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INTERMOLECULAR INTER-IONIC INTERACTIONS OF L-ISOLEUCINE, L-PROLINE AND L-GLUTAMINE WITH K_2SO_4 AT DIFFERENT TEMPERATURES RANGING FROM 303.15 K - 323.15 K

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ABSTRACT

Ultrasonic velocity and density values have been measured for ternary systems (amino acid + salt + water): L-isoleucine, L-proline and L-glutamine in aqueous 0.5M K_2SO_4 solution used as solvent for several concentrations of amino acids at different temperatures in the range of 303.15 to 323.15K. The ultrasonic velocity values have been found to increase with increase in amino acid concentration and temperature in all the systems. The increase in ultrasound velocity with increase in concentration has been discussed in terms of electrostatic interactions occurring between terminal groups of zwitter-ions (NH^{4+} and COO^-) and K^+, $SO4^{-2}$ ions. The interactions of water dipoles with cations/anions and with zwitter-ions have also been taken into consideration. It has been observed that the ion-zwitter-ion and ion-dipole attractive forces are stronger than those of ion-hydrophobic repulsive forces.

***KEYWORDS*: Intermolecular/Interionic Interactions, L-isoleucine, L-proline, L-glutamine, K_2SO_4**

I. INTRODUCTION

As amino acids and peptides are the building blocks of the proteins, their study provides important information, which can be related to the behaviour of larger biomolecules such as proteins. Thermodynamic properties of these model compounds provide valuable information about solute-solvent and solute-solute interactions, which in turn may help to understand several biochemical processes such as protein hydration, denaturation, aggregation etc. [1-20]. In aqueous medium, amino acids exist essentially as dipolar ions manifesting a unique hydration behaviour, which appears to be subtly linked to the vital biological phenomenon. Because of such subtle linkage, studies of hydration behaviour of amino acids and peptides in different media are also considered of significance in unfolding the role of dipolar ions in the living phenomenon. Moreover,

amino acids are important food additives and have many applications in the pharmaceutical industries, whereas peptides are widely used in drug production that is a result of their ability to act as hormones and their role as signal transmitters in cell communication [21,22].

A literature survey reveals that few attempts [23-28] have been made to evaluate isothermal compressibility (κ_T), for binary liquid mixtures. A number of authors [29-33] have determined the isothermal compressibility values for aqueous solutions of amino acids, peptides and proteins. The data has been discussed in terms of intermolecular/interionic interactions operative in the systems. The knowledge of isothermal compressibility and excess compressibility value may enable one to account for the extent and nature of interactions in mixtures [34, 35, 23, 24]. The excess compressibility values may further be used to evaluate theoretically the sound velocity which describes equilibrium as well as non-equilibrium properties [36].

The ultrasonic velocity and density data of solutions are employed to determine some important thermodynamic parameters such as isothermal compressibility (κ_T), internal pressure (P_i), solubility parameter (δ) and Pseudo-gruneisen parameter (Γ). These parameters impart interesting information about the various interactions operative in solutions.

In continuation of our previous work, [37] we report in this paper the measurements of density and ultrasonic velocity values for ternary systems (amino acid + salt + water): L-isoleucine/L-proline/L-glutamine + K_2SO_4 + water as functions of concentration of amino acid and temperature have been measured. Using the u and ρ data, the κ_T, $P_{i,}$, δ, and Γ values have been computed.

II.EXPERIMENTAL SECTION

The amino acids: L-isoleucine, L-proline and L-glutamine used in this work were obtained from SRL (India). The salt: potassium sulphate was purchased from E. Merck (India). All the chemicals were of ≥99% purity. The amino acids were dried at ~110^{o}C, kept in vacuum desiccator over P_2O_5 for several hours before use. The salts were recrystallized twice in triply distilled water, dried in a vacuum oven and then kept over P_2O_5 in a vacuum desiccator at room temperature for a minimum of 24 hours before use. All the solutions were made by weight using a balance having a resolution of ±0.1mg. Stock solution of 0.5M concentration of K_2SO_4 was prepared in triply distilled water and was used as solvent for the preparation of solutions. The specific conductivity of the water used was less than 18×10^{-6} $\Omega^{-1}cm^{-1}$. Solutions of amino acids of different molal concentration were prepared in aqueous solution of 0.5M K_2SO_4. An ultrasonic interferometer based on variable-path principle was used for the measurement of ultrasound velocity at a frequency of 4 MHz in the temperature range: 303.15 – 323.15K

by a method described elsewhere [38]. An average of 10 readings were taken as a final value of ultrasound velocity. Water from ultra-thermostat (Type U-10) was circulated through the brass jacket surrounding the cell and the quartz crystal. The jacket was well insulated and the temperature of the solution under study was maintained to an accuracy of $\pm 0.01^{o}$. The instrument was calibrated with the triple distilled water. The ultrasonic velocity values of water at different temperatures were taken from literature for calibration purpose [39]. The densities of solutions were measured by pyknometer using a method described elsewhere [38]. The densities of pure water at various required temperatures were taken from literature for calibration purpose [40]. Thermostated water/paraffin bath was maintained at a desired temperature ($\pm 0.01^{o}$) for about 30 minutes prior to recording of readings at each temperature of study. Several very close readings recorded at each temperature were averaged.

III.RESULTS AND DISCUSSION

Using the measured u and ρ values, the isothermal compressibility κ_{T1} and κ_{T2}, internal pressure (P_i), solubility parameter (δ), and Pseudo-gruneisen parameter (Γ), values have been computed employing the following relations:

Isothermal compressibility (κ_{T1}) $= 1.33x10^{-8}/(6.4x10^{-4}\ u^{3/2}\ \rho)^{3/2}$

…. .(1)

Isothermal compressibility (κ_{T2}) $= 17.1x10^{-4}/T^{4/9}\ u^{2}\ \rho^{1/3}$……..…….(2)

Internal pressure $P_i = (\alpha_T/\kappa_{T1}) - P$ ……..(3)

solubility parameter $\delta = (\alpha_T/\kappa_{T1})^{1/2}$……..(4)

Pseudo- gruneisen parameter $\Gamma = \gamma - 1/\alpha_T T$……..….(5)

The isothermal compressibility values have been computed using the McGowan's [41] expression, replacing the arbitrary constant in the denominator of McGowan's expression by a temperature term, Pandey et al. [42] suggested a relation for the evaluation of isothermal compressibility.

The experimentally measured density values (ρ) for L-isoleucine, L-proline and L-glutamine in aqueous 0.5M K_2SO_4 solution as functions of molal concentration and temperature (303.15, 308.15, 313.15, 318.15 and 323.15) have been listed in Table1.

Table- 1: Density values ($\rho/10^3$ kg m^{-3}) as functions of concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1.0593	1.0579	1.0561	1.0542	1.0519
0.0284	1.0597	1.0582	1.0564	1.0544	1.0521
0.0474	1.0600	1.0684	1.0565	1.0545	1.0522
0.0665	1.0603	1.0586	1.0567	1.0546	1.0523

0.0857	1.0605	1.0588	1.0569	1.0547	1.0524
0.1049	1.0608	1.0590	1.0570	1.0548	1.0525
0.1243	1.0611	1.0592	1.0571	1.0549	1.0526
0.1437	1.0613	1.0593	1.0573	1.0551	1.0527
0.1633	1.0617	1.0596	1.0575	1.0552	1.0528

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1.0593	1.0579	1.0561	1.0542	1.0519
0.0953	1.0606	1.0592	1.0576	1.0557	1.0534
0.2909	1.0658	1.0643	1.0626	1.0606	1.0584
0.4934	1.0709	1.0694	1.0677	1.0656	1.0633
0.7032	1.0760	1.0745	1.0727	1.0706	1.0683
0.9206	1.0812	1.0796	1.0777	1.0756	1.0733
1.1462	1.0863	1.0847	1.0827	1.0806	1.0782

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1.0593	1.0579	1.0561	1.0542	1.0519
0.0379	1.0604	1.0590	1.0573	1.0554	1.0532
0.0762	1.0622	1.0607	1.0590	1.0570	1.0548
0.1147	1.0640	1.0625	1.0607	1.0587	1.0565
0.1535	1.0659	1.0643	1.0624	1.0604	1.0581
0.1926	1.0677	1.0660	1.0641	1.0620	1.0597
0.2320	1.0695	1.0678	1.0658	1.0637	1.0614
0.2717	1.0714	1.0695	1.0675	1.0654	1.0630

The measured ultrasonic velocity values of L-isoleucine, L-proline and L-glutamine in the said aqueous electrolyte solution have been listed in Table 2.

Table-2: Ultrasonic velocity values (u/m. s^{-1}) as functions of concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1571.2	1578.8	1587.6	1592.6	1597.6

0.0284	1573.8	1580.4	1589.2	1593.6	1598.2
0.0474	1575.6	1582.0	1590.6	1595.2	1599.4
0.0665	1578.0	1584.8	1592.2	1596.4	1600.4
0.0857	1579.6	1587.7	1594.4	1598.4	1602.8
0.1049	1581.8	1590.7	1593.4	1596.2	1601.2
0.1243	1582.1	1591.7	1595.8	1600.4	1605.0
0.1437	1585.0	1592.0	1598.8	1604.4	1608.4
0.1633	1586.0	1593.8	1600.8	1605.7	1609.4

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1571.2	1578.8	1587.6	1592.6	1597.6
0.0953	1577.2	1585.2	1592.4	1597.2	1601.6
0.2909	1589.2	1596.4	1604.4	1608.6	1612.8
0.4934	1604.2	1611.4	1618.0	1622.4	1625.6
0.7032	1616.0	1621.4	1625.8	1630.4	1635.8
0.9206	1627.2	1631.2	1634.8	1640.2	1644.9
1.1462	1640.4	1644.4	1648.2	1651.8	1656.8

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	1571.2	1578.8	1587.6	1592.6	1597.6
0.0379	1574.0	1581.6	1588.6	1594.2	1598.8
0.0762	1576.4	1585.6	1591.2	1596.2	1601.4
0.1147	1581.0	1588.4	1594.8	1600.6	1605.6
0.1535	1583.2	1590.8	1598.4	1603.2	1607.4
0.1926	1585.4	1592.8	1600.0	1606.0	1610.0
0.2320	1588.6	1596.5	1604.4	1608.4	1613.6
0.2717	1592.2	1598.8	1605.0	1610.4	1614.0

The ultrasonic velocity values increase with increase in concentration of amino acids as well as with temperature in all the systems under investigation. The increase in ultrasonic velocity values with increase in concentration for all the systems is almost linear. This increase in ultrasonic velocity values in aqueous amino acids electrolyte solutions may be attributed to the overall increase of cohesion brought about by the solute-solute, solute-

solvent and solvent-solvent interactions in solutions. Amino acids in aqueous solutions essentially behave as zwitter-ions having NH_4^+ and COO^- groups at two ends of the molecule. The K^+, SO_4^{-2}, ions furnished by electrolyte interact electrostatically with NH_4^+ and COO^- groups of amino acid zwitter-ions. In addition, the water dipoles are strongly aligned to the cations/anions as well as to the amino acids zwitter-ions by electrostatic forces. These interactions comprehensively introduce the cohesion into solutions under investigation. The cohesive forces further enhanced on addition of solute molecules in solutions. The added amount of amino acids, zwitter- ions may also occupy the cavities of water clusters which may lead to the formation of denser structure of the aqueous electrolyte solution

The calculated κ_{T1} and κ_{T2} values have been listed in Tables 3 ad 4, respectively.

Table-3: Isothermal compressibility (κ_{T1} x 10^{12}, m^2N^{-1}) as functions of concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	48.48	48.05	47.57	47.36	47.10
0.0284	48.27	47.92	47.44	47.28	47.13
0.0474	48.12	47.80	47.34	47.17	47.05
0.0665	47.94	47.59	47.22	47.08	46.98
0.0857	47.82	47.25	47.06	46.94	46.81
0.1049	47.65	47.37	47.12	46.90	46.91
0.1243	47.60	47.22	46.96	46.80	46.65
0.1437	47.40	47.06	46.75	46.53	46.52
0.1633	47.30	46.99	46.60	46.43	46.42

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	48.48	48.05	47.57	47.36	47.19
0.0953	47.97	47.53	47.21	46.96	46.82
0.2909	46.82	46.44	46.03	45.89	45.82
0.4934	45.51	45.15	44.84	44.70	44.65
0.7032	44.45	44.21	44.05	43.90	43.72
0.9206	43.45	43.31	43.21	43.01	42.87
1.1462	42.37	42.23	42.13	42.04	41.90

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	48.48	48.05	47.57	47.36	47.19
0.0379	48.21	47.78	47.42	47,18	47.02
0.0762	47.92	47.40	47.14	46.94	46.74
0.1147	47.49	47.09	46.78	46.54	46.35
0.1535	47.21	46.81	46.44	46.25	46.13
0.1926	46.95	46.57	46.22	45.97	45.86
0.2320	46.62	46.21	45.83	45.71	45.52
0.2717	46.26	45.95	45.68	45.47	45.39

Table- 4: Isothermal compressibility (κ_{T2} x 10^{12}, m^2N^{-1}) as functions of concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	50.61	49.85	49.06	48.52	48.03
0.0284	50.42	49.73	48.94	48.45	47.98
0.0474	50.28	49.61	48.85	48.35	47.90
0.0665	50.11	49.43	48.74	48.27	47.84
0.0857	50.00	49.11	43.02	48.13	47.68
0.1049	49.84	49.22	48.64	48.27	47.77
0.1243	49.80	49.08	48.49	48.01	47.54
0.1437	49.61	48.94	48.30	47.76	47.33
0.1633	49.52	48.87	48.16	47.67	47.23

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	50.61	49.85	49.06	48.52	48.03
0.0953	50.14	49.36	48.67	48.15	47.70
0.2909	49.07	48.36	47.64	47.18	46.79
0.4934	47.85	47.17	46.55	46.09	45.72
0.7032	46.85	46.29	45.81	45.36	44.87
0.9206	45.91	45.45	45.03	44.54	44.10
1.1462	44.90	44.44	44.03	43.64	43.21

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	50.61	49.85	49.06	48.52	48.03
0.0379	50.36	49.60	48.92	48.35	47.87
0.0762	50.09	49.25	48.66	48.13	47.62
0.1147	49.69	48.96	48.33	47.77	47.27
0.1535	49.43	48.70	48.01	47.51	47.07
0.1926	49.18	48.48	47.81	47.25	46.83
0.2320	48.88	48.15	47.45	47.01	46.52
0.2717	48.54	47.91	47.32	46.79	46.40

The overall trend in the isothermal compressibility has been found to be decreasing with increase in concentration as well as in temperature. The decrease in κ_T values with increase in concentration seems to be the result of a corresponding decrease in free volume. If it is assumed that the size of the ion is not pressure dependent and the electrostricted water is already compressed to its maximum extent by the charge on the ions, the compressibility of a solution is mainly due to the effect of pressure on the bulk water molecules. As the concentration of the electrolyte increases and a large portion of water molecules are electrostricted, the amount of bulk water decreases causing the compressibility to decrease [43]. The decrease in the values of isothermal compressibility with an increase in temperature may be associated with the loss of water molecules around the ions. The calculated isothermal compressibility $\kappa_{T1,}$ values have been further used for evaluating the internal pressure, solubility parameter and Pseudo-gruneisen parameter. The Internal pressure values of the systems under study have been obtained using the equation [44].

The computed values of P_i are listed in Table 5.

Table- 5: Internal pressure ($P_i x10^{-9}$, Nm^{-2}) as functions of concentration and temperature

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	2.064	2.123	2.179	2.230	2.280
0.0284	2.134	2.188	2.249	2.297	2.346
0.0474	2.199	2.254	2.316	2.367	2.415
0.0665	2.266	2.324	2.385	2.435	2.484
0.0857	2.331	2.402	2.455	2.506	2.558
0.1049	2.399	2.457	2.515	2.562	2.618
0.1243	2.461	2.526	2.587	2.642	2.698
0.1437	2.531	2.596	2.661	2.722	2.777
0.1633	2.596	2.661	2.732	2.792	2.843

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	2.064	2.123	2.179	2.230	2.280
0.0953	1.966	2.020	1.986	2.118	2.162
0.2909	2.066	2.120	2.177	2.222	2.266
0.4934	2.177	2.234	2.289	2.338	2.382
0.7032	2.282	2.335	2.386	2.437	2.491
0.9206	2.388	2.439	2.488	2.544	2.598
1.1462	2.503	2.556	2.609	2.661	2.718

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	2.064	2.123	2.179	2.230	2.280
0.0379	2.016	2.070	2.123	2.172	2.219
0.0762	2.084	2.145	2.196	2.244	2.294
0.1147	2.160	2.217	2.272	2.325	2.375
0.1535	2.229	2.288	2.349	2.400	2.449
0.1926	2.359	2.421	2.483	2.542	2.593
0.2320	2.432	2.498	2.565	2.618	2.675
0.2717	2.508	2.571	2.633	2.693	2.746

An examination of tables reveals the overall trend in internal pressure has been found to be increasing with increase in temperature, which may apparently be attributed to a decrease in the repulsive forces among the components of the system. The change in concentration of the solution also brings about changes in internal pressure. The change may be attributed to the overall increase of cohesive forces in solutions. It is noteworthy that internal pressure has direct relevance in respect of the force of intermolecular interaction since it happens to be the outcome of such forces per unit area. The increase in the values of internal pressure is closely associated with the expansivity of the system with temperature, as a consequence of which the molecular/ionic species get closer to the extent envisaged by the expansivity of the investigated systems.

The solubility parameter (δ) is obtained by taking the square root of the internal pressure. The calculated values have been presented in Table 6.

Table-6: Solubility parameter, δ x 10^{-4}, $(Nm^{-2})^{1/2}$ as functions of concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol	Temperature (K)

kg^{-1})	303.15	308.15	313.15	318.15	323.15
0.0000	4.543	4.608	4.668	4.722	4.775
0.0284	4.619	4.677	4.743	4.793	4.844
0.0474	4.689	4.747	4.813	4.865	4.915
0.0665	4.761	4.821	4.883	4.934	4.984
0.0857	4.829	4.901	4.955	5.006	5.058
0.1047	4.898	4.957	5.015	5.062	5.117
0.1243	4.960	5.026	5.086	5.140	5.194
0.1437	5.031	5.095	5.159	5.217	5.270
0.1633	5.095	5.159	5.227	5.284	5.332

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	4.543	4.608	4.668	4.722	4.775
0.0953	4.434	4.495	4.456	4.602	4.650
0.2909	4.545	4.604	4.665	4.714	4.760
0.4934	4.666	4.726	4.784	4.835	4.881
0.7032	4.778	4.832	4.884	4.936	4.991
0.9206	4.886	4.938	4.988	5.044	5.097
1.1462	5.003	5.056	5.108	5.199	5.214

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	4.453	4.608	4.668	4.722	4.775
0.0379	4.490	4.550	4.608	4.661	4.710
0.0762	4.566	4.632	4.686	4.738	4.790
0.1147	4.648	4.709	4.766	4.822	4.874
0.1535	4.721	4.784	4.846	4.899	4.949
0.1926	4.857	4.920	4.983	5.041	5.092
0.2320	4.932	4.998	5.064	5.116	5.172
0.2717	5.008	5.070	5.131	5.189	5.240

These values have been found to increase in temperature. Such an increase may be attributed to an increase in the cohesive energy density. The trend of variation of δ with the said amino acid concentration and temperature is similar to that of internal pressure since it is the square root of P_i. There is also a significant change in solute concentration when the systems have been examined keenly at different temperatures.

The pseudo-gruneisen parameter (Γ), which happens to be a measure of the degree of molecular/ionic association has been evaluated where γ is the specific heat ratio obtained from the relation, $\gamma = C_P/C_V = \kappa_{T1}/\kappa_s$. The calculated Γ values have been listed in Table 7.

Table- 7: Pseudo-Gruneisen parameter (Γ) as functions of amino acid concentration and temperature:

(I) L-isoleucine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	-8.729	-8.562	-8.426	-8.269	-8.115
0.0284	-8.480	-8.330	-8.185	-8.040	-7.898
0.0474	-8.254	-8.108	-7.964	-7.824	-7.686
0.0665	-8.039	-7.896	-7.757	-7.619	-7.484
0.0857	-7.835	-7.696	-7.560	-7.426	-7.294
0.1049	-7.642	-7.505	-7.371	-7.240	-7.112
0.1243	-7.458	-7.324	-7.193	-7.065	-6.940
0.1437	-7.282	-7.151	-7.023	-6.898	-6.776
0.1633	-7.116	-6.987	-6.862	-6.739	-6.619

(II) L-proline in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	-8.729	-8.562	-8.426	-8.269	-8.115
0.0953	-9.260	-9.098	-8.934	-8.784	-8.628
0.2909	-9.037	-8.879	-8.724	-8.570	-8.419
0.4934	-8.827	-8.672	-8.520	-8.370	-8.222
0.7032	-8.628	-8.476	-8.327	-8.180	-8.035
0.9206	-8.440	-8.291	-8.144	-8.000	-7.859
1.1462	-8.262	-8.116	-7.971	-7.830	-7.692

(III) L-glutamine in aqueous K_2SO_4 solution

Concentration (mol kg^{-1})	Temperature (K)				
	303.15	308.15	313.15	318.15	323.15
0.0000	-8.729	-8.562	-8.426	-8.269	-8.115
0.0379	-8.985	-8.828	-8.674	-8.522	-8.372
0.0762	-8.745	-8.592	-8.441	-8.292	-8.147
0.1147	-8.518	-8.369	-8.221	-8.077	-7.935
0.1535	-8.304	-8.158	-8.014	-7.873	-7.733

0.1926	-7.893	-7.753	-7.616	-7.481	-7.349
0.2320	-7.710	-7.574	-7.439	-7.307	-7.178
0.2717	-7.537	-7.402	-7.270	-7.142	-7.015

The decrease in values with increase in temperature may apparently be attributed to an increase in the kinetic energy of molecules, which in turn, increase the thermal motion of molecules and disrupts the molecular association. The Γ values also show a decreasing trend of variation with increase in amino acid concentration in aqueous electrolytic solutions. However it may be noted that such a variation with change in concentration of solute is insignificant.

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