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Viscosity coefficient and activation parameters for viscous flow of a homologous amino acids in aqueous xylose solutions

K.Rajagopal , J.Johnson

[1]*Department of Physics, Government College of Engineering, Tirunelveli, Tamilnadu, India*
[1]*Department of Physics, Research scholar, M. S. University, Tirunelveli, Tamilnadu India*

---**ABSTRACT**---

Values of viscosity(η) have been determined for four amino acids (glycine, L-alanine, L-valine and L-leucine) in aqueous xylose solutions (0.05, 0.10, 0.15, 0.20) M at T = (298.15,303.15, 308.15, 313.15) K. Viscosity B-coefficients of Jones-Dole equation, B- coefficients transfer (ΔB), temperature dependent of B- coefficient, free energy of activation per mole of solvent ($\Delta\mu_1^{0*}$) and solute ($\Delta\mu_2^{0*}$) and thermodynamic activation parameter , $G_2°(1{\to}1')$, are estimated using viscosity data. The linear correlations of B and $\Delta\mu_2^{0*}$ for a homologous series of amino acids have been used to calculate the contribution of charged end groups (NH_3^+, COO^-), CH_2 and other alkyl chain of the amino acids. Our study concludes the existence of strong solute solvent interaction in the studied systems. Furthermore, structure making and breaking behaviour of all the four amino acids have also been assessed in aqueous xylose solutions. The thermodynamics of viscous flow has also been discussed

Keywords - Amino acids, Xylose, B- coefficients, Free energy of activation per mole of solvent ($\Delta\mu_1^{0*}$) and solute ($\Delta\mu_2^{0*}$).

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I. INTRODUCTION

Sugar solutions play an important role in the biological and food industries. It is widely recognized that sugars as cosolutes help in stabilizing biological macromolecules. Experimental findings indicate that this action is performed either as a result of direct interactions between them and/or through alteration of the water structure [1-4]. Since proteins are large complex molecules, the direct estimation of protein-sugar interactions is difficult. Amino acids, being the essential component of proteins, are models well suited for the study of protein. Keeping this in mind, a number of researchers have studied the amino acid/peptide sugar interactions by employing the viscometric technique. Some authors have reported the thermodynamic study of amino acid in aqueous carbohydrate / saccharide solutions viz. Back et al [5] have reported the increasing thermal stability of proteins in the presence of sugars and polyols, A. Pal et al [6] have studied the Partial molar adiabatic compressibilities of transfer of some amino acids from water to aqueous lactose solutions at different temperatures, C. Zhao et al [7] have estimated partial molar volumes and viscosity B-coefficients of arginine in aqueous glucose, sucrose and L-ascorbic acid solutions at T=298.15 K, Ali et al [8] have investigated the volumetric, viscometric, and refractive index behaviour of α-amino acids and their groups' contribution in aqueous D-glucose solution at different temperatures, Riyazuddeen et al [9] have measured the densities, speeds of sound, and viscosities of (L-Proline + Aqueous Glucose) and (L-Proline + Aqueous Sucrose) Solutions in the Temperature Range (298.15 to 323.15) K. Rajiv Bhat et al [10] have recorded the transfer of some amino acids & peptides from water to aqueous glucose & sucrose solutions at 298.15 K., Nain et al [11]have deduced the solute–solute and solute–solvent interactions in (l-arginine + d-xylose/l-arabinose + water) solutions at different temperatures by using volumetric and viscometric methods and [12]volumetric, ultrasonic and viscometric studies of solute–solute and solute–solvent interactions of l-threonine in aqueous-sucrose solutions at different temperatures viz., 298.15 K, 303.15 K, 308.15 K, 313.15 K . The present paper is a continuation of our research project on the interactions study on ternary systems comprising amino acids + drugs / electrolytes / aqueous sugar systems [13-21].In this paper, we report the viscosity , η, of homologous amino acids in aqueous xylose solutions at different temperatures. Using the viscosity, η, data, the Jones-Dole viscosity B-coefficient, Temperature dependence of B- coefficient, B- coefficients transfer (ΔB), free energy of activation per mole of solvent ($\Delta\mu_1^{0*}$) and solute ($\Delta\mu_2^{0*}$) are estimated. The linear correlations of B and $\Delta\mu_2^{0*}$ for a homologous series of amino acids have been used to calculate the contribution of charged end groups (NH_3^+, COO^-), CH_2 and other alkyl chain of the amino acids. Our study concludes the existence of strong solute solvent interaction in the studied systems. Furthermore, structure making and breaking behaviour all the four amino acids have also been assessed in aqueous xylose solutions. The thermodynamics of viscous flow has also been discussed.

II. EXPERIMENTAL

Xylose (mass fraction purity > 0.990) is procured from S.D. Fine. Chem. Ltd. Mumbai, Glycine (99.7% assay), is procured from Merck Ltd. Mumbai, L-valine (99% assay) and L-leucine (+99 % assay) are obtained from ALDRICH (U.S.A) . L-alanine (99% assay) is procured from SISCO, Mumbai. The amino acids and xylose are used after drying in a desiccator over P_2O_5 for 72 hrs before use. Aqueous xylose solutions of molality 0.05M, 0.10M, 0.15M and 0.20M are prepared using doubly deionized distilled water with a conductivity of 1.5×10^{-4} $\Omega^{-1} \cdot m^{-1}$ and are used as solvents to prepare the molal concentrations of amino acids. For glycine, L-alanine, L-valine, molalities of (0.02, 0.04, 0.06, 0.08 and 0.1) M and for L-leucine, molaities of (0.02, 0.04, 0.05, 0.06 and 0.08) M are used respectively. The mass measurements are made using a high precision and electronic balance (Model HR 300, Japan) with a precision of ± 0.1 mg. Viscosity is measured by means of a suspended level Ubbelhodde viscometer and flow times have been measured using a Racer digital stopwatch having an accuracy of ±0.01s. An average of three sets of flow time reading has been taken for each solution for calculation of viscosity[22]. The overall experimental reproducibility is estimated to be within $\pm 2 \times 10^{-3}$ m Pa·s. The temperatures of the solutions are maintained to an uncertainty of ± 0.01 K in an electronically controlled thermostatic water bath (Eurotherm, Mittal enterprises, New Delhi).

III. RESULTS

The experimental values of viscosity (see table 1) is used to evaluate the relative viscosities of homologous amino acids in various concentrations of aqueous xylose solutions at different temperatures using the following equation (1).

$$\eta_r = \eta / \eta_0 \qquad (1)$$

Table 1 Viscosity (η) of α – amino acids in aqueous xylose solutions at different temperatures

m (mol kg-1)	η / $m\,Pa\,s$ at various m_s / mol kg^{-1}				
	0.00 (Water)	0.05	0.10	0.15	0.20
	T = 298.15 K				
	Glycine				
0	0.8905	0.9054	0.9212	0.9352	0.9495
0.02	0.8943	0.9081	0.9243	0.9388	0.9535
0.04	0.8968	0.9108	0.9271	0.9419	0.9571
0.06	0.8998	0.9133	0.9301	0.9452	0.9608
0.08	0.9026	0.9160	0.9330	0.9486	0.9644
0.10	0.8905	0.9054	0.9212	0.9352	0.9495
	Alanine				
0	0.8905	0.9054	0.9212	0.9352	0.9495
0.02	0.8958	0.9101	0.9262	0.9406	0.9554
0.04	0.9003	0.9147	0.9310	0.9460	0.9610
0.06	0.9051	0.9192	0.9359	0.9513	0.9668
0.08	0.9096	0.9236	0.9407	0.9568	0.9725
0.10	0.9139	0.9278	0.9454	0.9619	0.9783
	Valine				
0	0.8905	0.9054	0.9212	0.9352	0.9495
0.02	0.8985	0.9139	0.9302	0.9447	0.9595
0.04	0.9060	0.9220	0.9385	0.9532	0.9683
0.06	0.9137	0.9299	0.9469	0.9620	0.9776
0.08	0.9215	0.9380	0.9551	0.9707	0.9868
0.10	0.9288	0.9456	0.9634	0.9793	0.9956
	Leucine				
0	0.8905	0.9054	0.9212	0.9352	0.9495
0.02	0.9000	0.9146	0.9310	0.9455	0.9603
0.04	0.9087	0.9240	0.9406	0.9554	0.9705
0.05	0.9128	0.9285	0.9454	0.9605	0.9759
0.06	0.9174	0.9330	0.9500	0.9653	0.9811
0.08	0.9260	0.9417	0.9593	0.9750	0.9910
	T = 303.15 K				
	Glycine				
0	0.7969	0.8095	0.8235	0.8363	0.8480
0.02	0.8000	0.8117	0.8261	0.8392	0.8513

0.04	0.8024	0.8139	0.8284	0.8418	0.8542
0.06	0.8048	0.8161	0.8309	0.8446	0.8573
0.08	0.8072	0.8182	0.8333	0.8474	0.8604
0.10	0.8096	0.8203	0.8358	0.8502	0.8634
Alanine					
0	0.7969	0.8095	0.8235	0.8363	0.8480
0.02	0.8016	0.8135	0.8277	0.8409	0.8529
0.04	0.8057	0.8173	0.8319	0.8455	0.8579
0.06	0.8095	0.8211	0.8359	0.8500	0.8627
0.08	0.8137	0.8248	0.8401	0.8547	0.8676
0.10	0.8175	0.8286	0.8441	0.859	0.8724
Valine					
0	0.7969	0.8095	0.8235	0.8363	0.8480
0.02	0.8039	0.8173	0.8317	0.8449	0.8571
0.04	0.8107	0.8245	0.8391	0.8526	0.8651
0.06	0.8174	0.8318	0.8467	0.8606	0.8732
0.08	0.8242	0.8391	0.8543	0.8685	0.8815
0.10	0.8307	0.8460	0.8617	0.8762	0.8897
Leucine					
0	0.7969	0.8095	0.8235	0.8363	0.8480
0.02	0.8051	0.8181	0.8325	0.8457	0.8579
0.04	0.8130	0.8264	0.8411	0.8545	0.8671
0.05	0.8168	0.8306	0.8455	0.8594	0.8720
0.06	0.8207	0.8346	0.8497	0.8637	0.8767
0.08	0.8280	0.8426	0.8581	0.8724	0.8857
T = 308.15 K					
Glycine					
0	0.7190	0.7300	0.7426	0.7539	0.7640
0.02	0.7210	0.7318	0.7447	0.7564	0.7668
0.04	0.7234	0.7337	0.7467	0.7588	0.7694
0.06	0.7254	0.7354	0.7487	0.7611	0.7720
0.08	0.7275	0.7372	0.7508	0.7634	0.7745
0.10	0.7294	0.7390	0.7528	0.7657	0.7771
Alanine					
0	0.7190	0.7300	0.7426	0.7539	0.7640
0.02	0.7231	0.7333	0.7462	0.7578	0.7682
0.04	0.7268	0.7367	0.7498	0.7618	0.7726
0.06	0.7301	0.7398	0.7533	0.7657	0.7766
0.08	0.7337	0.7431	0.7568	0.7695	0.7809
0.10	0.7372	0.7464	0.7604	0.7735	0.7850
Valine					
0	0.7190	0.7300	0.7426	0.7539	0.7640
0.02	0.7250	0.7372	0.7501	0.7618	0.7722
0.04	0.7314	0.7437	0.7568	0.7687	0.7795
0.06	0.7372	0.7504	0.7638	0.7759	0.7868
0.08	0.7431	0.7570	0.7707	0.7833	0.7945
0.10	0.7490	0.7634	0.7775	0.7903	0.8020
Leucine					
0	0.7190	0.7300	0.7426	0.7539	0.7640
0.02	0.7260	0.7380	0.7509	0.7626	0.7732
0.04	0.7334	0.7455	0.7588	0.7707	0.7814
0.05	0.7368	0.7493	0.7628	0.7749	0.7861
0.06	0.7401	0.7530	0.7666	0.7790	0.7901
0.08	0.7464	0.7604	0.7743	0.7870	0.7986
T = 313.15 K					
Glycine					
0	0.6523	0.6631	0.6729	0.6833	0.6932

0.02	0.6542	0.6646	0.6747	0.6853	0.6955
0.04	0.6561	0.6661	0.6764	0.6873	0.6977
0.06	0.6579	0.6675	0.6781	0.6892	0.6999
0.08	0.6598	0.6691	0.6797	0.6911	0.7022
0.10	0.6616	0.6704	0.6815	0.6931	0.7042
Alanine					
0	0.6523	0.6631	0.6729	0.6833	0.6932
0.02	0.6554	0.6659	0.6759	0.6867	0.6969
0.04	0.6589	0.6687	0.6791	0.6901	0.7006
0.06	0.6620	0.6715	0.6820	0.6934	0.7043
0.08	0.6650	0.6743	0.6850	0.6969	0.7081
0.10	0.6680	0.6770	0.6880	0.7001	0.7115
Valine					
0	0.6523	0.6631	0.6729	0.6833	0.6932
0.02	0.6576	0.6697	0.6798	0.6905	0.7007
0.04	0.6633	0.6757	0.6859	0.6970	0.7075
0.06	0.6687	0.6818	0.6923	0.7037	0.7144
0.08	0.6740	0.6877	0.6986	0.7104	0.7213
0.10	0.6790	0.6938	0.7050	0.7169	0.7279
Leucine					
0	0.6523	0.6631	0.6729	0.6833	0.6932
0.02	0.6584	0.6705	0.6806	0.6912	0.7016
0.04	0.6649	0.6774	0.6878	0.6987	0.7091
0.05	0.6677	0.6809	0.6916	0.7027	0.7131
0.06	0.6706	0.6845	0.6950	0.7063	0.7168
0.08	0.6767	0.6910	0.7021	0.7136	0.7248

Where η and η_0 are the viscosities of the solution(AAs +xylose + Water) and solvent (xylose + Water). The B-coefficients values are evaluated by fitting the η_r values to the Jones-Dole equation (2) by a least squares method [23] as follows.

$$\eta_r = \eta / \eta_0 = 1 + B \cdot c \qquad (2)$$

Where 'c' is the molarity (calculated from molality data). The values of B-coefficients along with the standard deviations of linear regression, σ are summarized in table 2. It is seen from the table 2 that, the values of B-coefficients for amino acids in water agree very well with available literature values [20, 24-30], thus validating our experimental procedures..

The B-coefficients data in aqueous xylose solutions have been used to calculate the corresponding (ΔB) transfer function as follows:

$$\Delta B = \Delta B \text{ (in W + X)} - \Delta B \text{ (in W)} \qquad (3)$$

Where W stands for water and X stands for xylose. The ΔB values as a function of molality of the solute amino acid at all the studied temperatures are given in table 3

The sign of temperature dependence of B- coefficient viz. (dB/dT) gives the information of structure making/breaking property of the solute in the solvent media [31] and the evaluated dB/dT for all four amino acids in aqueous xylose solutions are included in table 4.

Thermodynamic transfer functions of amino acids may be expressed by the McMillan-Mayer Theory [32] of solutions that permits the formal separation of the effects due to interactions involving two or more solute molecules. This approach has been further discussed by Friedman and Krishnan [33] and Frank et al. [34] in order to include solute - cosolute interactions in the solvation spheres. According to this treatment, a thermodynamic transfer function at infinite dilution can be expressed as

$$\Delta B_{\varphi}^{0} = 2\,\eta_{AB}\,m_B + 3\,\eta_{ABB}\,m_B^2 + \text{----} \qquad (4)$$

Where, in η_{AB} and η_{ABB}, A stands for aminoacid and B stands for xylose and m_B is the molality of xylose (cosolute). The constants η_{AB} and η_{ABB} are pair and triplet interaction parameters, obtained by fitting ΔB_{φ}^{0} data to equation (11). The parameters η_{AB} and η_{ABB} for viscosity are listed in Table 5.

The viscosity data are used to estimate the free energy of activation per mole of the solvent ($\Delta\mu_1^{0*}$) and solute ($\Delta\mu_2^{0*}$) as suggested by Feakins et al. [35] and Eyring et al. [36] using the following equations (5-7).

$$B = (\overline{V}_1^{o} - \overline{V}_2^{o}) / 1000 + \overline{V}_1^{o} / 1000 \quad RT\,(\Delta\mu_2^{0*} - \Delta\mu_1^{0*}) \qquad (5)$$

$$\Delta \mu_1^{0*} = RT \ \ln \left(\eta_0 \overline{V_1}^0 / hN \right) \qquad (6)$$

Equation (6) can be rearranged as

$$\Delta \mu_2^{0*} = \Delta \mu_1^{0*} + RT \ / \overline{V_1}^0 [1000 \quad B - (\overline{V_1}^0 - \overline{V_2}^0)] \qquad (7)$$

Where $\overline{V_1}^0 = (\Sigma x_i m_i / \rho)$ is the mean volume of the solvent and $\overline{V_2}^0 = V_\phi^0$ is the partial molar volume at infinite dilution of the solute. The terms x_i and m_i denote the mole fractions and molecular weights of water (1) and xylose (2) and ρ is the density of the solvent mixture (xylose + water), 'h' is the Planck's constant, 'N' is the Avogadro's number, η_0 is the viscosity of the solvent and 'R' is the gas constant. The values of $\Delta \mu_1^{0*}$, $\overline{V_1^0}$ and $\Delta \mu_2^{0*}$ are reported in tables 6 and 7.

According to transition state theory [35], every solvent molecule in one mole of solution must pass through the transition state and also interact more or less strongly with solute molecules. Thus, the activation free energy $\Delta \mu_2^{0*}$ include the free energy transfer of solute from ground state to transition state solvents [ΔG_2° $(1 \rightarrow 1')$] and the free energy of solute through its own viscous transition state [ΔG_2° $(2 \rightarrow 2')$]. The [ΔG_2° $(1 \rightarrow 1')$] values, calculated by using methods similar to those reported elsewhere [37] are also given in Table 8.

The linear regression analysis of D_ϕ^0 values as a function of number of carbon atoms (n_c) in the alkyl chain of the amino acids can be represented as[38]

$$D_\phi^0 = D_\phi^0 (NH_3^+, COO^-) + n_c D_\phi^0 (CH_2) \qquad (8)$$

Where $D_\phi^0 (NH_3^+, COO^-)$ and $D_\phi^0 (CH_2)$ are the zwitterionic end groups and the methylene group contribution to D_ϕ^0, respectively. Here D_ϕ^0 stands for B and $\Delta \mu_2^{0*}$ respectively. As suggested by Hakin et al.[39,40] the contributions of the other alkyl chain of the α-amino acids are calculated as follows:

$$D_\phi^0 (CH_3) = 1.5 \, D_\phi^0 (CH_2) \qquad (9)$$
$$D_\phi^0 (CH) = 0.5 \, D_\phi^0 (CH_2) \qquad (10)$$

The alkyl chains of homologous series of the α-amino acids studied in this work are CH_2-(gly), CH_3CH-(Ala), CH_3CH_3CHCH-(Val) and $CH_3CH_3CHCH_2CH$-(Leu), the values of $D_\phi^0 (CH_2)$ obtained by this procedure characterize the mean contribution of CH- and CH_3- groups to D_ϕ^0 of the α-amino acids[41]. The results are given in tables 9 and 10.

IV. DISCUSSION

The experimental measurements of viscosity data of homologous amino acids in aqueous xylose solution at different temperatiues yield information on viscosity B-Coeffieients of Jones-Dole equation that will reflect size and shape effects as well as structural effects induced by solute solvent interation[42,43].Further, the B- Coeeficients provide information about the solvation of the solutes and and effects on the structure of the solvent in the near environment o solute molecules.

Table 2 Viscosity B – Coefficient of α – amino acids in aqueous xylose solutions at different temperatures

Amino Acid	$B * 10^3$ / m^3 mol^{-1} at various m_s / mol kg^{-1}					
	0.00 (Water)		0.05	0.10	0.15	0.20
	Present Work	Literature				
T = 298.15 K						
Glycine	0.159 (0.024)	0.153[a]	0.145 (0.009)	0.158 (0.009)	0.175 (0.017)	0.192 (0.011)
Alanine	0.259 (0.002)	0.258[b]	0.246 (0.009)	0.262 (0.012)	0.286 (0.015)	0.301 (0.012)
Valine	0.433 (0.033)	0.447[c], 0.423[d]	0.443 (0.010)	0.454 (0.007)	0.466 (0.007)	0.479 (0.006)
Leucine	0.493 (0.007)	0.487[b]	0.504 (0.017)	0.516 (0.012)	0.529 (0.009)	0.542 (0.018)
T = 303.15 K						
Glycine	0.153 (0.025)		0.133 (0.023)	0.148 (0.009)	0.165 (0.016)	0.179 (0.012)
Alanine	0.253 (0.021)		0.234 (0.006)	0.250 (0.011)	0.272 (0.018)	0.287 (0.010)
Valine	0.427 (0.021)		0.450 (0.016)	0.461 (0.008)	0.472 (0.012)	0.483 (0.020)
Leucine	0.487 (0.043)		0.511 (0.007)	0.523 (0.018)	0.537 (0.016)	0.551 (0.025)
T = 308.15 K						
Glycine	0.148 (0.024)	0.148[e]	0.123 (0.023)	0.137 (0.007)	0.154 (0.016)	0.168 (0.028)
Alanine	0.248 (0.015)	0.247[e]	0.225 (0.022)	0.240 (0.015)	0.260 (0.018)	0.275 (0.025)
Valine	0.422 (0.037)	0.418[a]	0.456 (0.017)	0.468 (0.019)	0.479 (0.034)	0.491 (0.036)
Leucine	0.480 (0.052)	0.423[c]	0.518 (0.014)	0.531 (0.028)	0.545 (0.017)	0.559 (0.019)
T = 313.15 K						
Glycine	0.144 (0.033)	0.144[f]	0.111 (0.049)	0.126 (0.024)	0.142 (0.024)	0.158 (0.041)
Alanine	0.244 (0.045)	0.247[g]	0.211 (0.029)	0.225 (0.022)	0.246 (0.052)	0.266 (0.039)
Valine	0.418 (0.107)	0.413[h]	0.461 (0.010)	0.475 (0.023)	0.486 (0.021)	0.496 (0.057)
Leucine	0.473 (0.065)	0.480[h]	0.525 (0.049)	0.540 (0.036)	0.553 (0.045)	0.562 (0.054)

[a]Ref 24,[b]Ref 25, [c]Ref 26, [d]Ref 27, [e]Ref 28, [f]Ref 29, [g]Ref 30,[h]Ref 20

The observed large and positive B coefficient values (see table 2) for all the four amino acids in aqueous xylose solution increase with increase in concentration of xylose suggest the presence of stronger solute–solvent interactions as compared to solute–solute interactions. However the decrease in B coefficient values with increase of temperature indicate the rupturing effect of thermal energy on the solute-solvent interactions of the studied systems.The viscosity *B* coefficient values for amino acids in aqueous xylose solutions at particular concentration and temperatures show the following order; glycine < alanine < valine < leucine.

Table 3 shows that the transfer *B* coefficient, *ΔB* (W → Xyl) in going from water to xylose are calculated by taking the difference between viscosity *B* coefficient in aqueous xylose and in water for each amino acid studied. The increase in *B* coefficients (i.e., positive *ΔB* values, with the exemption of glycine and alanine at low concentration.) from water to xylose is due to interactions of xylose with either R groups or charged centers of amino acids. In other words the main contribution to *ΔB* (W → Xyl) values comes from the interactions between charged centers of amino acids and xylose molecules, rather than from interactions between R groups of amino acids and xylose molecules cause an increase in viscosity and thus in *B* coefficient. Similar results are available in literature [44].

Table 3 Viscosity B - Coefficient transfer (ΔB) α– amino acids in aqueous xylose solutions at different temperatures

Amino Acids	various m_s / mol kg^{-1}			
	0.05	0.10	0.15	0.20
	$\Delta B*10^3$	$\Delta B*10^3$	$\Delta B*10^3$	$\Delta B*10^3$
	m^{3}mol^{-1}	m^{3}mol^{-1}	m^{3}mol^{-1}	m^{3}mol^{-1}
T = 298.15 K				
Glycine	-0.014	-0.001	0.016	0.033
Analine	-0.013	0.003	0.027	0.042
Valine	0.010	0.021	0.033	0.046
Leucine	0.011	0.023	0.036	0.049
T = 303.15 K				
Glycine	-0.020	-0.005	0.012	0.026
Analine	-0.019	-0.003	0.019	0.034
Valine	0.023	0.034	0.045	0.056
Leucine	0.024	0.036	0.05	0.064
T = 308.15 K				
Glycine	-0.025	-0.011	0.006	0.020
Analine	-0.023	-0.008	0.012	0.027
Valine	0.034	0.046	0.057	0.069
Leucine	0.038	0.051	0.065	0.079
T = 313.15 K				
Glycine	-0.033	-0.018	-0.002	0.014
Analine	-0.032	-0.019	0.002	0.022
Valine	0.043	0.057	0.068	0.078
Leucine	0.052	0.067	0.080	0.089

The variation of B with temperature, dB/dT provides (see table 4) direct evidence regarding structure-making or breaking ability of the solute in the solution. When dB/dT is negative , the solute acts as structure-maker and when dB/dT is positive it acts as structure breaker. The negative values of (dB/dT) for glycine and alanine (see table 4) indicate[45] that, these two amino acids act as structure-maker while positive (dB/dT) values for valine and leucine supports the structure breaking ability of these amino acids in aqueous-xylose solutions.

Table 4 Temperature Coefficient (dB/dT) of α – amino acids in aqueous xylose solutions at different temperatures.

Amino Acids	dB/dT / m^3 mol^{-1} K^{-1} at various m_s / mol kg^{-1}			
	0.05	0.10	0.15	0.20
Glycine	-0.0022	-0.0021	-0.0022	-0.0023
Analine	-0.0023	-0.0024	-0.0026	-0.0023
Valine	0.0012	0.0014	0.0013	0.0012
Leucine	0.0014	0.0016	0.0016	0.0014

Table 5 Values of pair (η_{AB}) and triplet (η_{ABB}) of α – amino acids in aqueous xylose at different temperatures

Glycine		Alanine		Valine		Leucine	
$10^3 \eta_{AB}$/ m³·mol⁻²·kg	$10^3 \eta_{ABB}$/ m³·mol⁻³·kg²	$10^3 \eta_{AB}$/ m³·mol⁻²·kg	$10^3 \eta_{ABB}$/ m³·mol⁻³·kg²	$10^3 \eta_{AB}$/ m³·mol⁻²·kg	$10^3 \eta_{ABB}$/ m³·mol⁻³·kg²	$10^3 \eta_{AB}$/ m³·mol⁻²·kg	$10^3 \eta_{ABB}$/ m³·mol⁻³·kg²
T = 298.15 K							
-0.184	0.968	-0.175	1.040	0.0950	0.0667	0.106	0.057
T = 303.15 K							
-0.245	1.147	-0.240	1.204	0.2450	-0.3867	0.250	-0.338
T = 308.15 K							
-0.303	1.300	-0.284	1.319	0.3688	-0.9011	0.409	-0.781
T = 313.15 K							
-0.393	1.571	-0.405	1.680	0.4750	-1.2667	0.576	-1.281

From table 5, it is seen that the values of pair interaction coefficient are negative and that of the triplet interaction coefficient are positive indicating the predominance of triplet interactions over the pair interactions in all the studied systems at different temperatures. similar results are available in literature.

It is evident from table 6 and 7 that $\Delta\mu_2^{0*}$ values are positive and much larger than $\Delta\mu_1^{0*}$ suggesting that the interactions between solute (amino acids) and solvent (water +xylose) molecules in the ground state are stronger than in the transition state, i.e., the interactions between solute (Amino acids) and solvent (xylose+ water) molecules in the ground state are stronger than in the transition state. This means that the formation of transition state is accompanied by the rupture and distortion of the intermolecular forces in solvent structure. Thus, the solvation of the solute in the transition state is unfavourable in free energy terms. Further, $\Delta\mu_2^{0*}$ increases from glycine to leucine at a particular temperature, indicating that the solvation of amino acid molecules becomes increasingly unfavourable as the hydrophobicity or the number of carbon atoms of the side chain increases from glycine to leucine. This feature is similar to that observed for glycine in aqueous solutions of transition metal chlorides [46]. The $\Delta\mu_2^{0*}$ values at particular concentration and temperature follow the order, Glycine < Alanine < Valine < Leucine. This reflects that the solute having a longer alkyl chain requires more energy in transferring from the ground state to the transition state. Similar results were also reported for glycine, alanine, and valine in aqueous urea [47] and also for glycine , alanine, serine, and valine in aqueous glucose solutions [8].

Table 6 Free energy of activation of solvent ($\Delta\mu_1^{0*}$) and mean volume of solvent ($\overline{V_1^0}$) of α – amino acids aqueous xylose solution at different temperatures

m_s mol kg⁻¹	$\Delta\mu_1^{0*}$ kJ mol⁻¹	$\overline{V_1^0}$ m³ mol⁻¹	$\Delta\mu_1^{0*}$ kJ mol⁻¹	$\overline{V_1^0}$ m³ mol⁻¹
	T = 298.15 K		T = 303.15 K	
0	9.16	18.07	9.04	18.09
0.05	9.21	18.14	9.09	18.16
0.1	9.27	18.21	9.14	18.23
0.15	9.31	18.28	9.19	18.30
0.2	9.36	18.35	9.24	18.38
mol kg⁻¹	T = 308.15 K		T = 313.15 K	
0	8.93	18.12	8.83	18.16
0.05	8.98	18.19	8.88	18.23
0.1	9.03	18.26	8.93	18.30
0.15	9.08	18.34	8.98	18.37
0.2	9.13	18.41	9.03	18.44

Table 7 Free energy of activation of solute ($\Delta\mu_2^{0*}$) of α – Amino acids in aqueous xylose solution at different temperatures

$\Delta\mu_2^{0*}$ / kJ mol⁻¹ at various ms / mol kg⁻¹					
Amino acids	0.00 (Water)	0.05	0.10	0.15	0.20
	T = 298.15 K				
Glycine	34.40	31.74	33.55	35.87	38.15
Analine	50.49	48.07	50.19	53.39	55.39
Valine	78.52	79.28	80.61	82.03	83.67

Leucine	89.16	90.01	91.45	92.96	94.46
			T = 303.15 K		
Glycine	33.90	30.45	32.56	34.93	36.86
Analine	50.21	46.97	49.15	52.14	54.16
Valine	78.64	81.29	82.63	83.93	85.30
Leucine	89.44	92.22	93.66	95.33	96.96
			T = 308.15 K		
Glycine	33.51	29.40	31.42	33.81	35.77
Analine	50.13	46.31	48.38	51.14	53.22
Valine	78.94	83.23	84.70	86.03	87.53
Leucine	89.59	94.44	96.02	97.72	99.35
			T = 313.15 K		
Glycine	33.26	28.08	30.27	32.57	34.86
Analine	50.19	45.13	46.97	49.90	52.71
Valine	79.31	84.97	86.74	88.09	89.31
Leucine	89.70	96.67	98.53	100.12	101.05

Table 8 Values of , $\Delta G_2^{\bullet}(1\rightarrow 1')$ from ground state to transition state of α – amino acids in aqueous xylose solution at different temperatures

$\Delta G_2^{\circ}(1\rightarrow 1')$ / kJ mol^{-1} at various m_s / mol kg^{-1}					
Amino acids	0.00 (Water)	0.05	0.10	0.15	0.20
			T = 298.15 K		
Glycine	25.24	22.53	24.28	26.55	28.79
Analine	41.33	38.85	40.93	44.08	46.03
Valine	69.36	70.06	71.34	72.72	74.31
Leucine	80.00	80.80	82.18	83.64	85.09
			T = 303.15 K		
Glycine	24.86	21.36	23.42	25.73	27.62
Analine	41.17	37.88	40.01	42.95	44.93
Valine	69.60	72.20	73.49	74.74	76.06
Leucine	80.40	83.13	84.52	86.14	87.73
			T = 308.15 K		
Glycine	24.58	20.42	22.38	24.73	26.65
Analine	41.20	37.33	39.35	42.06	44.09
Valine	70.01	74.25	75.67	76.95	78.40
Leucine	80.66	85.46	86.98	88.64	90.22
			T = 313.15 K		
Glycine	24.43	19.20	21.34	23.59	25.83
Analine	41.37	36.25	38.04	40.92	43.68
Valine	70.48	76.09	77.81	79.11	80.28
Leucine	80.88	87.79	89.60	91.14	92.03

It is seen from table 8 that, the thermodynamic activation parameter [ΔG_2° (1→1')] values increase from glycine to L-leucine at particular concentration and temperature, indicating the requirement of more energy for the amino acids with longer alkyl side chains for the transfer from ground state solvent to transition state solvent. This effectively means that more solute- solvent bonds must be broken to form transition state.

Table 9 Group contributions of B-coefficient of α – amino acids in aqueous xylose solutions at different temperatures.

$B * 10^3$ / m^3 mol^{-1} at various m_s / mol kg^{-1}				
Group	0.05	0.10	0.15	0.20
		T=298.15 K		
NH$_3^+$ COO$^-$	0.060	0.075	0.097	0.115
CH$_2$	0.091	0.090	0.088	0.087
CHCH$_3$	0.182	0.180	0.176	0.174
CHCH(CH$_3$)$_2$	0.364	0.360	0.352	0.348
CHCH$_2$CH(CH$_3$)$_2$	0.455	0.450	0.440	0.435
		T=303.15 K		
NH$_3^+$ COO$^-$	0.040	0.057	0.078	0.093

CH_2	0.097	0.096	0.094	0.094
$CHCH_3$	0.194	0.192	0.188	0.188
$CHCH(CH_3)_2$	0.388	0.384	0.376	0.376
$CHCH_2CH(CH_3)_2$	0.485	0.480	0.470	0.470
T=308.15 K				
$NH_3^+ COO^-$	0.024	0.039	0.059	0.073
CH_2	0.102	0.101	0.100	0.099
$CHCH_3$	0.204	0.202	0.200	0.198
$CHCH(CH_3)_2$	0.408	0.404	0.400	0.396
$CHCH_2CH(CH_3)_2$	0.510	0.505	0.500	0.495
T=313.15 K				
$NH_3^+ COO^-$	0.003	0.018	0.038	0.059
CH_2	0.107	0.107	0.106	0.103
$CHCH_3$	0.214	0.214	0.212	0.206
$CHCH(CH_3)_2$	0.428	0.428	0.424	0.412
$CHCH_2CH(CH_3)_2$	0.535	0.535	0.530	0.515

The group contribution values of viscosity B-coefficient and $\Delta\mu_2^{0*}$ are shown in tables 9 &10 It is observed from table 9 that viscosity B-coefficient increases with increase in number of carbon atoms (n_c), in the alkyl chain of the amino acids. Moreover, the magnitudes of B (NH_3^+, COO^-) systematically increase with the increase in the concentration of xylose at all temperatures. The variation of B (CH_2) with concentration of xylose is almost insensitive. Similar results on group contribution to B-coefficient are available in literature [32, 48,49]. The magnitude of the values indicates the predominance of the interactions between zwitterionic centers of the amino acids with xylose molecules in the solution. It is interesting to add that the contribution to the B-coefficient increase with the increase in chain length.

Table 10 Group contributions free energy of activation of solute($\Delta\mu_2^{0*}$) of α – Amino acids in aqueous xylose solution at different temperatures

Group	$\Delta\mu_2^{0*}$ / kJ mol⁻¹ at various m_s / mol kg⁻¹			
	0.05	0.10	0.15	0.20
	T=298.15 K			
$NH_3^+ COO^-$	17.95	20.08	23.21	25.64
CH_2	14.77	14.62	14.28	14.09
$CHCH_3$	29.54	29.24	28.56	28.18
$CHCH(CH_3)_2$	59.08	58.48	57.12	56.36
$CHCH_2CH(CH_3)_2$	73.85	73.10	71.40	70.45
	T=303.15 K			
$NH_3^+ COO^-$	15.37	17.80	20.80	22.91
CH_2	15.78	15.56	15.26	15.13
$CHCH_3$	31.56	31.12	30.52	30.26
$CHCH(CH_3)_2$	63.12	62.24	61.04	60.52
$CHCH_2CH(CH_3)_2$	78.90	77.80	76.30	75.65
	T=308.15 K			
$NH_3^+ COO^-$	13.24	15.47	18.36	20.52
CH_2	16.70	16.55	16.27	16.14
$CHCH_3$	33.40	33.10	32.54	32.28
$CHCH(CH_3)_2$	66.80	66.20	65.08	64.56
$CHCH_2CH(CH_3)_2$	83.50	82.75	81.35	80.70
	T=313.15 K			
$NH_3^+ COO^-$	10.53	12.74	15.68	18.78
CH_2	17.71	17.62	17.32	16.90
$CHCH_3$	35.42	35.24	34.64	33.80
$CHCH(CH_3)_2$	70.84	70.48	69.28	67.60
$CHCH_2CH(CH_3)_2$	88.55	88.10	86.60	84.50

It is seen from table 10, that the contribution of $\Delta\mu_2^{0*}$ (NH_3^+, COO^-) group increases with the increasing concentration of the xylose but decreases with increase in temperatures.However the contribution of (CH_2) group decreses with increasing concentration of xylose and increases with increase in temperatures. This

indicates that the interactions between co-solute and charged end groups (NH_3^+, COO^-) of amino acids are much stronger than those between the co-solute and (CH_2) groups.

V. CONCLUSION

The viscosities, η of some homologous amino acids in aqueous xylose solvents (0.05, 0.10, 0.15, 0.20) M have been experimentally measured and are reported at different temperatures. Using the experimental data, various parameters,viz., A, Jones–Dole coefficient, B, Gibbs energy of activation per mole of solvent, $\Delta\mu_1^{0*}$ and Gibbs energy of activation per mole of the solute, $\Delta\mu_2^{0*}$ are deduced and reported. The positive values of viscosity *B*-coefficient of the amino acids in aqueous xylose solutions show that the interactions involving the charged centers of amino acid with the OH group of aqueous xylose are dominating and indicating the presence of strong- solute solvent interactions. . From the temperature dependence of B- coefficient data, it is found that glycine and alanine act as structure maker while valine and leucine as structure breaker in aqueous xylose solutions.

REFERENCES

[1]. Antipova, A. S., & Semenova, M. G., & Belyakova, L. E.. The effect of sucrose on the thermodynamic properties of ovalbumin and sodium caseinate in bulk solution and at air–water interface. *Colloids and Surfaces.B.Colloids and surfaces B,(12)*, 1999 , 261-270.
[2]. Lee, J. C., &Timasheff, S. N. , The stabilization of proteins by sucrose.. *J. Biol. Chem,(256)*, 1981,7193- 7201.
[3]. Timasheff, S. N., &Arakawa, T.In Protein Structure: A Practical Approach; Creighton, T. E., Ed. Stability of protein structure by solvents; *Oxford University Press*: Oxford UK., 1989.
[4]. Antipova, A. S., & Semenova, M. G. Effect of sucrose on the thermodynamic incompatibility of different biopolymers , *Carbohydr. Polym (28)*, 1995,359-365
[5]. Back, J. F., &David Oakenfull., & Malcolm B. Smith.Increased thermal stability of proteins in the presence of sugars and polyols, *Biochemistry, 18(23)*, 1979,5191-5196.
[6]. Amalendu Pal, & Nalin Chauhan. Partial molar adiabatic compressibilities of transfer of some amino acids from water to aqueous lactose solutions at different temperatures. *J. Mol. Liq,(162)*, 2011,38 – 44.
[7]. Zhao, C., &Ma, P., &Li, J. Partial molar volumes and viscosity B-coefficients of arginine in aqueous sucrose and L-ascorbic acid solutions at T=298.15 K.*J. Chem. Thermodyn (37)*, 2005,37–42.
[8]. Anwar Ali, & Soghra Hyder, & Saba Sabir, & Dinesh Chand, &Anil Kumar Nain. Volumetric, viscometric, and refractive index behaviour of α-amino acids and their groups' contribution in aqueous d- glucose solution at different temperatures. *J.Chem.Thermodyn(38)*, 2006,136-143.
[9]. Riyazuddeen, &Mohd Amil UsmaniJ . Densities, Speeds of Sound, and Viscosities of (L-Proline +Aqueous Glucose) and (L-Proline + Aqueous Sucrose) Solutions in the Temperature Range (298.15 to 323.15) K.*J.Chem.Engg.Data (56)*, 2011,3504-3509
[10]. Rajiv Bhat, & Nand Kishore , &Jagdish C. Ahluwalia .Thermodynamic studies of transfer of some amino acids & peptides from water to aqueous glucose & sucrose solutions at 298.15K. *J.Chem. Soc. Fara. Trans I,(84)* , 1988,2651 – 2665.
[11]. Anil Kumar Nain, & Monika Lather, & Neetu. Probing solute–solute and solute–solvent interactions in (l-arginine + d-xylose/l-arabinose + water) solutions at different temperatures by using volumetric and viscometric methods.*The Journal of Chemical Thermodynamics(63)*, 2013,67-73.
[12]. Anil Kumar Nain, &Renu Pal, &Neetu..Volumetric, ultrasonic and viscometric studies of solute– solute and solute–solvent interactions of l-threonine in aqueous-sucrose solutions at different temperatures.*The Journal of Chemical Thermodynamics (64)*, 2013, 172-181.
[13]. Rajagopal, K., &Edwin Gladson, S. Partial molar volume and partial molar compressibility of four homologous α-amino acids in aqueous sodium fluoride solutions at different temperatures. *J.Chem. Thermodyn.(43)*, 2011,852-867.
[14]. Rajagopal, K., &Edwin Gladson, S.Thermodynamic Analysis of Homologous *α*-Amino Acids in Aqueous Potassium Fluoride Solutions at Different Temperatures.*Journal of Solution Chemistry(41)*, 2012,646- 679 .
[15]. Rajagopal,K.,&Jayabalakrishnan,S. Volumetric, ultrasonic speed and viscometric studies of salbutamol sulphate in aqueous methanol solution at different temperatures. *J. Chem. Thermodyn(42)*, 2010,984- 993.
[16]. Rajagopal, K., &Jayabalakrishnan, S.Volumetric and viscometric studies of 4- amino butyric acid in aqueous solutions of sulbutamol sulphate at 308.15 K.*Chin. J. Chem. Eng (17)*, 2009,796-804.
[17]. Rajagopal, K., &Jayabalakrishnan, S.Volumetric and viscometric studies of 4–aminobutyric acid in aqueous solutions of metformin hydrochloride at 308.15, 313.15 and 318.15 K'.*J. Serb.Chem. Soc (76)*, 2011,129-142.
[18]. Rajagopal,K.,&Jayabalakrishnan,S.Ultrasonic Studies of 4-Aminobutyric Acid in Aqueous Metformin Hydrochloride Solutions at Different Temperatures. *Int .J. Thermophys (31)*, 2010, 2225–2238.
[19]. Rajagopal, K., &Jayabalakrishnan, S. Ultrasonic Studies of 4-Aminobutyric Acid in Aqueous Salbutamol Sulphate Solutions at Different Temperatures. *Chinese Journal of Chemical Engineering,18(1)*,2010,659-666.
[20]. Rajagopal, K., &Jayabalakrishnan, S.Effect of temperature on volumetric and viscometric properties of homologous amino acids in aqueous solutions of Metformin hydrochloride. Chinese *J. Chem. Eng,(18)*,2010,425-445.
[21]. Rajagopal,K.,&Johnson,J. Thermodynamic interactions of l-histidine in aqueous fructose solutions at different temperatures. *International Journal of Scientific and Research Publications (15)*, 2015,2.
[22]. Rajagopal, K., &Johnson, J. Studies on volumetric and viscometric properties of l- histidine in aqueous xylose solution over temperature range (298.15 to 313.15) K.*Int.J.Chem.Tech.Research (8)*, 2015,346- 355.
[23]. Jones,G.,and Dole,M.The viscosity of aqueous solutions of strong electrolytes with special reference to barium chloride.*J. Am. Chem. Soc(51)*,1929,2950-2964.
[24]. Daniel, J., &Cohn, E.J Studies in the Physical Chemistry of Amino Acids, Peptides and Related Substances.VI.The Densities and Viscosities of Aqueous Solutions Amino Acids.*J.Am.Chem.Soc(58)* 1936,415- 423.
[25]. Lark, B.S.,& Patyar, P.,& Banipal, T.S. Temperature effect on the viscosity and heat capacity behavior of some amino acids in water and aqueous magnesium chloride solutions. *J. Chem. Thermodyn, (39)*, 2007, 344-360.

[26]. Yan, Z., &Wang, J.,& Liu, W., &Lu, J. Apparent molar volumes and viscosity B-coefficients of some amino acids in aqueous solutions from 278.15 to 308.15K.*Thermochim. Acta, (334)* , 1999,17-27.

[27]. Banipal, T.S., & Damanjit Kaur, & Banipal, P.K.Apparant Molar Volumes and Viscosities of Some Amino Acids in Aqueous Sodium Acetate Solutions at 298.15 K. *J.Chem. Engg. Data (49)* ,2004,1236-   1246.

[28]. Sandhu, J.S.,& Kashyap, U.Viscosities of some amino acids in methanol- water mixtures. *Indian   J   Chem. A(26),*1987,952-955.

[29]. Islam, M. N., &Wadi, R. K. Temperature dependence of apparent molar volumes and viscosity coefficients of amino acids in aqueous sodium sulphate solutions from 15 to 35oC.*Phys. Chem. Liq (41),*   2004,533-544.

[30]. Bhattacharya, M.M., & Sengupta, M. Ion solvent interaction of amino acids, alanine in aqueous solution   in the cationic anionic and zwitterionic form. *Z. Phys. Chem. (N.F) (121)*, 1980,135-139.

[31]. Sharma,T.S.,&Ahluwali,J.C. Experimental studies on the structures of aqueous solutions of hydrophobic solutes *.Chem.Soc.Rev, (2)*, 1973, 203-232.

[32]. McMillan,W.G.,&Mayer,J.E. The statistical thermodynamics of multi component system. *J.Chem.Phys   (13)* 1945,276-305.

[33]. Friedman,H.L., & Krishnan,C.V. Studies of hydrophobic bonding in aqueous alcohols Enthalpy measurements and model calculations*. J. Solution Chem (2)* ,1973, 119-140.

[34]. Franks, F.,& Pedley, M.,& Reid, D.S.. Solute interactions in dilute aqueous solutions, Part-I, Microcalorimetric study of the hydrophobic interaction. *J. Chem. Soc Faraday I, (72),* 1976,359-367.

[35]. Feakins, D., &Bates, F.M., & Waghorne, W.E., &Lawrence, K.G.().Relative viscosities and quasi thermodynamics of solutions of tert-butyl alcohol in the methanol water system: a different view of the alkyl water interaction. *J. Chem. Soc. Faraday, Trans I(89),* 1993,3381-3388.

[36]. Eyring, H.,& Glasstone, S., & Laidler, K. *The Theory of Rate processes*, McGraw Hill, New York. 1941.

[37]. Banipal, T.S.,& Singh,G. Thermodynamic study of behavior of some amino acids, diglycine and lysozyme in aqueous and mixed aqueous solutions.*Thermo chim. Acta (412),* 2004, 63-83.

[38]. Pal, A., &Kumar, S. Volumetric and viscometric studies of glycine in binary aqueous solutions of sucrose at different temperatures. *Indian J. Chem. A(44),*2005, 469-475.

[39]. Hakin, A.W.,& Duke, M.M.,& Marty, J.L.,& Presuss, K.E. Some thermodynamic properties of aqueous amino acid systems at 288.15, 298.15, 313.15 and 328.15 K: group additivity analyses of standard   state   volumes and heat capacities. *J. Chem. Soc., Faraday Trans(90)* 1994,2027-2035

[40]. Hakin, A.W.,& Duke, M.M.,& Groft, L.L.,& Marty, J.L., & Rashfeldt, M.L.Calorimetric investigations of   aqueous amino acid and dipeptide systems from 288.15 to 328.15 K. *Can. J. Chem(73),*1995,725-734

[41]. Yan, Z.,& Wang, J., &Lu, J. Viscosity behaviour of some amino acids and their groups in water- sodium acetate mixtures. *Biophys. Chem, (99),* 2002, 199-207.

[42] . Stokes, R. H.,& Milles,(1965).R. *International Encyclopedia of Physical Chemistry and Chemical Physics;*Pergamon: New York, 1965.

[43]. Bai, T.C., &Yan, G.B.(). Viscosity B-coefficients and activation parameters for viscous flow of a solution   of heptanedioic acid in aqueous sucrose solutions. *Carbohydrate Research (338),* 2003,2921- 2927.

[44]. Belibagli, K.,& Ayranci, E. Viscosities and apparent molar volumes of some amino acids in water   and in 6*M* guanidine hydrochloride at 25°C. *J. Solution Chem. (19),* 1990,867-882.

[45]. Dey, N., &Saikia, B.K.Viscosities of glycine and Dl-alanine in water acetonitrile mixtures between   25 and 40°C .*Can. J. Chem. (58),* 1980, 1512–1515.

[46]. A.P. Mishra, S.K. Gautam,. Viscometric and volumetric studies of some transition metal chlorides in glycine water solution *Indian J. Chem., Part A 40(1)*, 2001, 100-104.

[47]. Pal, A., Kumar, S. Viscometric and volumetric studies of some amino acids in binary aqueous   solutions of urea at various temperatures. *J. Mol. Liq. (109),* 2004, 23-31.

[48]. Yan, Z.,& Wang, J.,& and Lu, J.. Apparent molar volumes and viscosities of some amino acids in aqueous sodium butyrate solutions at 298.15 K. *J. Chem. Eng. Data(46),* 2001,217-222.

[49]. Banipal, T.S.,& Kaur, D.,& and Banipal, P.K. Effect of magnesium acetate on the volumetric and transport behavior of some amino acids in aqueous solutions at 298.15 K. *J. Chem. Thermodyn., (38),* 2006,1214-1226.