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Effect of Additives on Volumetric and Viscometric Properties of Amino Acids

Kuldeep Kumar[*1], Jyotsna[1], Nancy Sharma[1], Renu Sharma[1] & Suvarcha Chauhan[2]

[1]*Department of Chemistry, Career Point University, Hamirpur (H.P.) 176041 India*
[2]*Department of Chemistry, Himachal Pradesh University, Shimal (H.P.) 171005 India*
E-mail: kuldeep.sharma.753@gmail.com

ABSTRACT: In this paper, we have reported the results of density, ρ, and viscosity, η, measurements of glycine and arginine at molalities ranging from (0.01-to 0.09) mol·kg^{-1} in the presence and absence of alcohols, electrolytes, and saccharides (0.05) mol·kg^{-1}at 298.15 K. By using experimental density and viscosity data, the partial molar volumes, ϕ_v^o, transfer partial molar volumes, $\Delta_{tr}\phi_v^o$, the viscosity B-coefficients by employing the Jones-Dole equation, and viscosity B-coefficient of transfer, $\Delta_{tr}B$, have been calculated. The trends of variation of different parameters have been interpreted in light of the solute-solvent/cosolute and solute-solute interactions occurring in the ternary systems. An attempt has also been made to compare the effect of different additives on volumetric and viscometer parameters of studied amino acids.

Keywords: Alcohol; arginine; electrolyte; glycine and saccharide

INTRODUCTION: Protein plays a crucial role in almost all biological processes and amino acids are the basic structural units of proteins. The application of proteins has increased so rapidly not only in biochemical research, but also in food, chemical and pharmaceutical industries. The amino acids in a protein backbone are influenced by the solvent molecules. Therefore, it is very important to have an idea on the solubility, stability and thermodynamics properties of these amino acids in various solvents and cosolvents. Thermodynamic properties of amino acids in aqueous electrolyte solutions can provide valuable information regarding the stability of proteins in these solutions, their solubility, separation and purification, solute–solvent and solute–solute interactions. The studies of interactions between ionic liquids and proteins are of immense significance due to their wide applications in biological systems, extraction/separation and electrochemical analysis [1].

Most proteins are not only surrounded by water but various kinds of organic and inorganic compounds which greatly effects the structures and properties of proteins including their solubility, denaturation, dissociation into subunits and the activity of enzymes [2-3]. Due to complicated structure of proteins, it is rather difficult to study their thermodynamic and transport properties. Amino acids are the low molar mass model compounds or building blocks of proteins which can be used for studies which are expected to set impacts on the solvation and conformation of proteins [4-5]. Amino acids differ from each other in size, charge, hydrogen-bonding capacity, hydrophobicity and chemical reactivity. Hence, these side chains contribute to the structure and function of proteins, individually and collectively. Since most of the biochemical processes are hosted by aqueous media, the study of simple biomolecules (amino acids, sugars) in aqueous solutions provide useful information for understanding the complex mechanism at molecular level [6-7].

Because of the complex structure of proteins, direct studies of solute–solvent effects on these biological macromolecules are quite difficult. Therefore, to study the interactions of these macromolecules, some simple model compounds such as amino acids which are the basic structural units of proteins are generally taken. There is a difference in the side chains of these model compounds due to the size, shape, charge, hydrogen-bonding capacity, hydrophobicity, and chemical reactivity, due to which these side chains contribute to the structure and function of proteins, individually and collectively. The study of viscous behavior of macromolecules in solution is important in understanding the mechanism of transport processes. Viscosity and its derived parameters provide valuable information regarding the shape and size of these molecules. As the viscosity of solution is a vital property in the process of separation, it would be of interest to examine the effect of saccharides on the viscosity of aqueous amino acid solutions.

Some insights about the molecular interactions (hydrophilic, hydrophobic and ionic interactions) could be made with the aid of thermodynamic and transport studies in aqueous media of different concentrations. The interactions of water with the various functional groups of proteins are important factors in determining the conformational stability of proteins [8-9]. The stabilization of native conformations of biological

macromolecules (proteins) is related to several non-covalent interactions including hydrogen-bonding, electrostatic and hydrophobic interactions [10, 11]. These interactions are affected by the surrounding solute and solvent molecules, which are studied through properties like partial molar volume, partial molar compressibility and viscosity studies. (Solute + solute) and (solute + solvent) interactions are elucidated by these convenient parameters.

The protein-saccharide interactions underlie many important aspects of biological processes occurring in living organisms, such as cell differentiation, cell adhesion, viral and bacterial infections [12-13] immune response metastatic spread and growth trafficking and tumor cell metastasis and some enzymatic reactions etc. Therefore, these interactions have been the subject of intense investigations over recent years. Analysis of the literature [14-19] shows that, in general, intermolecular interactions between large organic molecules (saccharides and proteins) in aqueous medium are non covalent and accompanied by small energy changes.

Thermodynamic properties of amino acids in aqueous electrolyte solutions can provide valuable information regarding the stability of proteins in these solutions, their solubility, separation and purification, solute–solvent and solute–solute interactions. The studies of interactions between ionic liquids and proteins are of immense significance due to their wide applications in biological systems, extraction/separation and electrochemical analysis Volumetric study on electrolytic aqueous solutions provides valuable information about the ion–ion, ion–solvent and solvent–solvent interactions. This information is of fundamental importance for understanding the reaction rates and equilibriums involving dissolved electrolytes and also helps in characterizing the structure and properties of the solutions [20-27]. The solution structure is of great importance in understanding the nature of action of bioactive molecules in the body system [28-32].

As typical hydroxy compounds, alcohols are usually used as sugar replacer due to its low calorie and little effect on blood sugar level, and thus have been used widely in the pharmaceutical and food industries. Therefore, the properties of amino acids in aqueous alcohol solution have also been studied by some workers in order to obtain a better understanding of solute solvent interactions and the role of alcohol on the conformational stability of proteins. It has been reported in these studies that polyhydric alcohols increase the thermal stability of proteins or reduce the extent of their denaturation by other reagents. Moreover, the properties of solution of alcohols in aqueous and mixed solution are important in many areas of applied chemistry and are essential for understanding chemistry of biological system.

On the other hand, electrolytes or salts are universally found in all living systems. At low concentration, they exert salting-in effects on polyelectrolytes such as proteins, and stabilize them through non-specific electrostatic interactions [33]. Electrolyte or salt is an ionic compound that results from the neutralization reaction of an acid and a base [30]. The long held belief that a high sodium chloride (NaCl) diet raises the risk of cardio-vascular disease is coming under scrutiny. More recently, dietary salt was demonstrated to attenuate nitric oxide production which contributes to vessel homeostasis by inhibiting vascular smooth muscle contraction and growth, platelet aggregation and leukocyte adhesion to the endothelium [34]. Potassium is vital in the human body, and oral potassium chloride (KCl) is the common means to replenish it, although it can also be diluted and given intravenously. It can be used as a salt substitute for food, but due to its weak, bitter, unsalty flavor, it is usually mixed with ordinary table salt (NaCl) for this purpose to improve the taste. It helps to maintain the body balance [35]. Magnesium sulfate ($MgSO_4$) is commonly known as Epsom Salt and used both externally as well as internally [36]. The distribution of ions near the protein surface and the stability of various structural motifs are observed to exhibit interesting dependence on the local sequence and structure. The structures of sodium and potassium chlorides in their solutions differ in being surrounded in their first spheres by relatively fewer or more of flickering water clusters due to their ionic size differences [37-42].

Therefore, in the present study, we proposed to measure density and viscosity values for amino acids, Glycine and Arginine, in aqueous solution of saccharides, electrolytes and alcohols at room temperature. From these values different physicochemical parameters like apparent molar volume (ϕ_v), partial molar volume (ϕ_v^o), partial molar volume of transfer ($\Delta\phi_v^o$), viscosities (η), etc. have been calculated and discussed in terms of amino acid-additive intermolecular interactions.

MATERIALS AND METHODS:

Materials: Distilled water with conductivity ~2-4×10^{-6} s·cm^{-1}and pH of 6.8–7.0 at 298.15 K has been used for all experiments. Saccharides (D-Glucose, D-Fructose, D-Galactose), alcohols (Glycerol, Mannitol, Methanol), electrolytes (NaCl, KCl, $MgSO_4$) and amino acids (Arginine, Gycine) (for biochemistry) with high purity have been purchased

from Nice Chemical Private Limited. All the chemicals have been recrystallized in distilled water and dried in oven for 24 hrs. After this they have been kept in a vacuum desiccator over anhydrous calcium chloride at room temperature for a minimum of 48 hours.

Methods:

Volumetric measurements: Density measurements of experimental solutions have been carried out by using pycnometer [43]. It is a flask with a close fitting ground glass stopper with a fine hole through it, so that a given volume can be accurately obtained. The apparatus was calibrated by using distilled water. So obtained density of distilled water was in good agreement with the density reported in literature [43]. The reproducibility of density data was ± 3×10^{-3} g.cm^{-3} at room temperature.

Viscometric measurements: Viscometric measurements have been carried out by using Ostwald viscometer [44] with flow time 354 s for pure water at 25 ^{o}C. The apparatus was calibrated by using distilled water. Experimental value of viscosity for water was very close to the value reported in literature [44]. The viscosity values were found to be reproducible within ± 0.005 cP.

RESULTS AND DISCUSSION:

Volumetric Measurements: Density measurements have been carried out for amino acids, arginine and glycine (0.01–0.09 mol·kg^{1}) in aqueous solution of methanol, glycerol, mannitol, fructose, glucose, galactose, NaCl, KCl and $MgSO_4$ (0.05mol·kg^{-1}) by using pycnometer at room temperature. Using density data, the apparent molar volumes (ϕ_v) for amino acids have been calculated from the relation [45, 46]:

$$\phi_v = \frac{M}{\rho} - \left[\frac{(\rho-\rho_o)}{m\rho\rho_o}\right] \qquad (1)$$

where m (mol·kg^{-1}) is the molality of the solution, M (kg·mol^{-1}) is the relative molar mass of solute (amino acid), ρ (kg·m^{-3}) is the density of the solution and ρ_o (kg·m^{-3}) is the density of the solvent. The molality, experimental densities and apparent molar volumes for glycine and arginine in pure water and 0.05 mol·kg^{-1} aqueous solutions of methanol, glycerol, mannitol, fructose, glucose, galactose, NaCl, KCl and $MgSO_4$ at room temperature are summarized in Table 1 and Table 2, respectively. A survey of these data revealed that densities increase monotonously with increase in molalities of amino acids. Further, the ϕ_v values are negative and increase with the concentration of both the amino acids. From Figures 1 and 2 it is clear that ϕ_v varies linearly with the molalities of both the amino acids, therefore, partial molar volumes (ϕ_v^o) have been obtained by fitting the experimental data to the equation [46, 43].

$$\phi_v = \phi_v^{\,o} + S_v m \qquad (2)$$

where S_v is the experimental slope and ϕ_v^o is the intercept [47]. The ϕ_v^o represents the solute-solvent interactions and S_v is volumetric pair wise interaction coefficient [43]. It is observed from Table 3 that, S_v values for both the amino acids in different aqueous solutions of additives are positive, indicating the existence of solute- solute interactions. It is noteworthy that, all the values of ϕ_v^o which reflects the solute-solvent interactions are negative (Table 3) and increase in the order, methanol < glycerol < mannitol; glucose < galactose < fructose and NaCl < KCl < $MgSO_4$. This is probably due to the reduction of electrostriction of water with type of additives. The limiting transfer properties can provide qualitative information regarding the interaction of a co-solvent and a solute without considering the effects of solute-solute interactions [48].

The ϕ_v^o data in water and in aqueous additive solutions have been used to calculate the partial molar volumes of transfer ($\Delta_{tr}\phi_v^o$) of amino acid from water to aqueous additive solutions by the equation [43]:

$$\Delta_{tr}\phi_v^o = \phi_v^{\,o}(aq.alcohol) - \phi_v^{\,o}(water) \qquad (3)$$

From above equation, it is clear that $\Delta_{tr}\phi_v^o$ values are free from solute-solute interactions and therefore provides information regarding only solute-solvent interactions. From Table 3 it can be seen that the $\Delta_{tr}\phi_v^o$ values are positive and increase in the order: methanol < glycerol < mannitol; glucose < galactose < fructose and NaCl < KCl < $MgSO_4$. This can be explained on the basis of the co-sphere overlap model [49,50]. According to this model the main types of interactions occurring between amino acids and different additives are:

(1). Ion-hydrophilic interactions between the zwitter ionic groups (NH_3^+, COO^-) of amino acids and the hydrophilic groups of additives.

(2). Hydrophilic-hydrophilic interaction between the hydrophilic groups of amino acids and the hydrophilic groups of additives.

(3). Ion-hydrophobic interaction between the zwitter ionic groups (NH_3^+, COO^-) of amino acids and the hydrophobic groups of additives.

(4). Hydrophobic-hydrophobic interactions between the alkyl chain of amino acids and hydrophobic groups of additives.

(5). Hydrophobic-hydrophilic interactions between the alkyl chain of amino acids and hydrophobic groups of additives.

Analyzing the above information, the interactions of the type (1) and type (2) make positive contribution to the partial molar volume of transfer, since the overlap of hydration cospheres of charged ions (NH_3^+, COO^-) of amino acids and the hydrophilic groups of additives (like -OH, K^+, Cl^-) could lead to the reduction of electrostriction of water molecules lying in the proximity of these amino acids. The interactions of type (3), (4), and (5) contribute negative to the $\Delta_{tr}\phi_v^o$ values. Therefore, the positive $\Delta_{tr}\phi_v^o$ values indicate that, the interactions of the type (1) and (2) predominate over other type of interactions.

Consequently, in the above order it can be said that with increase in hydrophilicity from methanol to glycerol to mannitol; glucose to galactose to fructose and NaCl to KCl to $MgSO_4$, the contribution of first two types of interactions increases which make the $\Delta_{tr}\phi_v^o$ values more and more positive. Further, it can be analyzed from Table 3 that $\Delta_{tr}\phi_v^o$ values of arginine are generally greater in magnitude as compared to glycine. It can be attributed to the fact that, in arginine, the zwitterionic groups (NH^{3+}, COO^-) and amino-group (CNHNHNH2) is more easy to interact with – hydrophilic groups of additives which produces greater $\Delta_{tr}\phi_v^o$ values than in case of glycine. Similar results have been reported by Ren et al. [51] in case of different amino acids in aqueous solutions of additives.

Table 1: Molality (m), density (ρ), apparent molar volume (ϕ_v), and viscosity (η) for glycine in pure water and 0.05 mol·kg^{-1} aqueous solution of Methanol, Glycerol, Mannitol, Fructose, Glucose, Glactose, KCl, NaCl and $MgSO_4$ at room temperature.

m (mol·kg^{-1})	m$^{1/2}$ (mol$^{1/2}$·kg$^{-1/2}$)	ρ (kg/m^3)	$\phi_v \times 10^4$ (m^3·mol^{-1})	η (cP)
		Pure Water		
0.00	–	1110	–	0.890
0.01	0.100	1115	-3.37	0.930
0.03	0.173	1123	-2.81	0.977
0.05	0.224	1129	-2.37	1.014
0.07	0.265	1132	-1.84	1.048
0.09	0.300	1134	-1.46	1.080
		Methanol		
0.00	–	1132	–	1.220
0.01	0.100	1136	-2.45	1.171
0.03	0.173	1143	-2.18	1.184
0.05	0.224	1149	-1.96	1.213
0.07	0.265	1154	-1.76	1.248
0.09	0.300	1157	-1.47	1.290
		Glycerol		
0.00	–	1139	–	1.250
0.01	0.100	1143	-2.42	1.300
0.03	0.173	1149	-1.89	1.402

0.05	0.224	1153	-1.48	1.502
0.07	0.265	1154	-0.98	1.599
0.09	0.300	1155	-0.70	1.694
		Mannitol		
0.00	–	1143	–	1.260
0.01	0.100	1147	-2.40	1.299
0.03	0.173	1154	-2.13	1.418
0.05	0.224	1160	-1.92	1.537
0.07	0.265	1165	-1.72	1.653
0.09	0.300	1169	-1.52	1.768
		Fructose		
0.00	–	1115	–	0.911
0.01	0.100	1117	-0.93	0.926
0.03	0.173	1121	-0.93	0.944
0.05	0.224	1124	-0.77	0.962
0.07	0.265	1127	-0.69	0.988
0.09	0.300	1130	-0.66	1.021
		Glucose		
0.00	–	1113	–	0.920
0.01	0.100	1116	-2.55	0.935
0.03	0.173	1121	-2.26	0.956
0.05	0.224	1123	-2.04	0.979
0.07	0.265	1130	-1.6	1.001
0.09	0.300	1134	-1.27	1.027
		Glactose		
0.00	–	1114	–	0.930
0.01	0.100	1117	-1.74	0.925
0.03	0.173	1122	-1.47	0.938
0.05	0.224	1126	-1.25	0.963
0.07	0.265	1130	-1.04	0.993
0.09	0.300	1132	-0.92	1.029
		KCl		
0.00	–	1119	–	0.90
0.01	0.100	1121	-0.93	0.77
0.03	0.173	1126	-1.19	0.78
0.05	0.224	1132	-1.39	0.80

0.07	0.265	1139	-1.57	0.87
0.09	0.300	1146	-1.68	0.96
		NaCl		
0.00	-	1124	-	0.92
0.01	0.100	1152	-20.97	0.87
0.03	0.173	1192	-16.29	0.90
0.05	0.224	1200	-10.64	0.93
0.07	0.265	1205	-7.92	0.97
0.09	0.300	1207	-6.18	1.02
		$MgSO_4$		
0.00	-	1156	-	0.97
0.01	0.100	1166	-6.78	0.94
0.03	0.173	1182	-5.71	0.96
0.05	0.224	1189	-4.17	1.00
0.07	0.265	1193	-3.20	1.06
0.09	0.300	1197	-2.67	1.10

Table 2: Molality (m), density (ρ), apparent molar volume (ϕ_v), and viscosity (η) for arginine in pure water and 0.05 mol·kg^{-1} aqueous solution of methanol, glycerol and mannitol, fructose, glucose, glactose, KCl, NaCl and $MgSO_4$ at room temperature.

m (mol·kg^{-1})	m$^{1/2}$ (mol$^{1/2}$·kg$^{-1/2}$)	ρ (kg/m^3)	ϕ_v ×10^4 (m^3·mol^{-1})	η (cP)
		Pure Water		
0.01	0.100	1116	-3.28	0.884
0.03	0.173	1126	-2.72	0.929
0.05	0.224	1134	-2.28	0.981
0.07	0.265	1139	-1.75	1.038
0.09	0.300	1141	-1.19	1.085
		Methanol		
0.01	0.100	1138	-3.13	1.204
0.03	0.173	1148	-2.59	1.218
0.05	0.224	1156	-2.16	1.240
0.07	0.265	1162	-1.76	1.265
0.09	0.300	1166	-1.37	1.288
		Glycerol		
0.01	0.100	1144	-2.32	1.261

0.03	0.173	1152	-1.79	1.299
0.05	0.224	1158	-1.38	1.338
0.07	0.265	1161	-0.88	1.381
0.09	0.300	1162	-0.43	1.424
		Mannitol		
0.01	0.100	1147	-1.53	1.284
0.03	0.173	1154	-1.27	1.330
0.05	0.224	1160	-1.06	1.374
0.07	0.265	1165	-0.87	1.418
0.09	0.300	1169	-0.67	1.466
		Fructose		
0.01	0.100	1118	-0.85	0.914
0.03	0.173	1123	-0.58	0.923
0.05	0.224	1128	-0.52	0.936
0.07	0.265	1132	-0.39	0.957
0.09	0.300	1135	-0.22	0.979
		Glucose		
0.01	0.100	1117	-1.66	0.921
0.03	0.173	1123	-1.38	0.932
0.05	0.224	1128	-1.01	0.945
0.07	0.265	1132	-0.95	0.955
0.09	0.300	1134	-0.84	0.973
		Galactose		
0.01	0.100	1117	-0.85	0.925
0.03	0.173	1122	-0.58	0.934
0.05	0.224	1126	-0.37	0.948
0.07	0.265	1128	-0.05	0.962
0.09	0.300	1130	0.13	0.982
		KCl		
0.01	0.100	1151	-23.33	0.910
0.03	0.173	1194	-17.25	0.930
0.05	0.224	1201	-10.75	0.950
0.07	0.265	1206	-7.77	1.020
0.09	0.300	1210	-6.03	1.090
		NaCl		
0.01	0.100	1152	-20.11	1.010

0.03	0.173	1191	-15.22	1.070
0.05	0.224	1203	-10.24	1.100
0.07	0.265	1211	-7.69	1.130
0.09	0.300	1218	-6.35	1.150
		$MgSO_4$		
0.01	0.100	1171	-9.60	1.030
0.03	0.173	1192	-7.25	1.080
0.05	0.224	1206	-5.73	1.110
0.07	0.265	1212	-4.27	1.120
0.09	0.300	1220	-3.62	1.140

Viscometer Measurements: Viscometric properties of these amino acids in aqueous solutions of additives can also provide valuable clues for investigating the solution behavior in light of different interactions. In view of this, the viscometric measurements of amino acids over a wide range of experimental conditions have been carried out in the aqueous solution of different additives at room temperature. The analysis of the data have been carried out by using Jones–Dole equation [51] of the form

$$\psi = (\eta_r - 1)/m^{1/2} = A + Bm^{1/2} \qquad (4)$$

where $\eta_r (= \eta/\eta_o)$ is the relative viscosity of the solution, η and η_o are the viscosities of solution and the solvent (aqueous additives), respectively, m is the molality of amino acid solutions, A is Falkenhagen coefficient and B is the Jones–Dole coefficient. Falkenhagen coefficient, A- accounts for the solute–solute interactions. Jones-Dole coefficient, B– is a measure of structural modifications induced by the solute–solvent interactions. The viscosity data for glycine and arginine in pure water and 0.05 $mol.kg^{-1}$ aqueous solutions of additives at room temperature are given in Table 1 and Table 2, respectively. A perusal of these Tables revealed that η values are increasing monotonously with increasing molalities of amino acids in all the cases. From the overall comparison, η values increase from glycine to arginine. From Figures 3 & 4, it is clear that $(\eta_r - 1)/m^{1/2}$ varies linearly with the molalities of both the amino acids. Therefore, the value of viscosity A and B- coefficients can be find out by using equation (4) and are tabulated in Table 3. It is observed that viscosity B-coefficient values are positive for both the amino acids, indicating the strong solute- solvent interactions. Further, the viscosity B–coefficient values have been used to calculate the viscosity B–coefficient of transfer ($\Delta_{tr}B$) of amino acid from water to aqueous additive solution by using the equation:

$$\Delta_{tr}B = B(aq.alcohol) - B(water) \qquad (5)$$

The $\Delta_{tr}B$ values are summarized in Table 3. From the data, it can be inferred that the $\Delta_{tr}B$ values are positive and increase with hydrophilicity of the additives, showing the interactions which are taking place are purely electrostatic. Similarly, the $\Delta_{tr}B$ values of arginine are greater than that of glycine in each case. These all outcomes of viscosity measurements are in accordance with the outcomes of volumetric measurements.

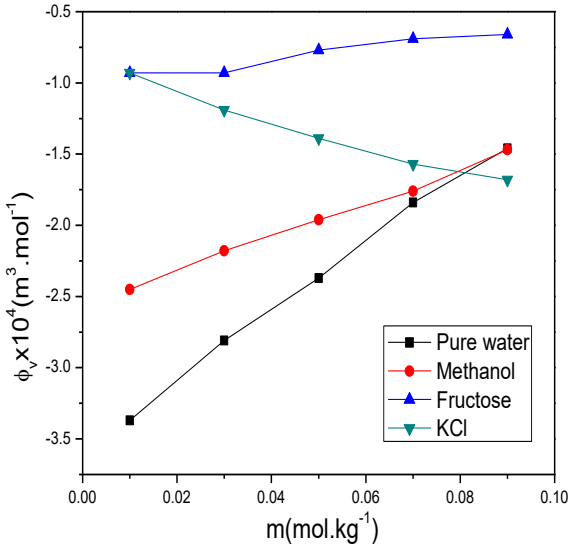

Figure 1: Plot of ϕ_v versus m for glycine in pure water and 0.05 mol.kg^{-1} aqueous solution of additive at room temperature.

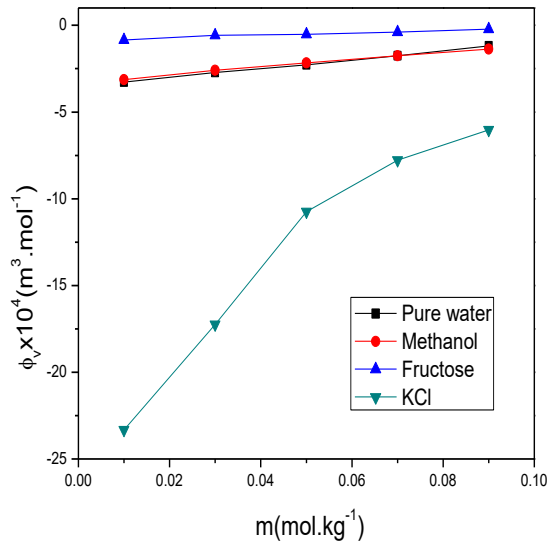

Figure 2: Plot of ϕ_v versus m for arganine in pure water and 0.05 mol.kg^{-1} aqueous solution of additive at room temperature.

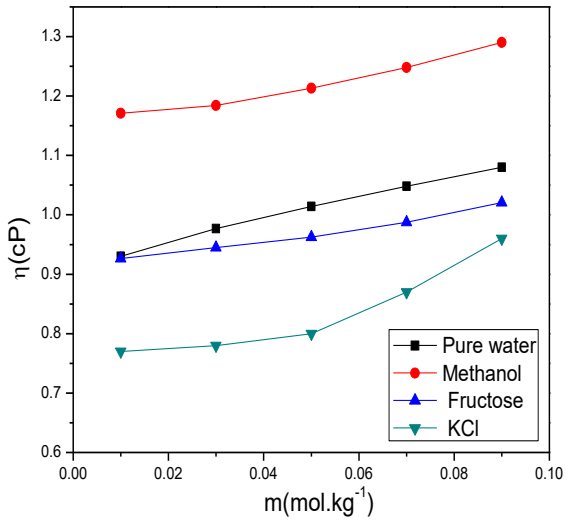

Figure 3: Plot of η versus m for glycine in pure water and 0.05 mol.kg^{-1} aqueous solution of additive at room temperature.

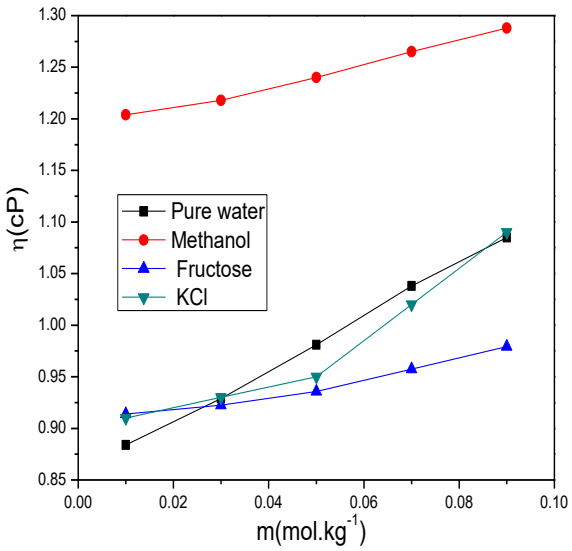

Figure 4: Plot of η versus m for argnine in pure water and 0.05 mol.kg^{-1} aqueous solution of additive at room temperature.

Table 3: Slope (S_v), intercept (ϕ_v^o), partial molar volume of transfer ($\Delta_{tr}\phi_v^o$) Falkenhagen coefficient (A), Jones- Dole coefficient (B), and viscosity B-coefficient of transfer ($\Delta_{tr}B$) for glycine and arginine in pure water and 0.05 mol·kg^{-1} aqueous solution of methanol, glycerol, mannitol, fructose, glucose, glactose, KCl, NaCl and $MgSO_4$ at room temperature.

Solvent	S_v ($m^3.kg.mol^{-2}$)	ϕ_v^o ($m^3 \cdot mol^{-1}$)	$\Delta_{tr}\phi_v^o$ ($m^3 \cdot mol^{-1}$)	A ($kg^{1/2}.mol^{-1/2}$)	B ($Kg.mol^{-1}$)	$\Delta_{tr}B$ ($kg.mol^{-1}$)
			Glycine			
Pure Water	25.00	-3.62	–	0.360	1.18	–
Methanol	12.25	-2.572	1.047	-0.628	2.11	0.93
Glycerol	19.50	-2.455	1.165	0.053	2.37	1.19
Mannitol	10.25	-2.437	1.182	-0.158	3.90	2.72
Fructose	1.14	-0.991	2.539	0.14	1.28	0.10
Glucose	16.50	-2.749	0.781	0.14	1.30	0.12
Glactose	10.75	-1.801	1.729	-0.10	1.49	0.31
NaCl	102.57	-0.88	9.64	-0.42	4.06	2.88
KCl	209.25	-21.88	18.35	-0.52	6.20	5.02
$MgSO_4$	6.75	-7.18	3.65	-0.67	3.04	1.86
			Arginine			
Pure Water	27.25	-3.64	–	0.190	0.69	–
Methanol	19.75	-3.15	0.49	-0.28	2.23	1.54
Glycerol	23.50	-2.55	1.08	-0.10	3.22	2.53
Mannitol	10.00	-1.57	2.07	-0.08	4.62	3.93
Fructose	7.50	-0.87	2.75	0.03	0.81	0.12
Glucose	4.25	-1.69	0.79	0.003	0.83	0.14
Glactose	12.25	-0.97	1.91	-0.07	2.07	1.38
NaCl	87.00	-20.04	18.23	-0.74	4.10	3.31
KCl	97.25	-24.68	22.87	-0.30	4.52	3.83
$MgSO_4$	32.50	-9.83	8.01	-0.89	3.26	2.57

CONCLUSIONS:

The findings suggest that interaction of amino acids in aqueous solution of additives is relatively unique and electrostatic interactions dominant over hydrophobic interactions. However, plausible explanations have been proposed to describe the experimental data. The information derived from the apparent molar volume data are found to be fairly consistent with the results of viscosity A– and B– coefficients of amino acids, when examined as a function of nature of amino acid as well as type of additives.

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