INTRODUCTION

Ultrasonic studies and their related thermodynamic properties have been extensively used to study physico-chemical behavior and molecular interactions in a variety of liquid mixtures and electrolytes\(^1\)-\(^3\). Amino acids are the fundamental structural units of proteins. It plays an important role both in animal metabolism and an industrial process. Study of these model compounds (amino acids) in aqueous electrolytic solutions provide information which can be of great help in understanding the effects of electrolytes on biomolecules\(^4\)-\(^7\).

Tetraalkylammonium salts are bulky in nature and are known to orient water molecules around them depending on their alkyl chain. It is of great interest to study electrolytes like tetraethylammonium bromide \((\text{C}_2\text{H}_5)_4\text{NBr}\) due to some properties of the salt solutions apparently caused by their large size and alkyl chain water interaction. They show a variety of physical, chemical and biological properties and most compounds are soluble in water and strong electrolytes. These compounds are used as solvents, intermediates and phase transfer catalysts. Thus keeping these considerations various parameters like apparent molar volume \((\varphi_a)\), limiting molar volume \((\bar{\varphi}_a)\), apparent molar compressibility \((\varphi_c)\), limiting molar compressibility \((\bar{\varphi}_c)\), and their constants \((\bar{S}_a, \bar{S}_c)\) and transfer volume \((\Delta \bar{\varphi}_c^2)\) are computed from the experimental density \((\rho)\), viscosity \((\eta)\) and ultrasonic velocity \((U)\) of L-threonine, L-leucine and L-histidine in water and aqueous tetraethylammonium bromide (0, 0.05 and 0.1 mol×dm\(^{-3}\)) have been measured at 303.15K. These measurements have been used to calculate some important parameters viz., adiabatic compressibility \((\beta)\), molar hydration number \((n_h)\), apparent molar compressibility \((\varphi_c)\), apparent molar volume \((\varphi_v)\), limiting apparent molar compressibility \((\bar{\varphi}_c)\) and their constants \((\bar{S}_a, \bar{S}_c)\) and transfer volume \((\Delta \varphi_v^2)\). The viscosity data have been analysed on the basis of the Jones-Dole equation, the viscosity A and B coefficients have been evaluated. The variation of these parameters with concentrations clearly suggests the role of alkyl cation on the ion-solvent interactions in aqueous medium. The structural influence of the large cations of quaternary ammonium salts upon solvent is also taken into consideration.

**Keywords:** Amino acids, tetraethylammonium bromide, apparent molar volume, apparent molar compressibility and transfer volume.
histidine data. The viscosity A and B coefficients were calculated by using Jones-Dole equations and split into contributions from the Zwitterionic end group (NH₂⁺, COO⁻) and the methylene groups (CH₂) of the amino acids using their linear variation with the number of carbon atoms in the alkyl chain of amino acids in aqueous (C₄H₉)₄ NBr at T=303.15K. All these parameters are interpreted to study the intermolecular interactions occurring between the various components of the ternary mixtures.

EXPERIMENTAL

Analytical reagent (AR) grade and spectroscopic reagent (SR) grade with minimum assay of 99.9% of L-threonine, L-leucine, L-histidine and tetraethylammonium bromide were obtained from E-Merck, Germany and SdFine chemicals, India, which were used as such without further purification. Water used in the experiment was deionised, distilled and was degassed prior to making solutions. Aqueous solutions of tetraethylammonium bromide (0, 0.05, 0.1 mol dm⁻³) were prepared by volume and used on the day they were prepared. Solution of amino acids in the concentration range of 0.02-0.1 mol dm⁻³ were made by volume on the molarity concentration scale with precision of ± 1 × 10⁻⁴ g on an electronic digital balance (Model: SHIMADZU AX-200). The density was determined using a specific gravity bottle by relative measurement method with an accuracy of ± 0.01 kg m⁻³. An Ostwald’s viscometer (10 ml) was used for the viscosity measurement. Efflux time was determined using a digital chronometer to within ±0.01 s. An ultrasonic interferometer having the frequency of 3 MHz (Mittal Enterprises, New Delhi, Model: F-81) with an overall accuracy of ± 0.1% has been used for velocity measurement. An electronically digital operated constant temperature bath (RAAGA Industries) has been used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. The accuracy in the temperature measurement is ± 0.1 K.

Theory

Using the measured data, the following volumetric, compressibility and transport parameters have been calculated using the standard relations.

Adiabatic Compressibility

\[ \beta = \frac{1}{U^2 \rho} \]  

(1)

Molar hydration number has been computed using the relation

\[ n_H = \left( \frac{n_1}{n_2} \right) \left[ 1 - \frac{\beta}{\beta_0} \right] \]  

(2)

where \( \beta \) and \( \beta_0 \) are adiabatic compressibility of solution and solvent respectively, \( n_1 \) and \( n_2 \) are number of moles of solvent and solute, respectively.

The apparent molar compressibility has been calculated from relation

\[ \varphi_K = \frac{1000}{m \rho_0} \left( \rho_0 \beta - \rho \beta_0 \right) + \left( \frac{\beta_0 M}{\rho_0} \right) \]  

(3)

where \( \beta_0 \) and \( \rho_0 \) are the adiabatic compressibility and density of solution and solvent respectively and \( m \) is the molar concentration of the solute, and \( M \) the molecular mass of the solute. \( \varphi_K \) is the function obtained by Gucker from Debye Huckel theory and is given by

\[ \varphi_K = \varphi_K^0 + S_K m^\alpha \]  

(4)

where \( \varphi_K^0 \) is the limiting apparent molar compressibility at infinite dilution and \( S_K \) is a constant. \( \varphi_K^0 \) and \( S_K \) of equation (4) have been evaluated by the least square method.

The apparent molar volume \( \varphi_V \) has been calculated using the relation.

\[ \varphi_V = \frac{M}{\rho} - \frac{1000}{m \rho_0} \left( \rho - \rho_0 \right) \]  

(5)

The apparent molar volume \( \varphi_V \) has been found to differ with concentration according to empirical relation as
\[ \varphi_v = \varphi_v^0 + S_v m^5 \]  

...(6)

where \( \varphi_v^0 \) is the limiting apparent molar volume at infinite dilution and \( S_v \) is a constant and these values were determined by least square method. Transfer volumes \( (\Delta \varphi_v^0) \) of each amino acid from water to aqueous tetraethylammonium bromide solutions have been calculated by the equation

\[ \Delta \varphi_v^0 = \varphi_v^0 \text{ (in aqueous tetraethylammonium bromide solution)} - \varphi_v^0 \text{ (in water)} \]  

...(7)

The viscosity A and B coefficients for the amino acids in aqueous tetraethylammonium bromide solutions were calculated from the Jones-Dole equation\(^8\&12\).

\[ \eta = \eta_0 + A m^B + B m \]  

...(8)

where, \( \eta \) and \( \eta_0 \) are the viscosities of the solution and solvent respectively and \( m \) is the molar concentration of the solute. A is determined by the ionic attraction theory of Falkenhagen-Vernon and therefore also called Falkenhagen coefficient\(^12\), B or Jones-Dole coefficient is an empirical constant determined by ion-solvent interactions.

**RESULTS AND DISCUSSION**

The experimental values of density (\( \rho \)), viscosity (\( \eta \)) and ultrasonic velocity (\( U \)), for different molarity of each of the three amino acids viz., L-threonine, L-leucine and L-histidine in water + tetraethylammonium bromide mixtures (0, 0.05 and 0.1 mol.dm\(^{-3}\)) at 303.15K are shown in Table-1. The values of adiabatic compressibility (\( b \)), molar hydration number (\( n_H \)), apparent molar compressibility (\( \varphi_x \)) and apparent molar volume

| Molarity (mol dm\(^{-3}\)) | ρ/(kg m\(^{-3}\)) | η/(×10\(^{-3}\) Nsm\(^{-2}\)) | U/(m.s\(^{-1}\)) |
|-----------------------------|------------------|-----------------------------|-----------------|
|                             | 0.0 M            | 0.05 M                      | 0.1 M           | 0.0 M | 0.05 M | 0.1 M | 0.0 M | 0.05 M | 0.1 M |
| System-I : water + tetraethylammonium bromide + L-threonine |
| 0.00                        | 995.7            | 998.2                       | 1001.0          | 0.7997| 0.8007| 0.8025| 1510.2| 1518.5| 1521.3|
| 0.02                        | 996.8            | 1001.1                      | 1004.5          | 0.8001| 0.8010| 0.8110| 1514.2| 1522.4| 1529.3|
| 0.04                        | 1000.1           | 1002.0                      | 1006.3          | 0.8020| 0.8067| 0.8270| 1519.2| 1529.2| 1536.5|
| 0.06                        | 1001.0           | 1003.6                      | 1007.8          | 0.8038| 0.8204| 0.8397| 1525.3| 1538.4| 1541.8|
| 0.08                        | 1003.4           | 1004.7                      | 1009.3          | 0.8056| 0.8246| 0.8758| 1532.1| 1541.4| 1546.9|
| 0.10                        | 1004.3           | 1007.1                      | 1011.3          | 0.8090| 0.8484| 0.8842| 1543.6| 1548.6| 1554.7|

System-II : water + tetraethylammonium bromide + L-leucine

|                              | 0.00              | 995.7                        | 998.2           | 1001.0 | 0.7997| 0.8007| 0.8025| 1510.2| 1518.5| 1521.3|
|                              | 0.02              | 997.7                        | 999.2           | 1002.0 | 0.8017| 0.8029| 0.8348| 1517.2| 1526.7| 1531.9|
|                              | 0.04              | 998.2                        | 1000.3          | 1004.8 | 0.8168| 0.8214| 0.8358| 1521.3| 1537.4| 1539.7|
|                              | 0.06              | 1000.1                       | 1001.3          | 1006.3 | 0.8250| 0.8263| 0.8594| 1527.8| 1541.3| 1544.8|
|                              | 0.08              | 1001.2                       | 1002.6          | 1007.8 | 0.8302| 0.8466| 0.8846| 1538.8| 1545.6| 1550.6|
|                              | 0.10              | 1003.0                       | 1005.6          | 1009.3 | 0.8460| 0.8545| 0.8972| 1545.3| 1551.3| 1562.8|

System-III : water + tetraethylammonium bromide + L-histidine

|                              | 0.00              | 995.7                        | 998.2           | 1001.0 | 0.7997| 0.8007| 0.8025| 1510.2| 1518.5| 1521.3|
|                              | 0.02              | 996.8                        | 999.6           | 1002.9 | 0.8211| 0.8411| 0.8763| 1519.7| 1528.5| 1540.4|
|                              | 0.04              | 997.5                        | 1000.6          | 1004.5 | 0.8416| 0.8618| 0.8811| 1524.6| 1542.4| 1551.2|
|                              | 0.06              | 998.6                        | 1002.7          | 1005.8 | 0.8712| 0.8814| 0.8909| 1529.8| 1548.7| 1562.8|
|                              | 0.08              | 1000.3                       | 1004.4          | 1006.7 | 0.8842| 0.8968| 0.8978| 1541.6| 1553.4| 1571.7|
|                              | 0.10              | 1001.5                       | 1005.2          | 1007.8 | 0.8988| 0.9001| 0.9041| 1546.3| 1562.1| 1579.0|
( ), limiting apparent molar compressibility ( ) and limiting apparent molar volume ( ) and their constants ( , ), transfer volume ( ) and viscosity A and B coefficients of Jones-Dole equation are given in Table 2 4.

The results of Table-1 reveal that the values of density ( ) and ultrasonic velocity ( ) increases with the increasing concentration of amino acids and tetraethylammonium bromide mixtures. This increasing value shows a strong electrolytic nature in which the interactions are caused by the proton transfer reactions of amino acids in water and tetraethylammonium bromide mixtures.

From Table-2, it is observed that the values of adiabatic compressibility decreases with the increases in molarity of amino acids and tetraethylammonium bromide content in the mixtures. The adiabatic compressibility values are larger in L-threonine compared to L-leucine, L-histidine which shows molecular interaction is greater in L-threonine than that of other two amino acids. Hydration is due to interaction between solute and water molecules. From the Table-2 the values of ( ) are positive in all systems and is found to increase with increasing the content of solutes. This increasing trend suggests that tetraethylammonium bromide has a hydration effect on all three amino acids.

The values of and (Table 3) are all negative over the entire range of molarity and these values are increases with the increasing of amino acid but however it found to be decrease with increasing the concentration of tetraethylammonium bromide. The magnitude of is in order: L-

| Molarity M/(mol dm⁻³) | β/× 10⁻¹⁰ m² N⁻¹ | η_H |
|-----------------------|------------------|-----|
|                      | Water + tetraethylammonium bromide |      |      |
|                      | 0.0 M | 0.05 M | 0.1 M | 0.0 M | 0.05 M | 0.1 M |
| System-I: water + tetraethylammonium bromide + L-threonine | | | | | | |
| 0.00 | 4.4035 | 4.3446 | 4.3165 | - | - | - |
| 0.02 | 4.3675 | 4.3141 | 4.2566 | 22.80 | 18.40 | 31.55 |
| 0.04 | 4.3289 | 4.2677 | 4.2092 | 22.37 | 17.25 | 28.18 |
| 0.06 | 4.2939 | 4.2101 | 4.1741 | 23.02 | 26.62 | 24.93 |
| 0.08 | 4.2457 | 4.1892 | 4.1405 | 25.24 | 22.27 | 23.14 |
| 0.10 | 4.1789 | 4.1404 | 4.0909 | 28.30 | 23.45 | 23.66 |
| System-II: water + tetraethylammonium bromide + L-leucine | | | | | | |
| 0.00 | 4.4035 | 4.3446 | 4.3165 | - | - | - |
| 0.02 | 4.3542 | 4.2937 | 4.2502 | 31.00 | 29.17 | 34.75 |
| 0.04 | 4.3286 | 4.2295 | 4.1980 | 23.62 | 33.13 | 31.22 |
| 0.06 | 4.2837 | 4.2028 | 4.1641 | 25.20 | 27.19 | 26.72 |
| 0.08 | 4.2180 | 4.1752 | 4.1269 | 29.24 | 24.31 | 24.91 |
| 0.10 | 4.1751 | 4.1323 | 4.0567 | 28.88 | 24.39 | 38.21 |
| System-III: water + tetraethylammonium bromide + L-histidine | | | | | | |
| 0.00 | 4.4035 | 4.3446 | 4.3165 | - | - | - |
| 0.02 | 4.3438 | 4.2819 | 4.2021 | 37.64 | 36.01 | 60.08 |
| 0.04 | 4.3129 | 4.2009 | 4.1372 | 28.54 | 41.26 | 47.07 |
| 0.06 | 4.2789 | 4.1580 | 4.0708 | 26.23 | 35.81 | 43.11 |
| 0.08 | 4.2065 | 4.1259 | 4.0212 | 31.06 | 31.43 | 38.89 |
| 0.10 | 4.1760 | 4.0768 | 3.9798 | 28.67 | 30.76 | 35.40 |
threonine < L–leucine < L–histidine. The negative values of \( \beta \) and \( \phi \) in all system indicate the presence of ion-solvent interaction. The negative values of indicate hydrophilic and ionic interaction occurring in these system\(^{12}\). The negative values of indicate electrostrictive solvation of ions\(^{13}\). The increasing

### Table 3: Values of adiabatic compressibility (\( \beta \)), apparent molar compressibility (\( \phi \)) and apparent molar volume (\( \psi \)) of amino acids in aqueous tetraethylammonium bromide solutions at 303.15K for

| Molarity | \( \phi_k (\times 10^{-7} \text{ m}^2 \text{ N}^{-1}) \) | \( \phi_v (\times 10^{-3} \text{ m}^3 \text{ mol}^{-1}) \) |
|----------|---------------------------------|---------------------------------|
| M/(mol dm\(^{-3}\)) | Water + tetraethylammonium bromide | Water + tetraethylammonium bromide |
| 0.02 | 2.4412 | 1.9385 |
| 0.04 | 2.3515 | 1.9085 |
| 0.06 | 2.2173 | 2.7117 |
| 0.08 | 2.3982 | 2.3244 |
| 0.1 | 2.6263 | 2.4294 |

System-I: water + tetraethylammonium bromide + L-threonine

| Molarity | \( \phi_k (\times 10^{-7} \text{ m}^2 \text{ N}^{-1}) \) | \( \phi_v (\times 10^{-3} \text{ m}^3 \text{ mol}^{-1}) \) |
|----------|---------------------------------|---------------------------------|
| 0.02 | 2.9072 | 2.7626 |
| 0.04 | 2.1489 | 3.1060 |
| 0.06 | 2.3210 | 2.5882 |
| 0.08 | 2.5675 | 2.3569 |
| 0.1 | 2.6068 | 2.4461 |

System-II: water + tetraethylammonium bromide + L-leucine

| Molarity | \( \phi_k (\times 10^{-7} \text{ m}^2 \text{ N}^{-1}) \) | \( \phi_v (\times 10^{-3} \text{ m}^3 \text{ mol}^{-1}) \) |
|----------|---------------------------------|---------------------------------|
| 0.02 | 3.1282 | 3.4396 |
| 0.04 | 2.4640 | 3.8536 |
| 0.06 | 2.2904 | 3.4364 |
| 0.08 | 2.7168 | 3.0874 |
| 0.1 | 2.5315 | 2.9827 |

System-III: water + tetraethylammonium bromide + L-histidine

### Table 4: Values of limiting apparent molar compressibility(\( \psi \)), limiting apparent molar volume (\( \phi \)) and their constants \( S_k \) and \( S_v \), transfer volumes(\( \Delta \phi \)) and A and B coefficients of Jones-Dole equation of amino acids in aqueous tetraethylammonium bromide solution at 303.15K for

| Amino acids | Molarity (M/mol dm\(^{-3}\)) | \( \phi_k (\times 10^{-7} \text{ m}^2 \text{ N}^{-1}) \) | \( \phi_v (\times 10^{-3} \text{ m}^3 \text{ mol}^{-1}) \) | \( s_l (\times 10^{-3} \text{ m}^3 \text{ mol}^{-1}) \) | \( l (\times 10^{-3} \text{ m}^3 \text{ L}^{-1/2} \text{ mol}^{-3/2}) \) | \( A (\text{dm}^3 \text{ mol}^{-1/2}) \) | \( B (\text{dm}^3 \text{ mol}^{-1}) \) |
|-------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| L-threonine | 0 | -2.02 | -181.91 | -1.72 | -323.09 | ... | 0.1228 | 1.4324 |
| 0.05 | -1.47 | -103.96 | -3.27 | -68.22 | 77.95 | 0.1452 | 1.3260 |
| 0.1 | -4.58 | -140.92 | -6.49 | -415.80 | 40.99 | 0.1483 | 1.5215 |
| L-leucine | 0 | -2.69 | -106.28 | -7.09 | -128.20 | ... | 0.1456 | 1.2032 |
| 0.05 | -3.35 | -41.60 | -2.99 | -62.54 | 64.46 | 0.4356 | 1.1046 |
| 0.1 | -4.44 | -45.94 | -5.22 | -140.73 | 60.12 | 0.1340 | 0.7132 |
| L-histidine | 0 | -3.23 | -47.13 | -2.54 | -19.21 | ... | 0.0285 | 1.2138 |
| 0.05 | -11.51 | -2.89 | -34.4 | -0.15 | 44.24 | 0.1013 | 1.0358 |
| 0.1 | -22.29 | -32.51 | -7.08 | -136.08 | 14.62 | 0.3753 | 0.1845 |
behaviour of suggests the existence of strong ion-ion interaction in all system studied. Tetraethylammoniumbromide are known to orient water molecules around them to the penetration of solute molecules into the solvent is highly achieved. From the magnitude of it can be concluded that the strong molecular association is found in L-threonine than that of other two amino acids and so L-threonine is an effective structure maker.

The limiting apparent molar compressibility provides information about ion solvent interactions and \( S_v \) about ion-ion interactions in the solution. From Table–4 values are negative and it decreases with increasing the concentration of tetraethylammonium bromide in all systems studied. Appreciable negative value of for all system reinforce our earlier view that existence of ion-solvent interactions. The magnitude of is in the order of L-threonine > L-leucine > L-histidine. The values of exhibits negative and it decreases with increase of tetraethylammonium bromide in all the three amino acids. It is well known that solutes causing electrostriction lead to decrease in the compressibility of the solution.

The values of \( S_v \) provides information about ion-solvent interaction. The \( S_v \) values are reported in

Table-4 are negative and increases with increase in concentration of tetraethylammonium bromide suggesting the stronger ion-solvent interactions. This is due to larger voids created by \((\text{C}_2\text{H}_5)_4\text{N}\text{Br}\) there by allowing better accommodation of small amino acids molecules in the voids. The magnitude of is in order L-threonine < L-leucine < L-histidine. Further the values of are negative which indicate the presence of strong ion-ion interaction and less complex ion formation taking place in the ternary mixtures. In general, the interactions between the amino acid and tetraethylammonium bromide can be classified into:

- ion-ion interactions between Zwitter ions \((\text{NH}_3^+\text{and COO}^-)\) of amino acids and cations \((\text{R}_4\text{N}^+)\), anion \((\text{Br}^-)\) of \(\text{R}_4\text{NBr}\);
- ion-ion polar group interactions between \((\text{R}_4\text{N}^+)\text{Br}^-\) and the hydrophobic side chain of amino acids;
- ion – non polar group interactions between \((\text{NH}_3^+\text{COO}^-)\) and the hydrophobic side chain \((\text{R}_4^-)\) of the electrolytes; and
- non-polar – non-polar group interactions between the hydrophobic side of amino acids and those of tetraethylammonium bromide.

Similar types of interactions were also suggested by Ali et al. The \( \Delta \phi \) values (Table-4) can also explained on the basis of co-sphere overlap model in terms of solute-co-solute interactions. According to this model, ion-ion interaction contributes positively, where as ion-non-polar group
interactions, contribute negatively to the $\Delta \phi^\text{L}_{\text{p}}$ values. Therefore from Figure-1, the positive values observed for L-threonine, L-leucine and L-histidine suggest that the interaction contribution of type (i) is stronger than that of type (ii), (iii) and (iv).

Table-4 shows that the values of A and B co-efficient are positive in all system studied. The values of the B co-efficient are decreases with increasing the content of tetraethylammonium bromide in all the three amino acid mixture. The observed positive values of A coefficient shows the existence of ion-ion interaction. B–coefficient is a measure of ion solvent interaction and it reveals the structural effects of the solute and solvent molecules. The positive B-coefficients are larger than A coefficient supporting the behaviour of $\phi^\text{L}_{\text{p}}$ and $\phi^\text{L}_{\text{VS}}$ respectively and both suggesting stronger ion-solvent interaction as compared to ion-ion interactions.

The magnitude of B values are in the order of L-threonine > L-leucine > L-histidine. The larger values of B indicate structure making capacity of the solute. The decreasing behaviour of B coefficient with increasing concentration of tetraethylammonium bromide shows the structure breaking effect.

**CONCLUSION**

In summary, $\phi^\text{L}_{\text{p}}$, $\phi^\text{L}_{\text{VS}}$ and viscosity B-coefficient values for L–threonine, L-leucine and L-histidine in aqueous tetraethylammonium bromide solution at 303.15K indicate the presence of strong ion-solvent interactions and these interaction are weakened with increasing molarity of tetraethylammonium bromide in the ternary mixtures. But from the magnitude of A and B coefficient, it can be inferred that L–threonine possess greater ion-solvent interaction than the other two amino acids. Further, transfer volume data suggest the predominance of ion-ion interactions over ion-non-polar interaction.

**REFERENCES**

1. Chauhan S., Syal V.K. and Chauhan M. S. Ultrasonic studies in binary solvent mixtures at different temperatures. *Indian J. Pure & Appl Phys.*, 33: 92-94 (1995).
2. Das Bijan, Roy Mahendra Nath and Hazzra Dilip K. Ionic dissociation of some lithium1,1,2-Dimethoxymethylene Raman spectroscopic and conductometric study *Indian J. Chem. Technol.*, 93 (1994).
3. Patel K.J, Jadhav S.G., Panwar R.B and Bhand M.D. *Indian J. Chem. A36* (1997).
4. Bolen D. W. and M. Yang. Effects of guanidine hydrochloride on the proton inventory of proteins: implications on interpretations of protein stability *Biochemistry*, 39(49), 15208-15216 (2001).
5. Tamura Y, K Gekko Compactness of thermally and chemically denatured ribonuclease A as revealed by volume and compressibility *Biochemistry*, 34(6): 1878-1884 (1995).
6. Hagihara Y., Aimoto S., Fink A. L., Goto Y. Guanidine hydrochloride-induced folding of Proteins *Journal of Molecular Biology*, 231(2): 180-184 (1993).
7. Makhatadze G.J., P.L.Privalov, *J.Mol.Bio.* 1226: 491-505 (1992); Jones G., M. Dole, *J.Am.Chem Soc.* 51: 2950-2964 (1929).
8. Jones, G and M.Dole The viscosity of aqueous solutions of strong electrolytes with special references to barium chloride *J.Am 2, Chem.Soc.*, 51, 2950-2964 (1929).
9. Gucker, F.T., The apparent and molal heat capacity, volume and compressibility of electrolytes, *Chem Rev.*, 13, 111-130 (1933).
10. Debye P, and  Hucelk E. Theory of electrolytes II, The limiting law of electrical conductivity *Physics Z*, 24 305-311 (1923).
11. Masson, D.O Solute molecular volumes in relation to solvation and ionisation 4, *Philos 8*: 218 (1929).
12. Pandey, J.D., K.Misra, A.Shukla, V.Mushram and R.D.Rai, Apparent molar volume, Apparent molar compressibility, verification
of Jones-Dole equation and thermodynamic studies of aqueous water and its derivatives, *Thermochemica Acta*, **117**: 245-259 (1987).

13. Dhanalakshmi and E. Jasmine Vasantharani, analysis of apparent molal volume and apparent molal compressibility of quartenary ammonium salts in non aqueous medium, *J. Pure Appl. Ultrasonic* **21**: 79 ISSN 0256-4637 (1999).

14. Anwar Ali, Shahla Khan, Soghra Hyder, Mohd Taviq Interactions of some α-amino acids with tetraethylammonium bromide in aqueous medium at different temperatures, *J. Chem. Thermodynamics*, **39**: 613-620 (2007).

15. Gurney, R.W., Ionic process in solution, 3, Mc.Graw Hill New York (Chapter.1) (1953).

16. Jahagirdar, D.V., B.R. Arbad, Smt. C.S. Patil and A.G. Shankarwar Studies in acoustic properties partial molal volumes, viscosity B-coefficients of lithium chloride in aqueous medium at five different temperature, *Indian Journal of Pure and Applied Physics*, **38**: 645-650 (2000).