molal volume (ϕ₀ᵥ), their constants (Sᵥ, Sₙ) and viscosity coefficients of A and B parameters of Jones-Dole equation were calculated and the results of these parameters have been discussed in terms of solute –solvent and solute-co-solute interactions.

The studies of ultrasonic velocities, refractive indices and surface tension are being increasingly used as tools for investigation of the properties of pure components and the nature of intermolecular interactions between the liquid mixture constituents [104]. Refractive indices (n₀), ultrasonic velocities (u) and surface
tension ($\sigma$) have been measured for the binary liquid mixture of Anisaldehyde +benzene over the entire composition range at 323.15 K. This study involves the evaluation of different thermo acoustical parameters along with the excess properties. The Redlich-Kister model was used to correlate the measured properties. It was found that in all cases, the experimental data obtained fitted with the values correlated by the corresponding models very well. The molecular interactions existing between the components were also discussed.

The ultrasonic velocity, density and viscosity measurements were carried out for the mixtures of benzamide with Propan-2-ol, butan-1-ol, 1-pentanol and n-hexanal in 1,4-dioxan at 303, 308 and 313K [105]. The derived acoustic and thermodynamic parameters namely adiabatic compressibility, free length, free volume, internal pressure, viscous relaxation time and Gibbs free energy were evaluated with a view to investigate the nature of molecular interaction. The obtained results support the occurrence of complex formation through intermolecular hydrogen bonding in these ternary liquid mixtures.

Precise measurements on the density of sodium polystyrenesulphonate solutions in methanol-water mixed solvent media containing 8, 16, and 25 weight percent of methanol at 308.15, 318.15, and 323.15 K are reported [106]. The degree of substitution of sodium polystyrenesulphonate used is 1, and the concentration is varied from $1 \times 10^{-2}$ to $3.8 \times 10^{-2}$ mono mol.$^{-1}$. The results showed a slight increase on the partial molar volumes with increasing polyelectrolyte concentration.

Molar volume, viscosity and conductance of ascorbic acid in water,0.01m aqueous sodium chloride and 2,4,6 wt.% of dextrose in 0.01m aqueous sodium chloride solutions have been evaluated from density, viscosity and conductance data respectively at temperatures 303.15, 308.15, 313.15, and 318.15K [107]. The solute solvent interactions for ascorbic acid in water, 0.01m aqueous sodium chloride and 2,4,6 wt.% of dextrose in 0.01m aqueous sodium chloride solutions have been inferred from $\phi_v^0$, B-coefficient of Jones-Dole equation and $\lambda_m^0$ values. The structure making/breaking behavior of ascorbic acid is inferred from the sign of $(d^2\phi_v^0/dT^2)_p$, dB/dT and temperature coefficient of Walden product. It has been found that ascorbic acid behaves as structure breaker in water, 0.01m aqueous sodium chloride and 2,4,6 wt.% of dextrose in 0.01m aqueous sodium chloride solutions. The energy of
activation for ascorbic acid in different systems has also been calculated from conductance and viscosity data.

Density, speed of sound and viscosity measurements have been made for L-alanine in aqueous fructose, maltose and lactose solutions, ranging from pure water to 25 mass % of saccharides at 288.15, 298.15 and 308.15K [108]. These measurements have been used to evaluate some important parameters, viz., apparent molar volume, limiting apparent molar volume, viscosity B-coefficients of Jones–Dole equation, transfer B-coefficients, apparent molar adiabatic compressibility, limiting apparent molar adiabatic compressibility and its transfer values at infinite dilution. The activation free energy in different saccharide solutions has been calculated from B-coefficients and partial molar volume data.

Partial molar volume of oxalic acid and its salts, viz., ammonium oxalate, sodium oxalate and potassium oxalate, have been determined in different compositions of water-rich binary aqueous mixtures of methanol from solution density measurements at 298.15K and in 3% (W/W) methanol + water at different temperatures [109]. The data have been analyzed by using Masson equation and the obtained parameters interpreted in terms of ion-ion and ion-solvent interactions. The partial molar volumes vary with temperature as a power series of temperature. Structure making/breaking capacities of electrolytes have been inferred from the sign of \( \left[ \frac{\partial^2 \Phi^o}{\partial T^2} \right]_p \), i.e., the second derivative of partial molar volume with respect to temperature at constant pressure. Oxalic acid and its salts act as structure breakers in binary aqueous mixtures of methanol.

Partial molar volume of some hydrated and anhydrous salts of transition metal sulphates, viz., copper sulphate, zinc sulphate and magnesium sulphate have been determined in water at five equidistant temperatures (298.15, 303.15, 308.15, 313.15 and 318.15K) [110]. The density data have been analyzed by means of Masson’s equation. The partial molar volumes \( (\Phi^o) \) and experimental slopes have been interpreted in terms of ion-ion and ion-solvent interactions [111].

The partial molar volumes vary with temperature as a power series of temperature. Structure making/breaking capacities of hydrated and anhydrous salts have been inferred from the sign of \( \left[ \frac{\partial^2 \Phi^o}{\partial T^2} \right]_p \), i.e., the coefficients of liquid Fe, Co and Ni metals are calculated [112]. To predict excess entropy, the pair distribution
functions are calculated from the solution of Ornstein–Zernike integral equation. It is shown that the scaling laws proposed by Dzugutov for diffusion and by Li et al. for viscosity lead to a good estimation for diffusion and viscosity coefficients at the melting point.

The densities, ρ and ultrasonic speeds, u of binary mixtures of methyl acrylate with 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol, including those of pure liquids, over the entire composition range were measured at temperatures (288.15, 293.15, 298.15, 303.15, 308.15, 313.15, and 318.15) K and atmospheric pressure [113]. Using the experimental data, the excess molar volume, V_m^E and deviations in isentropic compressibility, Δk_s, partial molar volumes, V_m,1^∞ and, V_m,2^∞ and excess partial molar volumes, V_m,1^0E,∞ and V_m,1^0E,∞ of the components at infinite dilution were calculated. The variation of these parameters with composition and temperature of the mixtures have been discussed in terms of molecular interaction in these mixtures. The values of V_m^E and Δk_s, were found to be negative for all the mixtures at each temperature studied, indicating the presence of specific interactions between methyl acrylate and alkanol molecules. The negative V_m^E and Δk_s values follow the order: 1-butanol>2-butanol>2-methyl-1-propanol>2-methyl-2-propanol. It is observed that the values of V_m^E, Δk_s, V_m,1^0E,∞ and V_m,2^0E,∞ depend upon the positions of hydroxyl and methyl groups in these alkanol molecules.

The ultrasonic velocity, density and viscosity of binary mixtures of tetrahydrofuran (THF) with methanol and o-cresol were measured at 293, 303 and 313 K over the entire range of composition [114]. Using these experimental data, various thermo-acoustic parameters such as deviation in isentropic compressibility Δk_s, excess molar volume V_m^E, viscosity deviation Δη and excess Gibb’s free energy of activation for viscous flow ΔG^E have been calculated and fitted to Redlich–Kister polynomial equation. The deviation/excess parameter were plotted against the mole fraction of THF over the whole composition range. The observed negative and positive values of deviation/excess thermo-acoustic parameters were explained on the basis of the intermolecular interactions present in these mixtures. Since methanol is less acidic than o-cresol, the removal of proton from methanol is less likely than the removal of proton from o-cresol which is more acidic than methanol. Hence the intermolecular interaction in the mixture of THF with o-cresol is found to be stronger than mixture of THF with methanol, which is reflected from the observed positive
and negative values of excess thermo-acoustic parameters. Thus it may be concluded that THF + o-cresol mixture exhibits strong intermolecular interaction. However, dispersive forces are responsible for THF + methanol mixture due to weak interaction. Further, Nomoto, Junjie, CFT and Flory’s theory were applied for evaluating the ultrasonic velocity theoretically. The theoretical evaluation of ultrasonic velocity based on molecular models in liquid mixtures has been used to correlate with the experimental findings and to know the thermodynamics of the mixtures. The comparison of theoretical and experimental results provides better understanding about the validity of the various thermodynamic, empirical, semi empirical and statistical theories.

The speed of sound (u) has been obtained at a frequency of 8.3 MHz in \{CH_3CH_2OCH_2CH_2OH + HOCH_2CH_2(OCH_2CH_2)_nOH\} for n=0, 1, 2, and 3 over the whole composition range of studied binary liquid mixtures, at T=298.15 K [115]. The speed of sound values were combined with those of our previous results for densities and viscosities to obtain isentropic compressibility (\(k_s\)), free volume (V_i), and intermolecular free length (L_d). From all these data excess isentropic compressibility (\(k_s^E\)), excess free volume (V^E_i) and excess intermolecular free length (L^E_d) as well as the deviations of the speed of sound (\(\Delta u\)) were obtained. The results are interpreted in terms of molecular interactions occurring in the solutions.

Density, \(\rho\), speed of sound, \(u\), and viscosity, \(\eta\), measurements have been carried out on diglycine (0.05–0.30 mol kg\(^{-1}\)) in aqueous glucose, galactose and fructose solutions ranging from pure water to 6 mass % of saccharides at 288.15, 298.15 and 308.15 K [116]. These data were used to calculate the corresponding apparent molar volume, \(V\Phi\), limiting apparent molar volume, \(V\Phi^0\), transfer volume \(\Delta u V\Phi^0\), viscosity B-coefficients of Jones–Dole equation, apparent molar adiabatic compressibility, \(K\Phi_s\), limiting apparent molar adiabatic compressibility, \(K\Phi_s^0\), and its transfer values \(\Delta u K\Phi_s^0\) at infinite dilution. The activation free energy, \(\Delta\mu_2^0\), for viscous flow in different aqueous saccharide solutions have been calculated from B-coefficient and partial molar volume data. Hydration numbers, \(n_H\) and interaction coefficients, \(Y_{AB}\), and \(Y_{ABB}\), have also been calculated from these data. These parameters have been discussed in terms of solute–solvent interactions. We have also attempted to examine the temperature and concentration dependence of such interactions.
Densities and sound velocities in triethyl phosphate (TEP), N, N-dimethylacetamide (DMA), N, N-dimethylformamide (DMF), dimethyl sulfoxide (DMSO), acetonitrile (AN) and methanol (MeOH) have been measured at the temperatures ranging from 294.15 to 333.15 K [117]. The Free Length Theory (FLT) in its basic form has been used to assess the self-association of pure solvents at a wide temperature range. Detailed discussion and the criticism of the concepts of the FLT have been presented. As an alternative, the analysis of the temperature derivatives of molar compressibility coefficients and molar volumes has been proposed.

Ultrasonic velocities and densities of anionic surfactant, sodium dodecyl sulfate (SDS), in aqueous solutions of gelatin (0.25, 0.50, 1.00%w/v) have been measured over a wide temperature range (20-40 °C) at an interval of 2 °C by using DSA-5000 [118]. The data was used to calculate partial molar volume (\(\Phi_v\)), adiabatic compressibility (\(\beta\)) and apparent molar compressibility (\(\Phi_k\)) in order to explain protein–surfactant interactions. Viscosity measurements (viscous relaxation time and activation energy parameter) of SDS in aqueous solutions of gelatin were also carried out to support the explanation. A minimum observed in case of activation parameter in the concentration region 6–8 mmol kg\(^{-1}\) of SDS supported the results obtained by other parameters indicating micellar solubilisation of the SDS in this region. The behavior of both \(\Phi_k\) and \(\Phi_v\) data indicates that SDS binding to gelatin is non-cooperative at low surfactant concentration but becomes cooperative at higher concentration.

Ultrasonic velocity measurements have been carried out in Nimonic 263 specimens thermally aged at 923 and 1073 K for durations up to 75 h and correlated with the results of hardness measurements and electron microscopy studies [119]. The ultrasonic velocities and hardness results obtained in the specimens thermally aged at both temperatures clearly indicated that ultrasonic velocity is more sensitive to the initiation of the precipitation, whereas the influence of precipitation on hardness can be observed only after the precipitates attain a minimum size to influence the movement of dislocations. Further, ultrasonic velocity measurements also revealed faster kinetics and a lesser amount of precipitation at 1073 K compared to 923 K due to higher solubility of precipitate-forming elements.

Density, speed of sound and viscosity of the binary systems 2-methyl-1-propanol + hexadecane and 2-methyl-1-propanol + squalane (2,6,10,15,19,23-
hexamethyltetracosane) have been measured over the entire range of composition at
T = (298.15, 303.15, and 308.15) K and atmospheric pressure using a vibrating tube
densimeter and sound analyzer Anton Paar model DSA-5000 and Ubbelohde
suspended level viscometer [120]. Excess molar volume, excess molar isentropic
compressibility and deviations of the speed of sound from their ideal values and
excess thermal expansion coefficient were evaluated from the experimental results
obtained. These derived properties were fitted to variable-degree polynomials.
Further, the Extended Real Associated Solution (ERAS) model has been applied to
excess molar volume for the present binary mixtures along with (2-methyl-1-propanol
+ hexane, + octane and + decane) and the findings are compared with the
experimental results.

Density (ρ), viscosity (η) and Ultrasonic velocity (U) measurement have been
measured for some divalent transition metal sulphates namely nickel sulphate
(NiSO₄), manganese sulphate (MnSO₄) and cobalt sulphate (CoSO₄) in aqueous
propylene glycol mixture (3:1 ratio) at 303.15K [121]. Using the experimental values,
the adiabatic compressibility (β), hydration number (nH), apparent molal
compressibility (φK), apparent molal volume (φV), limiting apparent molal
compressibility (φ₀K), limiting apparent molal volume (φ₀V) and their constants
(SK, SV), transfer volume (Δφ₀V), B-coefficient of Jones-Dole equation were
calculated and these results have been discussed in terms of ion-solvent and ion-ion
interactions.

Ultrasonic velocity and density of four ternary liquid systems have been
determined experimentally at 298.15 K [122]. All the four ternary systems comprise
of a polar molecule, viz., chlorobenzene or chloronaphthalene (first component) and a
mixture of two alkanes (second and third component) consisting of different size and
shapes. Excess molar volume has been calculated and these values along with the
other computed parameters, viz., Kₘ, Eₘ, Eₕ, E, ΔV and δu have also been computed.
The main aim of the present investigation is to study the influence of a polar molecule
in terms of size, shape and polarity to a mixture of hydrocarbons (binary) on the
experimental and thermodynamic excess properties.

Charge-transfer complexes formed between iodine (σ-acceptor) and pyrrole,
thiophene and pyridine (π as well as n-electron donors) have been studied
spectrophotometric and ultrasonic techniques at 303.15 K in dimethyl sulphoxide
The measured values of ultrasonic velocity, density and viscosity and the derived acoustical parameters such as adiabatic compressibility ($K$), free length ($L_f$), internal pressure ($\pi$), molar volume ($V_m$) and available volume ($V_a$) have been used to study the molecular interactions and the complexes of heterocyclic aromatic compounds. The excess thermodynamic parameters like excess velocity ($U^E$), excess adiabatic compressibility ($K^E$), excess free length ($L_f^E$), excess molar volume ($V_m^E$) and excess available volume ($V_a^E$) have been computed and the sign and magnitude of these parameters indicate the strength of interactions and the formation of charge-transfer complex. The formation constants of the charge-transfer complexes were determined by the Benesi–Hildebrand equations (optical method) and compared with those obtained from Kannappan method (ultrasonic method). The formation constants of complexes of iodine with aromatic compounds depend on the structure of the donor and acceptor molecules.

Densities and ultrasonic speeds of binary mixtures of benzaldehyde with $n$-hexane and cyclohexane at 30 °C were measured over the entire composition range [124]. From these experimental data, the adiabatic compressibility ($K_s$), intermolecular free length ($L_f$), acoustic impedance ($Z$), relative association ($R_a$) and relaxation strength ($r$) were calculated. Also, the excess adiabatic compressibility ($K^E_s$), intermolecular free length ($L^E_f$), acoustic impedance ($Z^E$), and ultrasonic velocity ($U^E$) were calculated. The observed variation of these parameters helps in understanding the nature of interactions in these mixtures. Further, theoretical values of the ultrasonic speed were evaluated using theories and empirical relations. The relative merits of these theories and relations were discussed.

Most current biomolecular simulations are based on potential energy functions that treat the electrostatic energy as a sum of pairwise Coulombic interactions between effective fixed atomic charges [125]. This approximation, in which many-body induced polarization effects are included in an average way, is expected to be satisfactory for a wide range of systems, but less accurate for processes involving the transfer and partition of ions among heterogeneous environments. The limitations of these potential energy functions are perhaps most obvious in studies of ion permeation through membrane channels. In many cases, the pore is so narrow that the permeating ion must shed most of its surrounding water molecules and the large energetic loss due to dehydration must be compensated by coordination with protein...
atoms. Interactions of cations with protein backbone carbonyl oxygens, in particular, play a critical role in several important biological channels. As a first step toward meeting the challenge of developing an accurate explicit accounting for induced polarization effects, the present work combines experiments and computation to characterize the interactions of alkali and halide ions with \( N \)-methylacetamide chosen to represent the peptide bond. From solubility measurements, we extract the solvation free energies of KCl and NaCl in liquid \( N \)-methylacetamide. Polarizable models based on the Drude oscillator are then developed and compared with available experimental and \textit{ab initio} data. The good agreement for a range of structural and thermodynamic properties in the gas and condensed phases suggests that the polarizable models provide an accurate representation of ion-amide interactions in biological systems.

Densities, viscosities, and refractive indices of mixing of methyl ethyl ketone with 1-pentanol, 2-pentanol, and 3-pentanol have been measured as a function of composition range at temperatures (298.15, 308.15, and 318.15) K and ambient pressure [126]. Excess molar volumes \( V^E_m \), viscosity deviations \( \Delta \eta \), and refractive index deviations \( \Delta n_D \) were calculated and correlated by the Redlich-Kister-type function to derive the coefficients and estimate the standard error. From the experimental data, partial molar volumes, \( V_{m,i} \), and partial molar volumes at infinite dilution, \( V^0_{m,i} \), were also calculated. The latter values are interesting from a theoretical point of view since at infinite dilution the only interactions present are solute-solvent interactions. The effect of temperature and \(-\)OH group position of pentanol isomers on the excess molar volumes, viscosity, and refractive index deviations of its mixtures with methyl ethyl ketone is discussed in terms of the nature and type of intermolecular interactions in binary mixtures.

Density data for binary mixtures of the ionic liquid 1-ethyl-3-methylimidazolium ethylsulfate ([EMIM][EtSO_4]) with acetone, acetonitrile, propylene carbonate, dichloromethane, methanol, ethanol, and water are presented [127]. Measurements were performed in dependence on composition for temperatures from (278.15 to 308.15) K using the vibrating-tube method with an expanded relative uncertainty (\( k = 2 \)) of less than 0.02 %. All calculated excess molar volumes are negative, indicating denser molecular packing than in the pure liquids. The size and
the structure of the solvent molecules as well as the nature of interaction between all mixture components seem to affect the extent of the observed compression effect.

The experimental densities of binary mixtures of cyclopentanone with 1,1,2,2-tetrachloroethane, 1,1,1-trichloroethane, trichloromethane, 1,2-dichloroethane, 1,3-dichloropropane, 1,4-dichlorobutane, and 1-chlorobutane have been measured at $T = (288.15, 298.15, 308.15,$ and $318.15)$ K and atmospheric pressure, over the whole composition range [128]. From these results, excess molar volumes, $V^E$, have been calculated and fitted to the Redlich-Kister polynomial equation. The excess molar volumes are negative for the cyclopentanone + 1,1,2,2-tetrachloroethane, 1,1,1-trichloroethane, trichloromethane, and 1-chlorobutane systems and positive for the other three systems over almost the whole mole fraction range and temperatures studied. The variation of these properties with composition of the binary mixtures is discussed in terms of molecular interactions between components and structural effects.

Density and viscosity were determined for binary mixtures containing the ionic liquid l-butyl-3-methylimidazolium thiocyanate ([BMIM][SCN]) and 1-alcohol (1-heptanol, 1-octanol, 1-nonanol, or 1-decanol) over the temperature range (298.15 to 348.15) K and ambient pressure [129]. The temperature dependence of density and viscosity for these systems can be described by an empirical second-order polynomial and by the Vogel-Fucher-Tammann equation, respectively. Excess molar volumes and viscosity deviations were calculated and correlated by the Redlich-Kister polynomial expansions. These systems exhibit negative molar excess volumes. Volume expansivity and excess volume expansivity were described as functions of temperature and composition. The polynomial correlations describe the variation of density and viscosity with composition. For each system and for a chosen number of the Redlich-Kister parameters, $A_n$, the partial excess molar volumes, $V_1^E$ and $V_2^E$, are presented. The Prigogine-Flory-Paterson (PFP) and the Flory-Benson-Tresczanowicz (FBT) models were used for the prediction of $V_m^E$ and $H_m^E$ of the measured systems. A comparison of the results for the four binary systems elucidates the influence of 1-alcohol carbon chain length on their physical properties.

Densities of six binary mixtures containing the ionic liquid l-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide or l-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide mixed with tetrahydrofuran or
acetonitrile or dimethyl sulfoxide were determined at atmospheric pressures in the temperature range between 293.15 K and 313.15 K [130]. On the basis of the experimental densities, excess molar volumes were calculated. Comparison of excess molar volumes of six binary systems reveals the slight influence of the IL’s cation on these physical properties and the small temperature dependence of $V^E$ for systems containing dimethyl sulfoxide.

The partial molar volumes $V^*_2$ and viscosity $B$-coefficient have been measured from density and flow time measurements for sulphanilamide, sulphanilic acid, and sulphosalicylic acid dihydrate in water and in aqueous solutions of (0.05, 0.1, 0.3, and 0.5) mol·kg$^{-1}$ sodium chloride at temperatures from (288.15 to 318.15) K, by the use of a vibrating tube digital densimeter and Micro-Ubbelohde type capillary viscometer, respectively [131]. The transfer volumes at infinite dilution calculated from partial molar volumes have both positive and negative values. The overall positive values at higher concentrations of sodium chloride are in the following order: sulphosalicylic acid dihydrate $>$ sulphanilic acid $>$ sulphanilamide, which is also the order of hydrophilicity of these drugs. The interaction coefficients, partial molar expansibilities $V^*_E$, and second-order derivative have also been calculated. The transfer $B$-coefficient values, $\Delta_B$, are calculated from viscosity $B$-coefficient data. Transition state theory has been used to calculate $\Delta\mu^{\text{eff}}$, the activation free energy for the viscous flow of solutions. The related activation parameters like $\DeltaH^{\text{eff}}$ and $\DeltaS^{\text{eff}}$ have been calculated. Also the excess molecular volume and contribution of various groups of the drug compound to $V^*_2$ have been calculated.

Densities and refractive indices have been measured for glycyglycine in aqueous FeCl$_2$ solution as a function of concentration at $T = (288.15$ to $318.15)$ K [132]. The apparent molar volumes and partial molar volumes were obtained from these density data. The limited partial molar expansivities have been calculated from the temperature dependence of the partial molar volume. The molar refractions were calculated from the experimental refractive index values for the studied mixture. The excess volumes and molar refractions were also calculated. The results are discussed in terms of molecular interactions.

It is a widely unknown or unrecognized fact that the vapour-liquid critical points of pure compounds and also of mixtures form a sail-like surface in the three-dimensional space of temperature, pressure, and molar volume or density [133]. The
available experimental critical points of all pure compounds lie on or near that critical
surface with some exceptions caused mainly by extraordinary intermolecular
interactions (e.g., strong acids or polar compounds like water). For this surface and
therefore the relation among the three critical properties, simple relation equations,
transformable and explicit in each property, were evaluated and optimized. With
these equations the critical volume, pressure, or temperature can be calculated from
the two remaining properties with an average absolute deviation of less than 5 % over
a set of recommended critical points for 421 organic compounds. This relation is also
applicable for the critical properties of binary and multi-component mixtures.
Therefore, a unique tool is available for a consistency test of experimental or
predicted data and for simple and reliable calculations of the often missing property,
for example, the critical molar volume.

The densities, viscosities, and conductivities were measured for the ternary
solution NaCl + urea + H2O, the quintuple solution NaCl + Na2SO4 + KCl + K2SO4 +
H2O and their binary subsystems at 298.15 K [134]. The results together with the
densities, viscosities, and conductivities of multi-component solutions reported in the
literature were used to study the predictability of the Young’s rule for density and
conductivity, the rule of Patwardhan and Kumar for density, Hu’s equation for the
viscosity of mixed electrolyte solutions based on the Eyring’s absolute rate theory and
the rule of Patwardhan and Kumar, and the semi ideal solution theory for
thermodynamic and transport properties. The results show that all the tested equations
can provide comparable and accurate predictions for the densities of multi-component
electrolyte solutions. The semi ideal solution theory is applicable to the aqueous
solutions of electrolytes and non electrolytes, and its predictions for the densities of
the examined solutions are in nice agreement with the experimental results. The
simple equation based on Eyring’s absolute rate theory and the rule of Patwardhan
and Kumar and the semi ideal solution theory can provide nice predictions for the
viscosity of the tested electrolyte solutions. The predictions for the viscosity of the
ternary solution NaCl + urea + H2O by the semi ideal solution theory are also in
accordance with the measured viscosities. The semi ideal solution theory can provide
better predictions for the conductivities of the tested electrolyte solutions than the
extended Young’s rule, and their predictions are both in good agreement with the
experimental results. The advantages of the semi ideal solution theory are briefly discussed and reviewed.

Viscometric constants were used to provide information on solute–solvent interactions in ternary water-sugar-salt solutions. Comparison was made between pure water and aqueous salt solution as solvents affecting the behavior of small carbohydrates [135]. The determination of intrinsic viscosity was made more accurate by applying triple extrapolation of the three equations (Huggins, Kramer and Meffroy-Biget). Results obtained with this triple extrapolation method were compared to that obtained with the Jones–Dole equation usually used. The B coefficient of the Jones–Dole equation was interpreted in terms of its components (Bsize) and (Bstructure), respectively assigned to the hydrodynamic volume and the contribution to solvent structural change. The determination of the apparent molar volumes in pure water enabled calculation of the hydration numbers. The determined apparent molar volumes of the studied sugars in aqueous salt solutions suggested a dehydration of the sugars explained by sugar–salt interactions. The most important perturbations observed in LiCl solutions compared to those in NaCl solutions were explained by LiCl being surrounded with more water molecules.

The solubility of α-5-(dithiolan-3-yl) pentanoic acid in mixed solvents (cyclohexane + ethyl acetate, heptanes + ethyl acetate, and hexane + ethyl acetate) was experimentally studied by an analytical method [136]. The data obtained were correlated by a semiempirical equation. Results showed that the solubility of 5-(dithiolan-3-yl) pentanoic acid increased with increasing temperature. In the same solvent systems, the molar fraction solubility increased with a decreasing solvent volume ratio.

Solubilities of ammonia in four conventional imidazolium ionic liquids: [Cn mim][BF4] (n = 2,4,6,8) have been measured. Isothermally fixed temperatures are 293.15, 303.15, 313.15, 323.15 and 333.15K; the pressure is from 0 to 1.0 MPa [137]. High solubilities of ammonia are found, and it is also found that the solubilities of ammonia increase when the length of cations’ alkyl increases (the ILs have the same anion), that is: [C8 mim]+ > [C6 mim]+ > [C4 mim]+ > [C2 mim]+. The solubility data have been correlated by the Krichevsky–Kasarnovsky equation, and then Henry’s constants and partial molar volumes of NH3 at infinite dilution are obtained. The thermodynamic properties such as solution enthalpy (ΔsoH), solution Gibbs free

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energy ($\Delta_{\text{sol}}G$), solution entropy ($\Delta_{\text{sol}}S$), and solution heat capacity ($\Delta_{\text{sol}}Cp$) of these systems are obtained.

The densities and viscosities of 2-bromopropane + ethanol binary mixtures had been determined using a digital vibrating U-tube densimeter and Ubbelohde capillary viscometer respectively from (298.15 to 318.15) K [138]. The dependence of densities and viscosities on temperature and concentration had been correlated. The excess molar volume of the binary system was calculated from the experimental density data. The excess molar volumes were related to compositions by polynomial regression and regression parameters, and total rmsd deviations were obtained. The results showed that the model agreed very well with the experimental data.

Passynski's hydration numbers were calculated for 1-propanol, 2-methylpyridine, 3-methylpyridine, 4-methylpyridine, 2,6-dimethylpyridine, and 2,4,6-trimethylpyridine in H$_2$O and D$_2$O, for the temperature range from 277K to 313 K [139]. Correlations between the hydration numbers and the association energies of 1:1 water-amine complexes as well as the net atomic charges on the nitrogen atom were found. It seems probable that the O-H....N bond promotes the structure due to the strengthening of the O-H....O bonds between water molecules neighboring that of amine. The higher the O-H....N bond energy, the stronger is the promoting effect. The calculated hydration numbers in H$_2$O are lower than their counterparts in D$_2$O. Thus D$_2$O appears more sensitive than H$_2$O to the solute-induced changes of structure.

The synthesis and complexive abilities of 5,11,17-tris(tert-butyl)-23 amino-25,26,27,28-tetra-propoxy-calix[4]arene towards alkali cations Li$^+$, Na$^+$, K$^+$, Rb$^+$, Cs$^+$ and alkali earth cations Mg$^{2+}$, Ca$^{2+}$, Sr$^{2+}$ and Ba$^{2+}$ in methanol-chloroform mixture have been evaluated at 25$^\circ$C, using UV-Vis spectrophotometric techniques [140]. The results showed that the ligand is capable to complex with all the cations by 1 : 1 metal to ligand ratios. The selectivity presented considering the calculated formation constants are in the order Li$^+$>Na$^+$> K$^+$> Rb$^+$> Cs$^+$ and Mg$^{2+}$> Ca$^{2+}$> Sr$^{2+}$> Ba$^{2+}$ with the ligand.

The applicability of the Pasynski method of determination of hydration numbers of simple organic compounds in aqueous solvents of fixed pH at 25 $^\circ$C from speed-of-sound and density measurements is tested and discussed [141]. It was shown
that for solutes which do not undergo protolytic reactions with a solvent the resulting values of hydration numbers are independent on the system pH—for these solutes $n_h$ can be determined both in pure aqueous solutions and in mixtures containing ions. For solutes which undergo reactions with an acid or base, the Pasynski method yields hydration numbers which are a combination of compressibilities of substrates and products of occurring reactions.

Density, viscosity and ultrasonic velocity have been measured for binary liquid mixtures containing Methylmethacrylate+2-Methoxy ethanol, Methylmethacrylate+2-Ethoxy ethanol, Methyl methacrylate+2 Butoxy ethanol at 303K [142]. The adiabatic compressibility, free length, free volume, internal pressure, relaxation time, acoustic impedance and Gibbs’s free energy values have been calculated from the experimental data. These parameters are used to discuss the molecular interactions in the mixtures.

Ultrasonic velocities and densities of the binary liquid mixtures of dimethyl sulphoxide (DMSO) with phenol, o-cresol, m-cresol, p-cresol and p-chlorophenol at 318.15 K, over the entire composition range were measured [143]. The theoretical values of ultrasonic velocity were evaluated using the Nomoto’s Relation (NR), Ideal Mixture Relation (IMR), Free Length Theory (FT) and Collision Factor Theory (FLT). The validity of these relations and theories was tested by comparing the computed sound velocities with experimental values. Further, the molecular interaction parameter ($\alpha$) was computed by using the experimental and the theoretical ultrasonic velocity values. The variation of this parameter with composition of the mixtures has been discussed in terms of molecular interaction in these mixtures.

The experimental data of densities ($\rho$), speeds of sound ($u$), and refractive indices ($n_\text{D}$) of aqueous solutions of different glycol ethers, namely, ethylene glycol iso-propyl ether (EGIPE), ethylene glycol monobutyl ether (EGMBE), diethylene glycol dimethyl ether (DEGDME), diethylene glycol monobutyl ether (DEGMBE), propylene glycol monomethyl ether (PGMME), and dipropylene glycol monomethyl ether (DPGMME), over the entire composition range, at temperature $T = 298.15$ K, and at one atmospheric pressure have been obtained [144]. The derived parameters such as the apparent molar volume ($\phi_v$) of solute, isentropic compressibility of solution ($\beta_S$), apparent molar isentropic compressibility ($\phi_{KS}$) of solute, excess molar volume ($V^E$) of solution, molar refraction ($[R]_1,2$), deviation in refractive index ($\Delta n_0$)
of solutions, deviation in molar refraction ($\Delta[R]$), and the deviation in isentropic compressibility ($\Delta\beta$) have been computed. The limiting apparent molar volumes of solutes ($\phi_v^0$), limiting apparent molar isentropic compressibilities of solutes ($\phi_{KS}$), and the limiting excess partial molar volumes of solutes ($V_{OE}$) have also been obtained. The results are interpreted in terms of hydrogen bonding, solute-solute, and solute-solvent interactions.

Density and ultrasonic speed of four amino acids (glycine, l-alanine, l-valine, and l-leucine) in aqueous sodium fluoride solutions (0.1 to 0.5 M) have been measured at $T = (308.15, 313.15, \text{ and } 318.15)$ K [145]. Apparent molar volumes, partial molar volumes, transfer volumes and hydration number are evaluated using density data. Adiabatic compressibility ($\beta$), change ($\Delta\beta$), and relative change in compressibility ($\Delta\beta/\beta_0$), apparent molar compressibility ($K_v$), partial molar compressibility, transfer compressibility and hydration number ($n_H$) have been calculated using ultrasonic speed data. The linear correlation of and for a homologous series of amino acids have been used utilised to calculate the contribution of charged end groups (NH$_3^+$, COO$^-$), CH$_2$ group and other alkyl chain of the amino acids. The analysis shows that the ion–ion interactions are much stronger than ion–hydrophobic interactions over the entire concentration range of sodium fluoride. It is observed that sodium fluoride has a strong dehydration effect on amino acids.

The density and ultrasonic velocity measurements were made for magnesium chloride (MgCl$_2$), calcium chloride (CaCl$_2$) and strontium chloride (SrCl$_2$) in 2% fructose prepared in 0.01 M aqueous NaCl at temperatures 303.15, 308.15, 313.15 and 318.15 K [146]. The measured parameters were then used to calculate various thermodynamic and acoustic parameters such as apparent molar volume ($\Phi_v$), limiting apparent molar volume ($\Phi_v^0$), limiting apparent molar volume expansibility ($\Phi_E^0$), adiabatic compressibility ($\beta$), intermolecular free length ($L$), relaxation time ($\tau$) and Gibb’s free energy of activation for relaxation process ($AG^*$). The results have been discussed in terms of ion-solvent, ion-ion interactions. Further structure making/breaking behavior of MgCl$_2$, CaCl$_2$ and SrCl$_2$ has been discussed and structure breaking behavior of these metal chlorides in 2% fructose in 0.01 M aqueous NaCl has been reported.

Partial molar volume and viscosity B-Coefficient of phosphoric acid, sodium salt of mono and diphosphates were determined in water in the temperature range
25-45\,^\circ\mathrm{C}\ [147].\ All\ these\ parameters\ exhibit\ the\ following\ order:\ 
\[ \mathrm{H}_3\mathrm{PO}_4 < \mathrm{HPO}_4 < \mathrm{HPO}_4^{2-} < \Phi_v^0 \] increased with temperature for $\mathrm{H}_3\mathrm{PO}_4$ and $\mathrm{H}_2\mathrm{PO}_4$ and decreased for $\mathrm{HPO}_4^{2-}$. Viscosity B-Coefficient exhibit constancy between 25-35\,^\circ\mathrm{C} for all the two salts and phosphoric acid. Hydration number (nH) at 25\,^\circ\mathrm{C}, obtained through viscosity show satisfactory agreement and follow the order $\mathrm{HPO}_4^{2-} > \mathrm{H}_2\mathrm{PO}_4^- > \mathrm{H}_3\mathrm{PO}_4$. Similarly, the magnitude of $B/\Phi_v^0 \times 10^3$ is also analyzed.

The experimental data of density and viscosity have been obtained for aqueous solutions of biologically active compounds like salbutamol sulphate (SS), diethylcarbamazine citrate (DEC), and chlorpheniramine maleate (CPM) in the concentration range (0 to 0.15) mol kg$^{-1}$ at three different temperatures [148]. The derived parameters, such as apparent molar volume of solute, limiting apparent molar volume of solute, limiting apparent molar expansivity, thermal expansion coefficient and Jones–Dole equation viscosity A and B coefficients, were obtained using the density and viscosity results. It has been observed that the electrolyte-salt (SS) as well as adducts exhibit a positive viscosity B coefficient having negative ($dB/dT$). These results are interpreted in the light of possible solute–solute and solute–solvent interactions.

Study of solution enthalpy and partial molar volume in various solvents of different polarity corresponds to the inaccessibility of capsulated charges inside of ferrocene for the interaction with surrounding molecules [149].

**OBJECTIVES OF INVESTIGATION**

Ascorbic acid, sodium chloride, potassium chloride, dextrose and sorbitol are required in a metabolism. Their deficiency as well as excess can lead to malfunctioning of cell mechanism. L- Ascorbic acid which is commonly known as vitamin C plays many important roles in our body. It prevents from infections and promotes repair of the skin. It protect coronary arteries by reducing formation of plaque, as it helps to prevent the oxidation of LDL cholesterol (the “bad” cholesterol), especially in combination with vitamin E. Some data also showed that vitamin C may boost blood levels of HDL cholesterol (the “good” cholesterol), which is also considered positive for the prevention of heart diseases. The risk of stroke may be reduced by an adequate intake of vitamin C through fruits, vegetables and supplements. Several studies have shown a blood-pressure lowering effect of vitamin C supplementation of about 500 mg vitamin C per day because it improves the
dilation of blood vessels. It also helps in prevention of cancer by inhibiting proliferation of cancerous cells. Just statistically significant reductions in risk of cancer were found in people consuming at least 80 to 110 mg of vitamin C daily. So biological importance of ascorbic acid makes it an interesting system to work on. Whereas the carbohydrates are converted into glucose in the digestive tract and act as a main source of energy to run our life. The glucose enters in the blood stream and thus contributes to blood glucose. The normal glucose level in total blood (5 liter) of human body is 3.3 to 7g. Its level is maintained by insulin. Insulin disperses glucose and our blood sugar fall. Sorbitol also known as glucitol, is a sugar alcohol. It is obtained by reduction of sugar changing the aldehyde group to additional hydroxyl group. It is a sugar substitute. Sorbitol is referred to as a nutritive sweetener because it provides dietary energy ie. 2.6kJ/gram. Sorbitol is often used in the diet foods like ice cream, mint, cough syrups, and sugar free chewing gum and it is also used in mouthwash and toothpaste. Sodium is critical in generation of electrical signals in the body especially in the brain, nervous system and muscles. Potassium ions control nervous system and heart beats. Irregular level of chloride ions leads to diarrhea, certain kidney diseases, and sometimes over activity of the parathyroid glands. As carbohydrates, sodium chloride, potassium chloride and ascorbic acid are found in bio-fluids and are important for living systems, so it is important as well as interesting to investigate their interactions in systems similar to bio-fluids.

The study of ascorbic acid in water, aqueous sodium chloride, dextrose + aqueous sodium chloride, potassium chloride, dextrose + aqueous potassium chloride and sorbitol + 0.01m aqueous potassium chloride system have not been attempted so far. It was therefore decided to investigate the interactions of ascorbic acid in water, 0.01m aqueous sodium chloride, 2, 4 and 6 weight percentage of dextrose + 0.01m aqueous sodium chloride, 0.01m aqueous potassium chloride, 2, 4 and 6 weight percentage of dextrose + 0.01m aqueous potassium chloride and 2, 4 and 6 weight percentage of sorbitol + 0.01m aqueous potassium chloride solutions at 303.15, 308.15, 313.15 and 318.15K temperatures is carried out to arrive at the nature of solute-solute and solute-solvent interactions by measuring their densities, molar volumes, viscosities, conductance and ultrasonic velocity.
The structure maker/breaker of ascorbic acid in water, aqueous sodium chloride, dextrose + aqueous sodium chloride, potassium chloride, dextrose + aqueous potassium chloride and sorbitol + 0.01m aqueous potassium chloride solutions was also determined.
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