CHAPTER –V

EXPLORATION OF SOLVATION CONSEQUENCES OF SOME BIOLOGICALLY POTENT MOLECULES IN AQUEOUS IONIC LIQUID SOLUTIONS WITH THE MANIFESTATION OF MOLECULAR INTERACTIONS

Absrtact: L-Aspartic and L-Glutamic acid (two solute molecules) interact with an ionic liquid (Benzyl tri-methyl ammonium chloride) in aqueous medium. The interactions have been explained on the basis of some parameters (apparent molar volume, viscosity B-coefficient, molar refraction, specific conductance) at different temperatures and different concentrations from density, viscosity, refractive index, conductance measurements, respectively. Using Masson equation, the experimental slopes and the limiting apparent molar volumes are obtained which explain the solute-solute and solute-solvent interactions. Viscosity parameters, A and B obtained from Jones-Doles equation explained the solute-solute and solute-solvent interactions in the solution. Molar refraction has been calculated from the Lorentz-Lorenz equation. The specific conductance also explained the interaction properties.

Keywords: L-Aspartic acid; L-Glutamic acid; Benzyl tri-methyl ammonium chloride; solute-solvent interaction; solute–solute interaction; Amino acids; Ionic

V.1 INTRODUCTION

Thermodynamic properties of amino acids in aqueous electrolyte solutions can provide valuable information regarding the conformation stability of proteins in these solutions, their solubility, denaturation, dissociation into subunits, the activity of enzymes, separation and purification, solute–solvent and solute–solute interactions [1–4]. In fact, to optimize and control the extraction of biomolecules by ionic liquids (ILs) from aqueous media, knowledge of their thermophysical and thermodynamic properties is required. There are extensive volumetric and viscometric studies of amino acids in aqueous electrolyte solutions [5-7]. Consequently, the study of the volumetric properties of amino acids in aqueous ionic liquid solutions will be very useful for obtaining information about various types of interactions occurring in these solutions, which are mostly hydrophobic and electrostatic. Studying these interactions can provide important insight into the conformational stability and unfolding behavior of globular proteins. Thermodynamic properties of amino acids in aqueous solutions containing salts can provide valuable information about solute–solute and solute–solvent interactions. The aqueous solution

containing salts affect conformational properties of amino acids and cause denaturation of proteins which is an important biological phenomenon. Therefore, keeping the importance and applicability in view, the systematic thermodynamic investigation of mixtures containing IL and amino acids is undertaken to understand the solvation behaviour of these biomolecules [8]. Study of transport properties of electrolytes in aqueous media is extremely important to obtain information regarding the solvation and association behaviour of ions in solutions. The electrical conductivity of electrolytes in solvents mainly depends on the concentration of the electrolyte and the viscosity of the solvent. The application of the salt is well understood from the study of ionic solvation. Volumetric, viscometric, refractometric and conductometric techniques render an insight into the molecular interactions that are prevailing in solution and helps in the better understanding of the behaviour of the salt in water.

An ionic liquid (IL) is a salt in the liquid state of melting point below some arbitrary temperature such as 373 K. They have specific intrinsic properties, such as negligible vapour pressure, high thermal stability, large liquid range, ability of dissolving a variety of chemicals, large electrochemical window. They are used as "designer solvents" and "green" replacements for volatile organic solvents used in reactions involving inorganic and biocatalytic reactions, etc. They are also utilized as heat transfer fluids for processing biomass and as electrically conductive liquids in electrochemistry (batteries and solar cells). They are used in analytical equipment. They make up electrolytes in lithium-ion batteries, super capacitors and metal plating baths [9-14]. The chemicals used in this study find wide industrial usage. Benzyl tri-methyl ammonium chloride or BTAC is soluble in water and has lyophilic and hydrophilic group. It can be used as phase transfer catalyst in many biphasic organic transitions used in the agrochemicals, polymer and pharmaceutical industries. BTAC can also be used as a corrosion inhibitor in oilfield. L-Aspartic acid and L-Glutamic acid are both water soluble polar aliphatic amino acids having very weak dipole–ion interaction. L-Aspartic acid is an α-amino acid that is used in the biosynthesis of proteins. Aspartic acid is commonly used to reduce feelings of tiredness, improve athletic performance, and increase the size and strength of muscles. Glutamic acid is an α-amino acid that is used by almost all living beings in the biosynthesis of proteins. It is also an excitatory neurotransmitter in the vertebrate nervous system.

In the modern technology, the application of the salt is well understood from the study of ionic solvation or ion association. Ionic association of electrolytes in solution depends on the mode of solvation of its ions that in turn depends on the nature of the solvent/solvent mixtures [15-18]. The association and solvation behaviour of ions in solution is obtained from the conductance measurement. Moreover, solvent properties as viscosity and the relative permittivity help in determining the extent of ion association

and the solvent-solvent interactions. The volumetric, viscometric, refractometric and conductometric behaviour of solutes has been found to be very useful in elucidating the various interactions occurring in solutions.

In continuation of our investigation, the present work deals with the transport and thermodynamic properties of L-Aspartic acid and L-Glutamic acid in aqueous Benzyl tri-methyl ammonium chloride at 293K, 303K and 313K.

V.2. EXPERIMENTAL SECTION

2.1. Source and purity of samples

The studied IL, Benzyl tri-methyl ammonium chloride, $C_{10}H_{16}ClN$ (M.W. 185.69 g/mole) and amino acids, L-Aspartic acid, $C_4H_7NO_4$ (M.W. 133.11 g/mole) and L-Glutamic acid, $C_5H_9NO_4$ (M.W. 147.13 g/mole) of puriss grade were purchased from Sigma Aldrich Germany, SRL India and TLC Japan, respectively and was used as purchased. The purity of mass of taken salts were ≥0.99. The amino acids were dried in vacuum over blue silica gel for at least 72 h at room temperature. The other chemicals were used without further purification. Doubly distilled deionized water with a conductivity of approximately 0.7 μS·cm−1 was used for preparation of the solutions.

2.2. Apparatus and procedure

The vibrating-tube Anton Paar Density-Meter (DMA 4500M) was used to measure the density (ρ) with a precision of 0.00001 x 10^{-3} ($kg \cdot m^{-3}$). The double-distilled water and dry air was used to calibrate the density meter [19]. The temperature was kept constant automatically within range ±0.01 K.

The viscosity was measured with the help of suspended Ubbelohde viscometer which was calibrated at room temperature (298K) using doubly distilled water. It was purified with methanol and using viscosity, density data from literature [20-21]. The viscometer was dried and cleaned perfectly through hot thermostat and then filled with experimental solution, vertically placed in a glass-walled thermostat (Bose–Panda instruments Pvt. Ltd.) This instrument was maintained to 0.01K. At thermal equilibrium the flow-time were recorded with the help of a stop watch with an accuracy of ±0.01s. The uncertainty for the measurement of viscosity was ±0.2X10^{-3}mPa.s.

Measurement of refractive index has been done with the help of a Digital Refractometer Mettler Toledo instrument. The accuracy for the refractive index measurement was ±0.0002units approximately. The refractometer was calibrated twice using distilled water for measurement of the refractive indices of experimental solutions. The calibration of instrument was made after

few seconds of each measurement [19]. The light source was light-emitting diode, λ=589.3 nm. The temperature of the solution was maintained during the experiment in a Brookfield Digital TC-500 Thermostatic water bath.

The conductivity measurement was done by Mettler Toledo Instrument (In Lab730 probe cell). The specification of the cell has measurement of conductivity range (0.01-1000 mS/cm). The cell type 4 graphite having a cell constant 0.56 cm^{-1}. The calibration of the cell has been done with 0.01 N (NaCl solution). The accuracy of the conductance measurement was ±0.5%. The specific conductance of the experimental solution having concentration (0.0010, 0.0025, 0.0040, 0.0055, 0.0070, 0.0085) m was reported at 293K, 303K, 313K and was converted into molar conductance by the following equation, $\Lambda = 1000\ \kappa / c$ (where c is the molar concentration of the studied amino acid solutions in the ionic liquid. κ is the specific conductance of the specified solutions [22-23].

The mixtures were prepared by mixing known volume of solutions in airtight-stoppered bottles. At first, we prepared 0.01m IL, 0.03m IL, 0.05m IL in 250ml water. Then there was preparation of 0.1m L-Aspartic acid and 0.1m L-Glutamic acid in the aqueous ionic liquid solutions. We prepared and used: 20ml, 0.01m IL + 0.01m amino acid in six sets (0.0010m, 0.0025m, 0.0040m, 0.0055m, 0.0070m, 0.0085m by dilution), 0.03m IL + 0.01m amino acid in six sets (0.0010m, 0.0025m, 0.0040m, 0.0055m, 0.0070m, 0.0085m by dilution), 0.05m IL + 0.01m amino acid in six sets (0.0010m, 0.0025m, 0.0040m, 0.0055m, 0.0070m, 0.0085m by dilution) at 293K, 303K, 313K for experimental purpose. Adequate precautions were taken to minimize evaporation losses during the actual measurements. Mass measurements for stock solutions were done on a Mettler AG-285 electronic balance with a precision of $\pm 0.0003 \times 10^{-3}$kg. The conversion of molarity into molality was accomplished using experimental density values. The uncertainty in molality of solution is estimated to be ±0.0001 mol. kg^{-1}.

V.3. RESULTS AND DISCUSSION

Experimental values of density (ρ), viscosity (η) and molar refraction (R_M) of different molality (m) of aqueous ionic liquid (BTAC) solution at 293K, 303K and 313K are shown in **Table 1**. **Table 2** gives the experimental values of refractive index (n_D) and specific conductance (κ) of different molality (m) of aqueous ionic liquid (BTAC) solution at 293K, 303K and 313K.

V.3.1. Density

In **Table 3** and **Table 4**, the density (ρ) values at 0.01m, 0.03m and 0.05m concentrations of aqueous (BTAC) ionic liquid solutions have been reported at 293K, 303K and 313K for different concentrations of L-Aspartic acid and L-Glutamic amino acid solutions, respectively which have been obtained by dilution method.

Table 5 and **Table 6** give the apparent molar volume (Φ_v) of L-Aspartic acid and L-Glutamic acid solution, respectively in 0.01m, 0.03m and 0.05m aqueous ionic liquid (BTAC) solution at different temperatures (293K, 303K, 313K). The apparent molar volumes (Φ_v) were determined from the solution densities using the following equation:

$$\Phi_v = M / \rho_0 - 1000 (\rho-\rho_0) /c \rho_0 \qquad (1)$$

where, M is the molar mass of the solute, c is the molarity of the solution, ρ and ρ_0 are the densities of the solution and solvent, respectively. It was observed that Φ_v values are positive and decreases with increase in concentration of L-Aspartic acid and L-Glutamic acid solutions. However, it increases with increase in temperature at lower concentration of the amino acids but the trend changes as concentration of amino acid increases in solution. The Φ_v values also increase with increase in concentration of the aqueous IL solutions at lower concentration of the amino acids but again the trend changes at higher concentration of the amino acid solutions. It was further observed that L-Glutamic acid have Φ_v values higher than that of L-Aspartic acid.

For the analysis of the interactions occurring here, the knowledge of the limiting apparent molar volumes are important. The limiting apparent molar volumes (Φ_v^0) were calculated using a least-squares treatment to the plots of (Φ_v) versus $\sqrt{c}$ using the following Masson equation [24]:

$$\Phi_v = \Phi_v^0 + S_v^* \sqrt{c} \qquad (2)$$

where, Φ_v^0 is the limiting apparent molar volume at infinite dilution and S_V^* is the experimental slope. **Table 8(a)** and **Table 8(b)** gives the limiting apparent molar volumes (Φ_v^0) and the experimental slopes (S_V^*) of L-Aspartic acid and L-Glutamic acid solutions, respectively in BTAC at different temperatures. In **Fig. 1(a)** and **Fig. 1(b)** we see the variation of Φ_v^0 values of L-Aspartic acid and L-Glutamic acid solutions, respectively at 0.01m, 0.03m and 0.05m of the IL at (293, 303 and 313) K. The Φ_v^0 values are positive and seem to increase with the increase in concentration of BTAC and also with the increase in temperature for both the amino acids. But S_V^* values are negative and decreases with the increase in concentration of the IL and with rise in temperature. Also it is observed that L-Glutamic acid have higher Φ_v^0 and S_V^*values than L-Aspartic acid at all conditions.

Φ_v^0 values indicate the extent of solute-solvent interaction. A perusal of **Table 8(a)** and **Table 8(b)** reveals that the Φ_v^0 values are positive and is maximum for L-Glutamic acid in 0.05m aqueous ionic liquid solution at 313K indicating highest solute-solvent interaction here and minimum for L-Aspartic acid in 0.01m aqueous ionic liquid solution at 293K, indicating that the

solute-solvent interaction is the least here. This is probably due to the release of a number of the solvent molecules from loose solvation layers during the solute-solvent interactions [25]. Also the higher Φ_v^0 values of L-Glutamic acid indicates that it interacts more with BTAC than L-Aspartic acid under any conditions. On the contrary, the S_V^*indicates the extent of solute-solute interaction. The values of S_V^*show that the extent of solute-solute interaction is highest in L-Glutamic acid 0.01m IL solution at 293K and minimum in 0.05m IL solution at 313K. Here again the higher values of S_V^*in L-Glutamic acid indicates that it exhibits better interaction among itself than L-Aspartic acid molecules under any conditions. Possible reasons for this behavior could be the structural orientation of the larger alkyl group of L-Glutamic acid than L-Aspartic acid as depicted by their molecular structures in **Scheme 1**. A quantitative comparison of the magnitude of Φ_v^0 values shows that it is much greater in magnitude than S_V^* values for the solutions. This suggests that strong solute-solvent interactions dominate over the weak solute-solute interactions in all the solutions [26-27]. There is hydrophobic hydration, or the caging effect of water molecules [28] which reflects hydrophobic interactions in the amino acids that cause volume contractions. Similar linear correlations have been observed earlier for homologous series of amino acids in aqueous electrolytes [29].

Temperature dependency of the limiting apparent molar volume (Φ_v^0) were studied between the temperature range 293K to 313K and the results obtained were found to follow the following polynomial equation [30]:

$$\Phi_v^0 = a_0 + a_1T + a_2T^2 \qquad (3)$$

where, a_0, a_1 and a_2 are the empirical coefficients depending on the nature of solute and mass fraction (W) of co-solvent whereas T is the temperature in Kelvin scale. **Table 9** shows the empirical coefficient values (a_0, a_1 and a_2) of L-Aspartic acid solution & L-Glutamic acid in different concentration of the IL (0.01m, 0.03m, 0.05m) at 293K, 303K, 313K.

First derivative of Equation (3) gives the values of limiting apparent molar expansibilities (Φ_E^0) which have been calculated for various temperatures and listed in **Table 10(a)** and **Table 10(b)** for L-Aspartic acid and L-Glutamic acid solutions, respectively.

$$\Phi_E^0 = (\delta\Phi_v^0 / \delta T)_P = a_1 + 2a_2T \qquad (4)$$

Limiting apparent molar expansibilities (Φ_E^0) for all the systems are found positive except for 0.05m IL at 313K in both the amino acids signifying the absence of caging or packing effect in the other solutions except this one. The solute–solvent interaction studied so far is now at a state that, it may be structure-breaker or synergistic structure-maker interaction. In this connection, Hepler developed a way to examine the nature of the solute–solvent interaction

taking place in the solution phase [31]. According to Hepler, values of $(\delta\Phi_E^0/\delta T)_P$ in the expression given below, determines whether, it is structure-breaker or structure-maker interaction [32]:

$$(\delta\Phi_E^0 / \delta T)_P = (\delta^2\Phi_v^0 / \delta T^2)_P = 2a_2 \qquad (5)$$

Generally, positive or small negative values of $(\delta\Phi_E^0/\delta T)_P$ strongly suggests structure-making rather than structure-breaking interaction. Here, the small negative values listed in **Table 10(a)** and **Table 10(b)** respectively for L-Aspartic acid and L-Glutamic acid solutions in IL (BTAC) at different temperatures confirms the mode of solute–solvent interaction is structure-making and as supported earlier the structure-making effect is strongest in 0.05m aqueous IL solution at 313K for both the amino acids and the effect being greater in L-Glutamic acid solutions with highest packing or caging effect.

V.3.2. Viscosity

In aqueous electrolytic solutions the extent of ionic hydration and structural interactions [33-35] within the ionic hydration cospheres [36] can be explored easily by studying viscosity coefficient with varying concentration and temperature of the aqueous solution. Experimental values of viscosity (η) of different molality of aqueous ionic liquid (BTAC) solution at 293K, 303K and 313K have been given in **Table 1**. Viscosity (η) values of L-Aspartic acid and L-Glutamic acid in aqueous (BTAC) ionic liquid, IL solution at 293K, 303K and 313K are given in **Table 3** and **Table 4**, respectively. The results show that the viscosity of the solutions increases with increasing molality of IL. This is due to the fact that upon increasing the molality of the ionic liquid, the number of collisions among the molecules also increases, resulting in a loss of kinetic energy. Therefore, the molecules tend to stick together with increasing viscosity.

Viscosity data so obtained were analysed with the help of Jones-Dole equation [37].

$$\eta_r = \eta / \eta^0 = 1 + A\sqrt{c} + Bc \qquad (6)$$

where, η and η^0 are viscosities of solution and solvent respectively, c is the concentration of solution in molality. In **Table 5** and **Table 6**, respectively $(\eta/\eta^0 - 1)/\sqrt{m}$ values of L-Aspartic acid and L-Glutamic acid solutions have been shown in 0.01m, 0.03m and 0.05m in aqueous IL (BTAC) solution at different temperatures (293K, 303K, 313K).

The $(\eta/\eta^0 - 1)/\sqrt{m}$ values are positive and seem to increase with increase in concentration of the amino acid in solutions and with increase in temperature from 293K to 313K. However, the $(\eta/\eta^0 - 1)/\sqrt{m}$ values are found to decrease and then increase as we increase the concentration of aqueous IL solution from 0.01m to 0.03m to 0.05m for 293K and 313K but trend changes for 303K. Same trend is noted for both L-Aspartic acid and L-Glutamic acid but the (η

/η^0 –1) / √m values are greater in L-Glutamic acid under all conditions. This is possibly due to stronger hydrophobic–hydrophobic interactions for longer alkyl chains of L-Glutamic acid.

Rearrangement of the above Equation (6) gives following:

$$(\eta_r - 1) / \sqrt{c} = A + B\sqrt{c} \qquad (7)$$

Here, viscosity A-coefficient is a constant, also known as Falken hagen coefficient [25], stands for long-range coulombic forces, so represents the solute-solute interaction in solution, while B-coefficient is an adjustable parameter, which is the measure of the effective hydrodynamic volume, reflects the solute-solvent interaction. Magnitude of viscosity B-coefficient depends on the shape, size and partial molar entropies of the ions. According to the Jones-Dole equation from the plots of $(\eta_r - 1) / \sqrt{c}$ vs √c, the viscosity A, B-coefficients obtained by linear least-square analysis, are reported in **Table 8(a)** and **Table 8(b)** for L-Aspartic acid and L-Glutamic acid solutions at (293, 303 and 313)K, respectively. **Fig. 2(a)** and **Fig. 2(b)** shows the variation of B values of L-Aspartic acid and L-Glutamic acid, respectively against 0.01m IL, 0.03m IL and 0.05m IL solutions at different temperatures.

The viscosity *B*-coefficient is an empirical constant which depends on size and shape effects as well as structural effects induced by solute+solvent interactions [7]. In all cases the viscosity *B*-coefficients are larger in the aqueous ionic liquid solutions which indicates promotion of the liquid structure in the presence of an ionic liquid, thus supporting the conclusions obtained from volumetric properties. From **Table 8(a)** and **Table 8(b)** it is evident that the values of the B-coefficient are positive, thereby suggesting the presence of strong solute-solvent interactions, that strengthened with an increase in the solvent viscosity value, in accordance with the results obtained from Φ_v^0 values explained earlier. The values of the A-coefficient are found to very small as compared to B-coefficients. These results indicate the presence of very weak solute–solute interactions. These results are in outstanding agreement with those obtained from S_V^* values. The extent of solute–solvent interaction obtained from the B-coefficient occurs into the local vicinity of the solute molecules in the solutions. The higher B-coefficient values for higher viscosity values is due to the solvated solute molecules associated by the solvent molecules all around because of the formation of associated molecule by solute-solvent interactions [38]. Further, these types of interactions are strengthened with rise in temperatures. It shows that the solute-solvent interaction increases with increase in temperature and the concentration of the IL solutions with more interaction between L-Glutamic acid and aqueous BTAC solutions. The replacement of water molecules by more co-solvent molecules from the solvation sphere brings solute and co-solvent closer thereby increasing viscosity B-coefficients and accounts for the higher solute-solvent interaction. The overall viscometric studies show that, viscosity B-

coefficients are positive and greater than viscosity A-coefficient, suggesting solute–solvent interaction predominant over the solute-solute interaction.

Extensive study of the viscosity B-coefficient such that, its first derivative over temperature is an upgradation of viscosity B-coefficient in predicting the nature of solute–solvent interaction as structure-maker or structure-breaker. The value of dB/dT is a measure of activation energy required for the viscous flow in solution. This is the reason, why the measure of dB/dT is indicative towards the structure making or structure breaking ability than sign or magnitude of the B-coefficient [39-41]. Viscosity B-coefficients of L-Aspartic acid and L-Glutamic acid solutions along with dB/dT values in different concentrations of IL at (293, 303 and 313) K are given in **Table 11(a)** and **Table 11(b)**, respectively. The small positive value of dB/dT signifies structure-making (kosmotropic) whereas the larger positive value identifies it as structure-breaking (chaotropic). Here the small positive dB/dT values indicate the amino acids to behave as structure-maker in the aqueous ionic liquid solution.

V.3.3. Refractive Index

Optical data of refractive index of the studied systems has provided interesting information allied to molecular interactions, structure of solutions in these assay. The refractive index of mixing can be interconnected by the application of a composition dependent polynomial equation and molar refraction, R_M in solution.

The molar refraction R_M can be evaluated from the Lorentz–Lorenz relation [42]:

$$R_M = \{(n_D^2 - 1) / (n_D^2 + 2)\}(M/\rho) \qquad (8)$$

where R_M, n_D, M and ρ are the molar refraction, the refractive index, the molar mass and the density of the solution, respectively. The refractive index of a substance is defined as the ratio c_o/c, where c is the speed of light in the medium and c_o is the speed of light in vacuum. Stated more simply, the refractive index of a compound describes its ability to refract light as it moves from one medium to another and thus, the higher the refractive index of a compound, the more the light is refracted [43]. As stated by Deetlefs et al. the refractive index of a substance is higher when its molecules are more tightly packed or in general when the compound is denser [44]. Generally, refractive index of a system is the ability to refract light and hence it can simultaneously measure the compactness of that system.

Table 1 and **Table 2** gives the experimental values of molar refraction (R_M) and refractive index (n_D) of different molality of aqueous IL (BTAC) solution at 293K, 303K and

313K, respectively. **Table 3** and **Table 4** show the molar refraction (R_M) variation of L-Aspartic acid and L-Glutamic acid, respectively in aqueous (BTAC) ionic liquid, IL solution at 293K, 303K and 313K. **Table 7(a)** and **Table 7(b)** displays the refractive index (n_D) of L-Aspartic acid and L-Glutamic acid solutions in aqueous IL (BTAC) solution at 293K, 303K and 313K, respectively.

Hence, it is observed that the refractive index (n_D) decrease but the molar refraction (R_M) increases with increase in temperature. However, both the parameters show an increase with increase in concentration of the amino acids and IL solutions. Again L-Glutamic acid have higher values than L-Aspartic acid. This is in good agreement with the volumetric and viscometric results attained here. The higher refractive index shows that the molecules are more tightly packed in the solution.

The limiting molar refraction, (R_M^0) listed in **Table 8(a)** and **Table 8(b)** can be calculated using the following equation-

$$R_M = R_M^0 + R_S \sqrt{m} \qquad (9)$$

where, 'm' is the molality of solution and R_M^0 is the limiting molar refraction that signifies solute–solvent interaction. So, this measurement operates as an expensive tool for studying the molecular interaction in solution. Gradual increase in the values of R_M^0 as shown in **Fig. 3(a)** and **Fig. 3(b)** with rise in mass fraction of co-solvent and temperature also signifies that solute–solvent interaction predominant over solute-solute interactions.

V.3.4. Electrical Conductance

Experimental values of specific conductance (κ) of different molality of aqueous IL (BTAC) solution at 293K, 303K and 313K are given in **Table 2**. **Table 7(a)** and **Table 7(b)** show the specific conductance (κ) of L-Aspartic acid and L-Glutamic acid in aqueous IL (BTAC) solution at 293K, 303K and 313K, respectively. **Table 12** shows the molar conductance (Λ) of L-Aspartic acid and L-Glutamic acid solution in (0.01m, 0.03m, 0.05m) IL at 293K, 303K and 313K. **Fig. 4(a) and Fig. 4(b)** gives the variation of molar conductance (Λ) with different concentrations of L–Aspartic acid in aqueous (0.01m, 0.03m, 0.05m) BTAC (IL) solution at 293K, 303K, 313K. The specific conductance (κ) values increase with increase in temperature and increase in concentration of aqueous IL solution and the amino acid solutions but the molar conductance (Λ) values decrease with the increase in concentration of amino acid solutions. However, the values are lesser in L-Glutamic acid solutions under all conditions.

The molar conductance (Λ) has been obtained from the specific conductance (κ) value using the following equation [38]:

$$\Lambda = (1000\ \kappa) / C \qquad (10)$$

Linear conductivity curves (Λ vs. *C*) were obtained for the amino acids in IL solutions and extrapolation of $\sqrt{C} = 0$ was used to evaluate the limiting molar conductance for the IL. The amino acids have terminal carboxylic (-COOH) group on both ends. IL has benzyl trimethyl ammonium cation and chloride anion. The terminal $–COO^-$ functional group of the amino acids interact with the N^+ centre of benzyl trimethyl ammonium ring through ion–dipole interaction. The molecular structure of the amino acids, L-Aspartic acid and L-Glutamic acid, and the ionic liquid, Benzyl tri-methyl ammonium chloride shown in **Scheme 1** gives an overview.

Another contributing factor in the amino acids is the carboxylic (-O-) atom. The lone pair donating tendency of carboxylic oxygen increases with the increase in +I effect of alkyl group of the studied amino acids. Thus +I effect in L-Glutamic acid is greater than in L-Aspartic acid. Hence, the interaction is more prominent in L-Glutamic acid due to the presence of more lone pair availability of oxygen atom, making the interaction strong with IL. So the free ions are more available for L-Aspartic acid giving higher conductance values than L-Glutamic acid.

V.4. CONCLUSIONS

Density, viscosity, refractive index and conductance measurements provide the information about ion-dipole interaction and show that the solute-solvent interaction between BTAC ionic liquid and L-Aspartic acid and L-Glutamic amino acid systems is higher than the solute-solute interaction. This is resulted by hydrophobic interactions which lead to volume contraction. The physico-chemical methodologies, describes the mode of interaction in solution. Calculation of limiting apparent molar volume, limiting molar refraction, viscosity B-coefficient and molar conductance makes it possible to identify the interaction as predominant solute–solvent interaction and indicate the predominance of solute-solvent interaction than the solute-solute interaction. The values of $(\delta\Phi_E^0/\delta T)_P$ and (dB/dT) have been calculated to provide the information that the solute–solvent interaction is structure-making. The extent of solvation is highest in L-Glutamic acid at 0.05m 313K and lowest in L-Aspartic acid at 0.01m 293K. The derived parameters obtained by analyzing various equations supplemented with experimental data sustain the same finale as discussed and explained above.

ACKNOWLEDGMENT

The authors are grateful to the UGC supported Major research project, Ref. No. RP/5032/FCS/2011 New Delhi for financial support in order to continue this research work.

One of the authors, Prof. M. N. Roy is thankful to University Grant Commission, New Delhi, Government of India for being awarded one-time grant under Basic Scientific Research via the grant-in-Aid No. F.4-10/2010 (BSR) regarding his active service for augmenting of research facilities to facilitate further research work.

Conflicts of Interest: There is no conflicts of interest.

TABLES

Table 1. Experimental values of density (ρ), viscosity (η) and molar refraction (R_M) of different molality (m) of aqueous IL (BTAC) solution at 293K, 303K and 313K

Conc. of Aq. IL (BTAC) soln. in molality, m (mol.kg^{-1})	ρ×10^{-3}(kg.m^{-3})			η(mPa.s)			R_M		
	293K	303K	313K	293K	303K	313K	293K	303K	313K
0.01	.99840	.99584	.99239	1.064	0.818	0.696	27.3547	27.3800	27.4676
0.03	.99872	.99614	.99270	1.231	1.010	0.892	27.3683	27.4317	27.5117
0.05	.99912	.99652	.99306	1.266	1.085	0.970	27.4246	27.4737	27.5544

Table 2. Experimental values of refractive index (n_D) and specific conductance (κ) of different molality (m) of aqueous IL (BTAC) solution at 293K, 303K and 313K

Conc. of Aq. IL (BTAC) soln. in molality, m (mol.kg^{-1})	n_D			κ (mS/cm)		
	293K	303K	313K	293K	303K	313K
0.01	1.3321	1.3315	1.3313	0.940	1.047	1.073
0.03	1.3324	1.3322	1.3320	2.710	2.860	2.970
0.05	1.3332	1.3330	1.3327	4.140	5.200	5.390

Table 3. Density (ρ), viscosity (η) and molar refraction (R_M) of L-Aspartic acid in aqueous (BTAC) ionic liquid solutions at 293K, 303K and 313K

Conc. of L-Aspartic acid soln. in molality, m (mol.kg^{-1})	ρ×10^{-3} (kg.m^{-3})			η(mPa.s)			R_M		
	293K	303K	313K	293K	303K	313K	293K	303K	313K
0.01m IL									
0.0010	0.99843	0.99587	0.99242	1.071	0.825	0.704	27.3688	27.4146	27.4819
0.0025	0.99851	0.99597	0.99250	1.081	0.836	0.715	27.3890	27.4219	27.4947
0.0040	0.99857	0.99603	0.99260	1.090	0.846	0.727	27.4030	27.4272	27.5070
0.0055	0.99866	0.99613	0.99272	1.100	0.857	0.740	27.4148	27.4320	27.5112
0.0070	0.99876	0.99624	0.99285	1.109	0.867	0.751	27.4195	27.4362	27.5226
0.0085	0.99887	0.99638	0.99298	1.117	0.877	0.763	27.4315	27.4398	27.5265
0.03m IL									
0.0010	0.99875	0.99617	0.99273	1.239	1.019	0.900	27.3899	27.4459	27.5184
0.0025	0.99885	0.99624	0.99281	1.249	1.032	0.915	27.4021	27.4535	27.5312
0.0040	0.99891	0.99633	0.99291	1.260	1.046	0.930	27.4079	27.4612	27.5435
0.0055	0.99901	0.99644	0.99303	1.272	1.060	0.945	27.4127	27.4668	27.5552
0.0070	0.99911	0.99656	0.99317	1.282	1.074	0.960	27.4174	27.4723	27.5588
0.0085	0.99924	0.99669	0.99332	1.292	1.088	0.975	27.4216	27.4765	27.5697
0.05m IL									
0.0010	0.99915	0.99655	0.99309	1.273	1.093	0.979	27.4312	27.4878	27.5686
0.0025	0.99923	0.99662	0.99316	1.285	1.108	0.997	27.4365	27.4934	27.5741
0.0040	0.99931	0.99672	0.99326	1.297	1.123	1.015	27.4418	27.4981	27.5789
0.0055	0.99942	0.99684	0.99338	1.310	1.138	1.033	27.4462	27.5023	27.5831
0.0070	0.99954	0.99698	0.99351	1.322	1.153	1.051	27.4504	27.5059	27.5870
0.0085	0.99968	0.99709	0.99367	1.334	1.169	1.068	27.4540	27.5103	27.5900

Table 4. Density (ρ), viscosity (η) and molar refraction (R_M) of L-Glutamic acid in aqueous (BTAC) ionic liquid solutions at 293K, 303K and 313K

Conc. of L-Glutamic acid soln. in molality ($mol.kg^{-1}$)	$\rho \times 10^{-3}$ ($kg.m^{-3}$)			η(mPa.s)			R_M		
	293K	303K	313K	293K	303K	313K	293K	303K	313K
0.01m IL									
0.0010	0.99844	0.99588	0.99243	1.073	0.827	0.706	30.2369	30.2897	30.3201
0.0025	0.99852	0.99596	0.99255	1.086	0.840	0.721	30.2593	30.3122	30.3498
0.0040	0.99861	0.99606	0.99262	1.099	0.853	0.735	30.2731	30.3340	30.3643
0.0055	0.99871	0.99617	0.99274	1.111	0.866	0.750	30.2865	30.3472	30.3855
0.0070	0.99881	0.99629	0.99287	1.124	0.880	0.765	30.3000	30.3601	30.3982
0.0085	0.99892	0.99642	0.99301	1.136	0.892	0.781	30.3132	30.3727	30.4105
0.03m IL									
0.0010	0.99876	0.99618	0.99274	1.241	1.023	0.903	30.2437	30.2972	30.3356
0.0025	0.99889	0.99627	0.99286	1.256	1.041	0.923	30.2646	30.3276	30.3566
0.0040	0.99896	0.99637	0.99295	1.270	1.059	0.942	30.2790	30.3405	30.3791
0.0055	0.99908	0.99649	0.99310	1.285	1.078	0.960	30.3001	30.3540	30.3918
0.0070	0.99920	0.99662	0.99325	1.300	1.097	0.979	30.3130	30.3660	30.4038
0.0085	0.99930	0.99677	0.99334	1.313	1.117	0.998	30.3182	30.3783	30.4155
0.05m IL									
0.0010	0.99916	0.99656	0.99310	1.278	1.096	0.983	30.2564	30.3048	30.3433
0.0025	0.99924	0.99665	0.99323	1.294	1.118	1.007	30.2787	30.3360	30.3726
0.0040	0.99933	0.99676	0.99331	1.311	1.141	1.032	30.2925	30.3479	30.3868
0.0055	0.99944	0.99689	0.99345	1.329	1.162	1.055	30.3057	30.3605	30.4074
0.0070	0.99957	0.99703	0.99360	1.347	1.185	1.080	30.3186	30.3727	30.4195
0.0085	0.99971	0.99717	0.99377	1.364	1.209	1.109	30.3311	30.3850	30.4309

Table 5. Apparent molar volume, (Φv) and ($\eta/\eta^0 - 1$) /√m of L-Aspartic acid solution in 0.01m, 0.03m and 0.05m aqueous BTAC solution at different temperatures (293K, 303K, 313K)

Conc. of L-Aspartic acid soln. in molality, m ($mol.kg^{-1}$)	$\Phi v \times 10^6$ ($m^3.mol^{-1}$)	$(\eta/\eta^\circ - 1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)	$\Phi v \times 10^6$ ($m^3.mol^{-1}$)	$(\eta/\eta^\circ - 1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)	$\Phi v \times 10^6$ ($m^3.mol^{-1}$)	$(\eta/\eta^\circ - 1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)
0.01m IL	**293K**		**303K**		**313K**	
0.0010	103.2104	0.206	103.4017	0.270	103.6557	0.357
0.0025	93.5224	0.319	89.9481	0.437	89.4333	0.542
0.0040	90.6615	0.386	85.9802	0.540	81.4533	0.702
0.0055	86.0340	0.456	80.6564	0.642	75.4453	0.851
0.0070	81.6876	0.505	76.1683	0.715	69.2768	0.943
0.0085	77.9260	0.540	69.7073	0.781	64.5830	1.043
0.03m IL	**293K**		**303K**		**313K**	
0.0010	103.4883	0.202	103.9725	0.278	104.2297	0.280
0.0025	89.8144	0.290	93.2958	0.432	89.4194	0.512
0.0040	85.6325	0.372	85.9687	0.562	81.0517	0.671
0.0055	80.5762	0.447	78.8222	0.667	73.7893	0.799
0.0070	77.3832	0.494	73.2053	0.756	66.2024	0.909
0.0085	73.2205	0.537	68.5227	0.836	60.3699	1.008
0.05m IL	**293K**		**303K**		**313K**	
0.0010	103.7505	0.172	104.0310	0.231	104.4923	0.291
0.0025	90.1393	0.298	93.2756	0.420	93.4597	0.555
0.0040	85.9127	0.387	83.4487	0.551	83.9379	0.732
0.0055	78.6512	0.468	75.1641	0.657	75.4340	0.874
0.0070	73.1665	0.528	67.6419	0.748	69.2737	0.997
0.0085	67.8722	0.582	66.0784	0.838	62.2337	1.094

Table 6. Apparent molar volume, (Φv) and $(\eta/\eta^0 - 1)/\sqrt{m}$ of L-Glutamic acid solution in 0.01m, 0.03m and 0.05m in aqueous (BTAC) solution at different temperatures (293K, 303K, 313K)

Conc. of L-Glutamic acid soln. in molality, m ($mol.kg^{-1}$)	Φv x 10^6 ($m^3.mol^{-1}$)	$(\eta/\eta^\circ-1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)	Φv x 10^6 ($m^3.mol^{-1}$)	$(\eta/\eta^\circ-1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)	Φv x 10^6 ($m^3.mol^{-1}$)	$(\eta/\eta^\circ-1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)
0.01m IL	**293K**		**303K**		**313K**	
0.0010	107.2332	0.265	107.4054	0.346	107.6381	0.451
0.0025	99.2768	0.413	99.4066	0.536	90.0886	0.717
0.0040	94.6775	0.520	92.2638	0.674	89.8522	0.833
0.0055	90.9240	0.595	87.3579	0.789	83.3127	1.045
0.0070	88.7094	0.672	85.9177	0.905	78.6931	1.184
0.0085	86.1094	0.733	79.0880	0.980	74.2348	1.324
0.03m IL	**293K**		**303K**		**313K**	
0.0010	107.2117	0.254	107.7843	0.402	107.6172	0.385
0.0025	93.8334	0.405	95.3694	0.612	90.6933	0.694
0.0040	92.1572	0.500	89.7329	0.766	87.3052	0.833
0.0055	87.3538	0.591	83.6384	0.907	81.7615	1.027
0.0070	84.2631	0.699	78.6561	1.029	72.7915	1.164
0.0085	80.1998	0.722	73.0749	1.148	67.0805	1.287
0.05m IL	**293K**		**303K**		**313K**	
0.0010	107.5815	0.296	107.7584	0.318	107.9944	0.418
0.0025	99.2207	0.441	95.9558	0.607	90.6812	0.762
0.0040	94.7233	0.560	87.4871	0.812	84.7603	1.007
0.0055	89.0525	0.670	80.1161	0.956	76.2246	1.180
0.0070	82.9417	0.762	74.3435	1.099	69.8954	1.355
0.0085	80.1718	0.838	69.6760	1.238	63.5114	1.550

Table-7(a). Refractive index (n_D) and specific conductance (κ) of L-Aspartic acid in aqueous IL (BTAC) solution at 293K, 303K and 313K.

Conc. of L-Aspartic acid soln. in molality, m ($mol.kg^{-1}$)	n_D			κ (mS/cm)		
	293K	303K	313K	293K	303K	313K
0.01m IL						
0.0010	1.3323	1.3320	1.3316	1.05	1.15	1.19
0.0025	1.3326	1.3321	1.3318	1.09	1.20	1.24
0.0040	1.3328	1.3322	1.3320	1.16	1.25	1.28
0.0055	1.3330	1.3323	1.3321	1.19	1.29	1.32
0.0070	1.3331	1.3324	1.3323	1.25	1.34	1.37
0.0085	1.3333	1.3326	1.3324	1.29	1.39	1.42
0.03m IL						
0.0010	1.3327	1.3325	1.3322	2.91	3.13	3.21
0.0025	1.3329	1.3327	1.3324	2.99	3.18	3.26
0.0040	1.3330	1.3329	1.3326	3.08	3.23	3.31
0.0055	1.3331	1.3330	1.3328	3.15	3.31	3.38
0.0070	1.3332	1.3331	1.3329	3.24	3.35	3.45
0.0085	1.3333	1.3332	1.3331	3.33	3.42	3.56
0.05m IL						
0.0010	1.3334	1.3332	1.3330	4.29	5.28	5.46
0.0025	1.3336	1.3333	1.3331	4.38	5.36	5.59
0.0040	1.3337	1.3335	1.3333	4.45	5.42	5.84
0.0055	1.3338	1.3336	1.3334	4.49	5.48	6.10
0.0070	1.3340	1.3338	1.3336	4.53	5.55	6.46
0.0085	1.3341	1.3339	1.3337	4.63	5.61	6.65

Tabble-7(b).viscosity (η) and $(\eta/\eta^{\circ}-1)/\sqrt{m}$ of L-Histidine in aqueous IL (BTBACl) solution at 298.15K, 303.15K and 308.15K.

Conc. of L-Histidine soln. in molality, m ($mol.kg^{-1}$)	η (mPa.s)			$(\eta/\eta^{\circ}-1)/\sqrt{m}$ ($kg^{1/2}.mol^{-1/2}$)		
0.001m IL	**298.15K**	**303.15K**	**308.15K**	**298.15K**	**303.15K**	**308.15K**
0.010040	0.993	0.911	0.866	0.122	0.133	0.140
0.025138	1.011	0.929	0.884	0.193	0.210	0.221
0.042820	1.030	0.948	0.903	0.241	0.271	0.284
0.0555472	1.045	0.965	0.923	0.277	0.311	0.343
0.070071	1.063	0.983	0.942	0.316	0.351	0.387
0.085988	1.083	1.002	0.961	0.355	0.390	0.427
0.003m IL						
0.010039	1.026	0.943	0.874	0.128	0.139	0.139
0.025137	1.043	0.965	0.893	0.187	0.237	0.227
0.040281	1.062	0.986	0.912	0.241	0.300	0.289
0.0555470	1.080	1.004	0.932	0.281	0.338	0.345
0.070706	1.100	1.025	0.955	0.323	0.384	0.406
0.085986	1.120	1.048	0.978	0.360	0.432	0.459
0.005m IL						
0.010040	1.042	0.951	0.898	0.136	0.161	0.146
0.025124	1.060	0.970	0.921	0.196	0.229	0.256
0.040279	1.080	0.994	0.945	0.252	0.309	0.337
0.055469	1.100	1.015	0.968	0.297	0.358	0.398
0.070704	1.121	1.040	0.992	0.340	0.418	0.454
0.085985	1.143	1.063	1.015	0.381	0.463	0.500

Table 8(a). Viscosity A, B-coefficients of L-Glutamine and L-Asparagine solution in different concentration of IL at 298.15K,303.15K, 308.15K

Temperature(K)	B ($kg^{1/2}. mol^{-1/2}$)	A ($kg.mol^{-1}$)	Temperature(K)	B ($kg^{1/2}. mol^{-1/2}$)	A ($kg. mol^{-1}$)
0.01m IL					
298.15	2.2104	0.0003	298.15	1.1866	0.0016
303.15	2.3155	-0.0008	303.15	1.3232	0.0012
308.15	2.54004	-0.0150	308.15	1.4985	-0.0139
0.03m IL					
298.15	2.4001	-0.0026	298.15	1.2077	0.0009
303.15	2.7347	-0.012	303.15	1.4727	-0.003
308.15	3.0271	-0.0481	308.15	1.6438	-0.0329
0.05m IL					
298.15	2.6441	-0.0092	298.15	1.2755	0.0007
303.15	3.253	-0.0212	303.15	1.5895	-0.0092
308.15	3.4996	-0.0532	308.15	1.8347	-0.0360

Table 8(b). Limiting apparent molar volumes (Φv^0), Limiting molar refraction (R_M^0), experimental slopes (S_V^*), viscosity A, B-coefficients of L-Glutamic acid solution in IL at different temperatures

Temperature(K)	**Φv^0 x 10^6 ($m^3. mol^{-1}$)**	**R_M^0**	**Sv* x 10^6 ($m^3. mol^{-3/2}.kg^{1/2}$)**	**B ($kg^{1/2}. mol^{-1/2}$)**	**A ($kg. mol^{-1}$)**
0.01m IL					
293	117.17	30.197	-344.26	7.7232	0.0237
303	121.57	30.245	-450.23	7.8217	0.0073
313	124.71	30.273	-551.01	9.1001	-0.0062
0.03m IL					
293	119.47	30.201	-429.65	10.602	0.0055
303	124.65	30.258	-555.52	12.331	-0.0030
313	128.15	30.292	-654.62	15.045	-0.1542
0.05m IL					
293	122.55	30.217	-459.38	14.278	-0.0079
303	128.09	30.268	-640.65	14.745	-0.0665
313	131.15	30.298	-734.15	18.372	-0.1669

Table 9. The empirical coefficient values (a_0, a_1 and a_2) of L-Aspartic acid solution & L-Glutamic acid in different concentration of the IL (0.01, 0.03m, 0.05m) at 293K, 303K and 313K

Conc. of aq. IL soln. in molality, m (mol.kg^{-1})	**a_0 x 10^6 (m^3.mol^{-1})**	**a_1 x 10^6 (m^3. mol^{-1}. K^{-1})**	**a_2 x 10^6 (m^3. mol^{-1}. K^{-2})**	**a_0 x 10^6 (m^3. mol^{-1})**	**a_1 x 10^6 (m^3. mol^{-1}. K^{-1})**	**a_2 x 10^6 (m^3. mol^{-1}. K^{-2})**
	L-Aspartic acid			**L-Glutamic acid**		
	293K	**303K**	**313K**	**293K**	**303K**	**313K**
0.01	-1890.7	12.636	-0.0198	-2420.5	16.025	-0.0252
0.03	-2982.8	19.643	-0.0310	-3223.1	21.230	-0.0336
0.05	-4071.0	27.062	-0.0436	-4686.2	30.918	-0.0496

Table 10(a). Values of limiting molar expansibilities (Φ_E^0) for L-Aspartic acid solution in IL(BTAC) at different temperatures.

Conc. of aq. IL soln. in molality, m (mol.kg^{-1})	**$\Phi_E^0 \times 10^6$ (m^3. mol^{-1}. K^{-1})**			**$(\delta\Phi_E^0/\delta T)_P \times 10^6$ (m^3. mol^{-1}. K^{-2})**
	293K	**303K**	**313K**	
0.01	1.0332	0.6372	0.2412	-0.0396
0.03	1.4770	0.8570	0.2370	-0.0620
0.05	1.5124	0.6404	-0.2316	-0.0872

Table 10(b). Values of limiting molar expansibilities (Φ_E^0) for L-Glutamic acid solution in IL(BTAC) at different temperatures

Conc. of aq. IL soln. in molality, m (mol.kg^{-1})	**$\Phi_E^0 \times 10^6$ (m^3. mol^{-1}. K^{-1})**			**$(\delta\Phi_E^0/\delta T)_P \times 10^6$ (m^3. mol^{-1}. K^{-2})**
	293K	**303K**	**313K**	
0.01	0.2578	0.7538	0.2498	-0.0504
0.03	1.5404	0.8684	0.1964	-0.0672
0.05	1.8524	0.8604	-0.1316	-0.0992

Table 11(a). Viscosity B-coefficients of L-Arginine along with dB/dT values in different concentrations of IL at (298.15, 303.15 and 308.15) K

Temperature (K)	0.01m IL		0.03m IL		0.05m IL		dB/dT
	B		B		B		
293	2.2104		2.4001		2.6441		0.029
303	2.3155		2.7347		3.253		0.0627
313	2.5004		3.0271		3.4996		0.0856

Table 11(b). Viscosity B-coefficients of L-Histidine along with dB/dT values in different concentrations of IL at (298.15, 303.15 and 308.15) K

Temperature (K)	0.01m IL		0.03m IL		0.05m IL		
	B		B		B		dB/dT
293	1.1866		1.2077		1.2755		0.0312
303	1.3233		1.4724		1.5895		0.0436
313	1.4985		1.6438		1.8347		0.0559

Table-12. Molar conductance (Λ) of L-Aspartic acid and L-Glutamic acid solution in (0.01m, 0.03m, 0.05m) IL at 293K, 303K and 313K

Concentration of amino acid solutions in molality, m (mol.kg^{-1})	**Molar Conductance of L-Aspartic acid solution Λ (S.cm^2.mol^{-1})**			**Molar conductance of L-Glutamic acid solution Λ (S.cm^2.mol^{-1})**		
	293K	**303K**	**313K**	**293K**	**303K**	**313K**
0.01m IL						
0.0010	1053.00	1152.00	1195.00	1010.00	1090.00	1160.00
0.0025	437.60	480.40	495.20	416.00	448.00	488.00
0.0040	291.00	312.75	318.75	267.50	285.00	312.50
0.0055	218.00	227.45	240.00	198.18	210.90	230.90
0.0070	177.85	191.57	195.28	160.00	168.57	190.00
0.0085	151.64	163.17	167.06	134.117	142.35	161.18
0.03m IL						
0.0010	2910.00	3130.00	3210.00	2890.00	3060.00	3110.00

0.0025	1198.80	1272.00	1304.00	1180.0	1236.00	1260.00
0.0040	770.50	810.00	827.50	752.50	780.00	807.50
0.0055	573.09	610.81	614.54	558.18	572.72	601.82
0.0070	462.88	478.57	492.85	447.14	454.29	485.65
0.0085	391.76	402.35	411.76	375.29	378.82	409.41
0.05m IL						
0.0010	4290.00	5280.00	5460.00	4270.00	5170.00	5350.00
0.0025	1752.00	2144.00	2236.00	1760.00	2080.00	2204.00
0.0040	1112.50	1352.00	1460.00	1092.50	1307.50	1435.00
0.0055	816.36	996.36	1109.09	800.00	954.54	1087.27
0.0070	651.42	792.88	922.88	637.14	752.85	902.85
0.0085	544.70	660.00	782.35	528.23	623.53	757.64

FIGURES

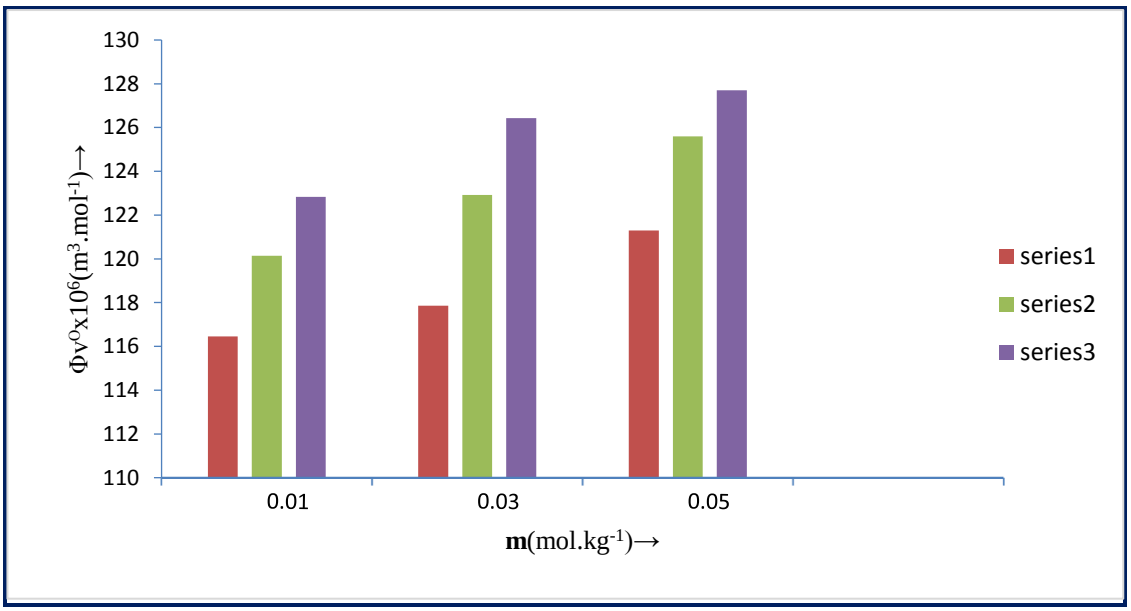


Figure 1(a) Variation of limiting apparent molar volume (Φ_v^0) of L-Aspartic acid solution at 0.01m, 0.03m and 0.05m of the aqueous IL solutions at 293K(Series1), 303K(Series2) and 313K(Series3)

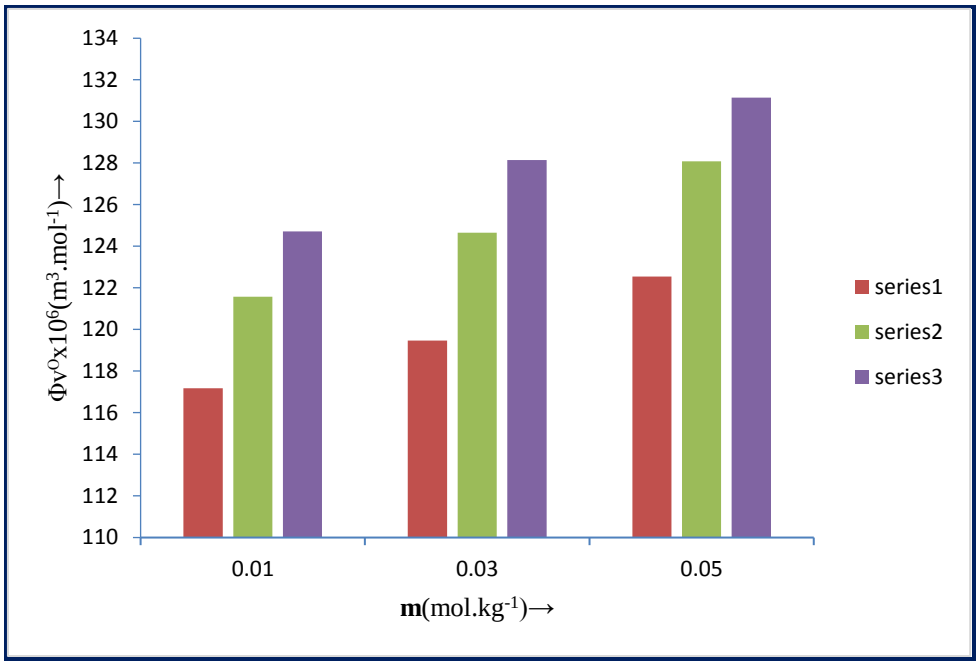


Figure 1(b) Variation of limiting apparent molar volume (Φ_v^0) of L-Glutamic acid solution at 0.01m, 0.03m and 0.05m of the aqueous IL solutions at 293K(Series1), 303K(Series2) and 313K(Series3)

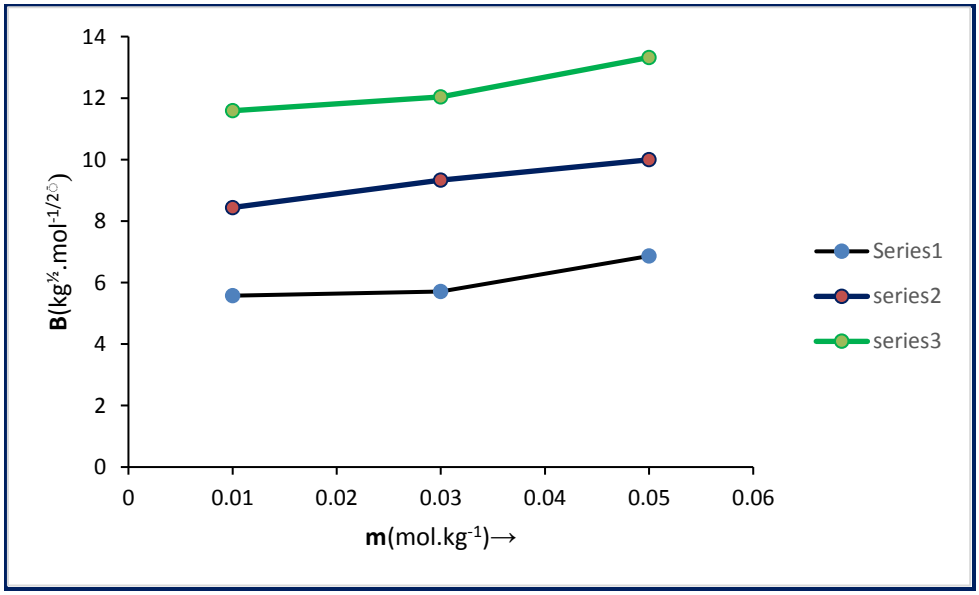


Figure 2(a) Variation of B values of L-Aspartic acid against 0.01m IL, 0.03m IL and 0.05m IL solutions at 293K(Series1), 303K(Series2) and 313K(Series3)

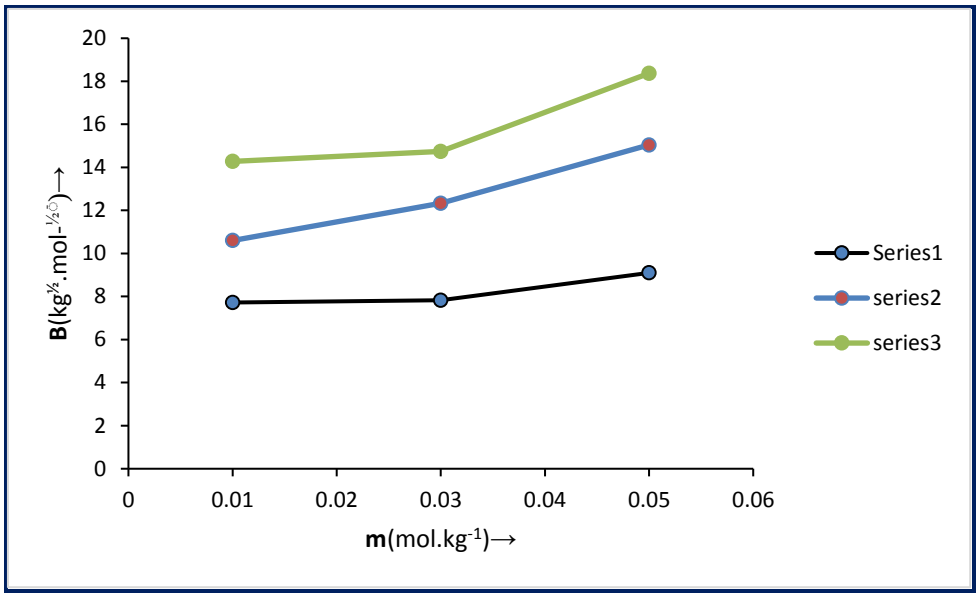


Figure 2(b). Variation of B values of L-Glutamic acid against 0.01m IL, 0.03m IL and 0.05m IL solutions at 293K(Series1), 303K(Series2) and 313K(Series3)

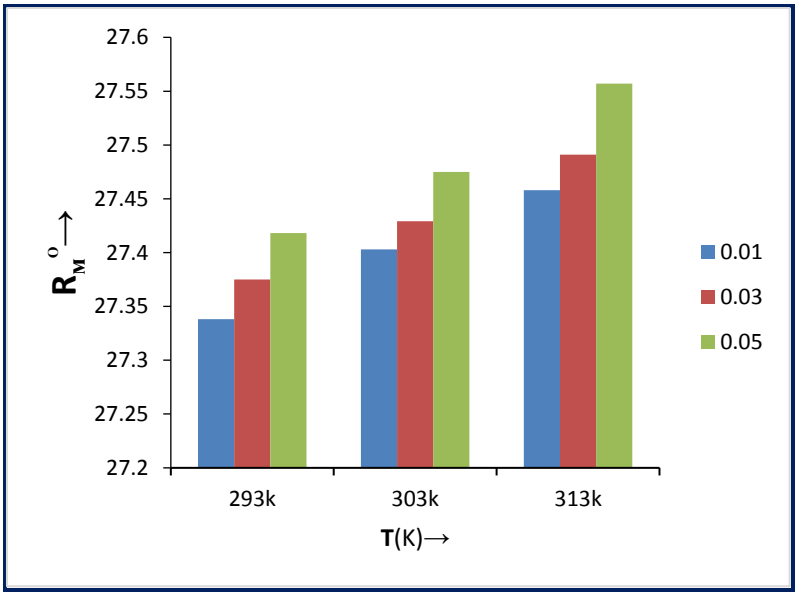


Figure 3(a). Variation of R_M^0 values of L-Aspartic acid solution against 293K, 303K and 313K in aqueous solution of IL at 0.01m(Series1), 0.03m(Series2) and 0.05m(Series3)

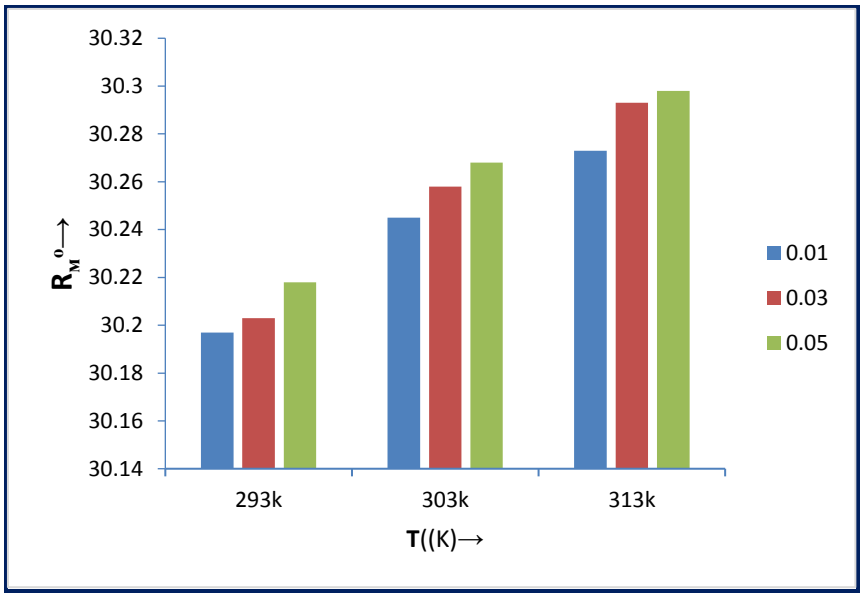


Figure 3(b). Variation of R_M^0 values of L-Glutamic acid solution against 293K, 303K and 313K in aqueous solution of IL at 0.01m (Series1), 0.03m(Series2) and 0.05m(Series3).

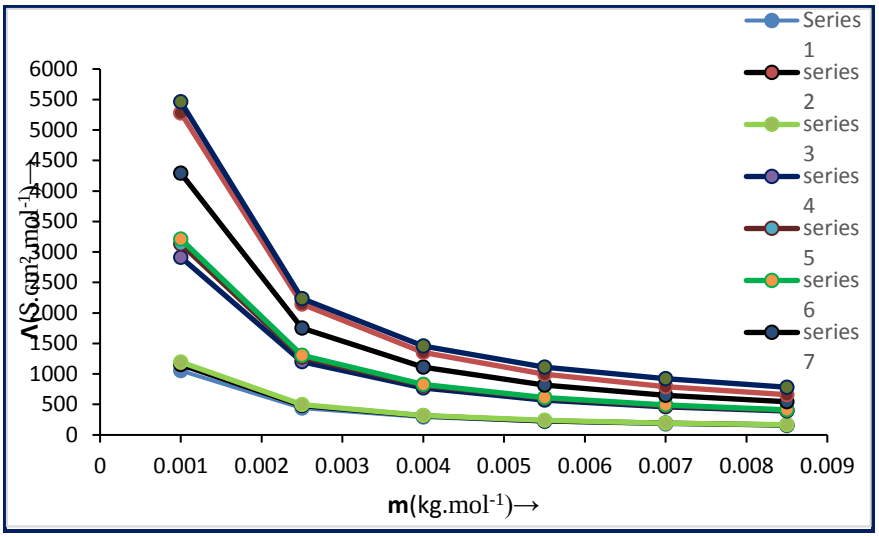


Figure 4(a). Variation of molar conductance (Λ) with different concentrations of L–Aspartic acid in aqueous (0.01m,0.03m,0.05m) BTAC (IL) solution at 293K, 303K, 313K 0.01m at 293K (Series1), 0.01m at 303K (Series2), 0.01m at 313K (Series3)0.03m at 293K (Series4), 0.03m at 303K (Series5), 0.03m at 313K (Series6)0.05m at 293K (Series7), 0.05m at 303K(Series8), 0.05m at 313K(Series9)

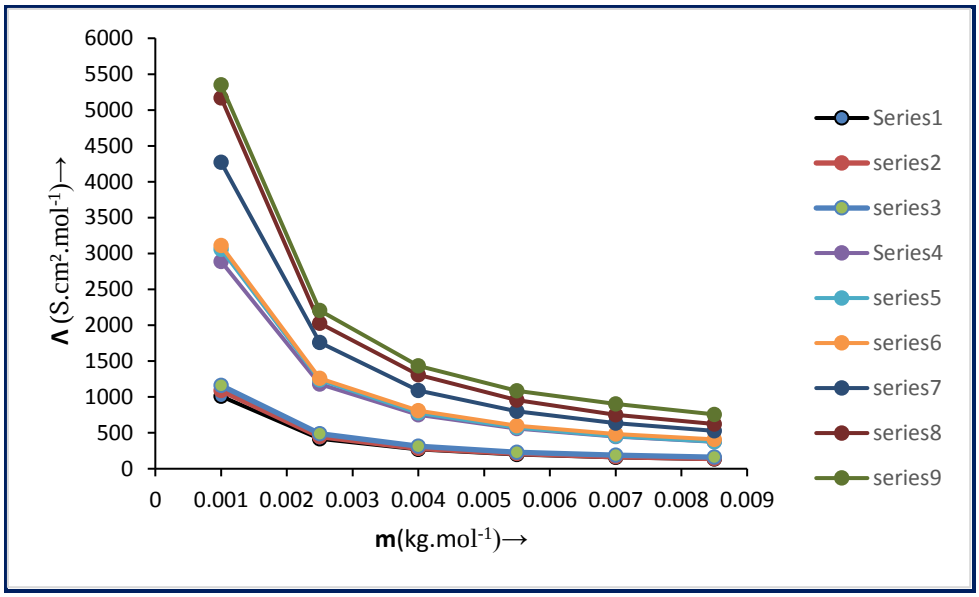
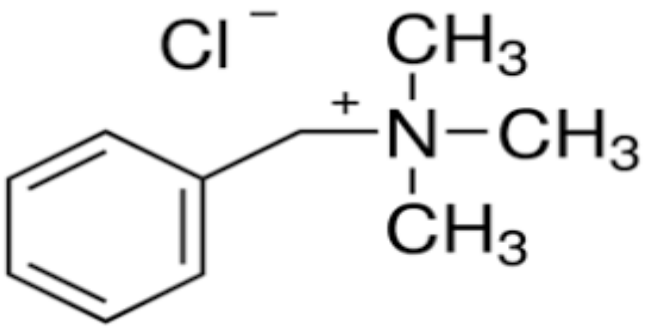
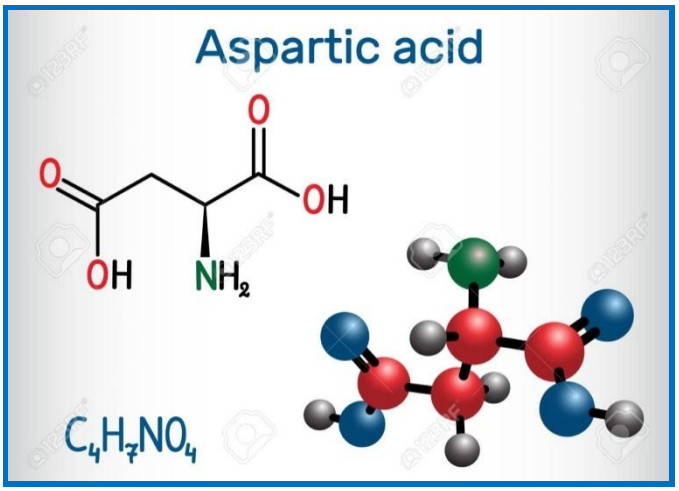


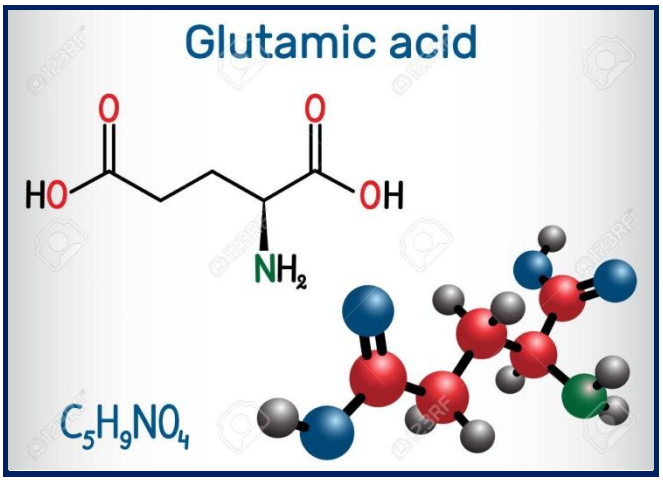
Figure 4(b). Variation of molar conductance (Λ) with different concentrations of L–Glutamic acid in aqueous (0.01m,0.03m,0.05m) BTAC (IL) solution at 293K, 303K, 313K 0.01m at 293K(Series1), 0.01m at 303K(Series2), 0.01m at 313K(Series3)0.03m at 293K(Series4), 0.03m at 303K(Series5), 0.03m at 313K(Series6)0.05m at 293K(Series7), 0.05m at 303K(Series8), 0.05m at 313K(Series9)

SCHEMES:



Benzyl tri methyl ammonium chloride





Scheme 1. Molecular structure of ionic liquid and amino acid