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EFFECT OF DISODIUM TARTRATE ON PARTIAL MOLAR VOLUMES AND COMPRESSIBILITIES OF L-SERINE IN AQUEOUS SOLUTIONS AT DIFFERENT TEMPERATURES

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ABSTRACT

Ultrasonic velocity, density and refractive index of L-serine in aqueous solutions of (0.5, 1.0 and 1.5) mol L^{-1} disodium tartrate have been measured at T= (303.15, 308.15 and 313.15) K. The effects of disodium tartrate and temperature on different thermodynamic properties have been evaluated. The apparent molar volume ($V_{2,\phi}$) and apparent molar isentropic compressibility ($\kappa_{S,2,\phi}$) have been computed from the ultrasonic velocity and density data. The limiting apparent molar volume ($V^{o}_{2,\phi}$) and compressibility ($\kappa^{0}_{s,2,\phi}$) were determined from respective graphical fittings. The transfer volumes ($\Delta_t V^{o}_{2,\phi}$) and compressibilities ($\Delta_t \kappa^{0}_{s,2,\phi}$) for amino acid from water to salt have been computed. The computed thermodynamic properties have been interpreted in terms of interactions between zwitterionic groups or side chain of amino acids and different polar or ionic sites in salt.

KEYWORDS: Amino acid· Partial molar volume· Disodium tartrate· Molecular interactions.

INTRODUCTION

Proteins are made up of similar kinds of monomeric subunits of amino acids and stabilized by the noncovalent interactions including electrostatic, hydrogen bonding, van der Waal and hydrophobic interaction. The molecular interactions of protein in solution are significantly influenced by temperature and the presence of additives, such as electrolytes/salts, non-electrolytes and organic solutes.[1-5] These additives strongly affect the structure and

properties of globular proteins, including their hydration, solubility, dissociation and activity of enzyme.[6-8] Due to complex structure of proteins, it is very difficult to predict interactions that take place between protein and salts. On the other hand, amino acids are monomer unit of protein and have a simple structure therefore are used as model compounds to investigate the protein-salt interaction in aqueous solutions.[9-11] The electrolytes influence the solution behavior of protein including electrostriction and conformation. Therefore, physicochemical properties of amino acids can provide useful information about the solute-solute and solute-solvent interaction as well as structure breaking and making tendency of amino acids in solution.

Many research groups in the last decade have been published a number of research articles on the thermodynamic properties of natural amino acids in aqueous salts solution. Recently, Harsh Kumar et al. reported the thermodynamic properties of L-serine and L-threonine in aqueous solution of trilithium citrate.[6] The apparent molar volume and isentropic compressibilities of ternary system (Water + glycine + NaBr, KCl, KBr and $MgCl_2$) have been studied by Rohini Badarayani and Anil Kumar.[12] Volumetric and viscometric properties of some amino acids in aqueous solutions of antibiotic drug were studied by Suvarcha Chauhan et al.[13] Furthermore, several researchers reported ultrasonic velocity and densities of amino acids in salts solution to understand the molecular interaction occurring among the amino acids and aqueous salts solutions.[14-17] The thermodynamic properties of amino acids in aqueous salts solution give an important information concern with structural fitting and solute-solvent interaction.

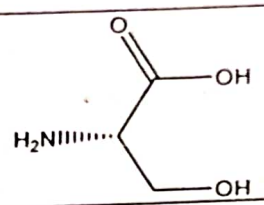
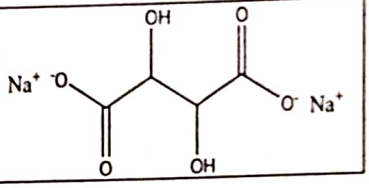
According to literature survey, there is no data on density, ultrasonic velocity and refractive index of amino acids in aqueous solution of disodium tartrate dihydrate (DST). Therefore, here, we have selected DST in the form of its dihydrate as an electrolyte; as it is often used as binding agent and emulsifier in many food products and its ions in aqueous solutions play an important role in many biochemical processes.[18-20] The ions (COO^-&Na^+) and hydrophilic (-OH) groups of DST interact with the end group of amino acids. Therefore, in view of lack of the work and in continuation with our program to study thermodynamic properties and molecular interactions in solution[21-23], here, we report the density, ultrasonic velocity and refractive index of L-serine in aqueous solutions of (0.5, 1.0 and 1.5) $mol{\cdot}L^{-1}$ DST at temperatures 303.15, 308.15 and 313.15 K. The density and ultrasonic velocity results are

further used to compute the different thermodynamic parameters which are used to understand the effects of DST on solution behavior of selected amino acid.

MATERIAL AND METHODS

L-serine (56-45-1, ≥ 99.00-101.00%) were acquired from HiMedia Laboratories Pvt. Ltd. Disodium tartrate dihydrate (DST, 6106-24-7, extra pure AR grade, ≥ 99 %) was purchased from HiMedia Laboratories Pvt. Ltd and used without further purification.

Table 1. Specification of chemicals.

Chemical name and CAS No.	Minimum Assay in %	Molecular weight/g·mol^{-1}	Source	Structure of compound
L-serine 56-45-1	99.00-101.00	105.09	HiMedia Laboratories Pvt. Ltd.	
Disodium Tartrate dihydrate 6106-24-7 (DST)	99.00	230.08	HiMedia Laboratories Pvt. Ltd.	

Aqueous solutions of DST (0.5, 1.0 and 1.5 mol·L^{-1}) were prepared by using triple distilled water and these were used as solvent to prepare L-serine solutions of different concentrations (0.002-0.220 mol·kg^{-1}). Weighing was done on Anamed (Model AA-2200) analytical balance having a precision of ±0.0001 g. All the solutions were prepared a fresh and stored in airtight bottles to avoid evaporation and contamination. The absolute uncertainty in the concentration of solutions is found to be less than ±1 × 10^{-4} mol·kg^{-1}. The specifications of chemicals used in the studied system are given in Table 1.

Densities were measured by using pycnometer (Borosil glass, Class "A", 10.00±0.30 ml). The pycnometer was calibrated by using triple distilled water. Ultrasonic velocity was measured using ultrasonic interferometer (Mittal, F05, 1516096, 1.9903 MHz ±0.0001) with micrometer (0.001 mm) and stainless steel sample cell. The constant temperature water bath (±0.1 °C) arrangement having digital temperature controller was used to maintain the temperature constant. The interferometer was calibrated with triple distilled water and methanol. Refractive index of solutions was measured by using the Cyber LAB-Cyber Abbe Refractometer (Amkette Analytics, ±0.0002, 1.3000 to 1.7000).

RESULTS AND DISCUSSION

The experimental values of densities, refractive index and ultrasonic velocities of L-serine in aqueous solutions of 0.5, 1.0 and 1.5 mol·L^{-1} DST at temperatures T= 303.15, 308.15 and 313.15 K are reported in Table 2. The density, refractive index and ultrasonic velocity values increase as an increasing in the concentration of amino acids as well as DST at all temperatures which suggest better association of molecule due to effective solute-solute and solute-solvent interactions.[24-26] Densities and refractive index decreases with an increase in temperature and ultrasonic velocities increases with increase in temperature, which is consistent with the trends of these properties for the aqueous solutions.

Table 2: Densities, ultrasonic velocities, refractive index, apparent molar volume, $V_{2,\phi}$ isentropic compressibilities, κ_s and apparent molar isentropic compressibilities, $\kappa_{S,2,\phi}$, of L-serine in aqueous solutions of DST at different temperatures

m, mol·kg^{-1}	p, g·cm^{-3}	u, m·s^{-1}	n	$V_{2,\phi}$, 10^{-6} m^3·mol^{-1}	κ_s, 10^{-10} m^{-2}·N^{-1}	$\kappa_{S,2,\phi}$, 10^{-15} m^3·mol^{-1}·Pa^{-1}
L-Serine + Water						
303.15 K						
0.0000	995.70	1509.23	1.3319	-	4.409	-
0.0201	996.59	1510.39	1.3324	60.83	4.399	-26.72
0.0605	998.35	1512.74	1.3329	61.20	4.377	-26.48
0.1011	1000.11	1515.11	1.3336	61.27	4.356	-26.41
0.1418	1001.84	1517.51	1.3342	61.49	4.334	-26.26
0.1828	1003.57	1519.93	1.3347	61.63	4.313	-26.13
0.2240	1005.30	1522.39	1.3353	61.72	4.292	-26.09
308.15 K						
0.0000	994.10	1519.85	1.3314	-	4.355	-
0.0201	994.98	1520.99	1.3319	61.36	4.344	-25.25
0.0606	996.73	1523.30	1.3325	61.63	4.324	-25.05
0.1012	998.47	1525.63	1.3331	61.75	4.303	-24.97
0.1421	1000.17	1528.03	1.3336	62.11	4.282	-24.83
0.1831	1001.87	1530.44	1.3341	62.29	4.261	-24.75
0.2244	1003.54	1532.90	1.3347	62.55	4.241	-24.62
313.15 K						
0.0000	992.30	1528.95	1.3305	-	4.311	-
0.0202	993.17	1530.10	1.3311	62.11	4.301	-24.42
0.0607	994.90	1532.40	1.3317	62.24	4.280	-24.17
0.1014	996.60	1534.73	1.3323	62.57	4.260	-23.90
0.1423	998.30	1537.07	1.3329	62.70	4.240	-23.74
0.1835	999.95	1539.43	1.3335	63.08	4.220	-23.37
0.2248	1001.57	1541.90	1.3341	63.43	4.200	-23.27
L-serine + 0.5 mol·L^{-1} DST						
303.15 K						
0.0000	1059.96	1578.61	1.3469	-	3.786	-

0.0189	1060.73	1580.08	1.3490	62.84	3.776	-25.11
0.0568	1062.26	1583.01	1.3495	62.97	3.757	-24.79
0.0949	1063.77	1585.96	1.3501	63.18	3.737	-24.54
0.1333	1065.28	1588.88	1.3510	63.31	3.718	-24.20
0.1718	1066.76	1591.81	1.3514	63.51	3.700	-23.87
0.2105	1068.21	1594.66	1.3519	63.77	3.681	-23.35
308.15 K						
0.0000	1058.48	1586.74	1.3463	-	3.752	-
0.0189	1059.24	1588.19	1.3474	63.35	3.743	-23.96
0.0569	1060.74	1591.11	1.3479	63.70	3.724	-23.66
0.0951	1062.23	1593.99	1.3484	63.86	3.705	-23.21
0.1335	1063.70	1596.86	1.3488	64.07	3.687	-22.80
0.1720	1065.16	1599.75	1.3493	64.21	3.668	-22.55
0.2108	1066.61	1602.49	1.3500	64.37	3.651	-21.96
313.15 K						
0.0000	1056.77	1594.87	1.3456	-	3.720	-
0.0189	1057.52	1596.31	1.3460	63.87	3.711	-23.08
0.0570	1059.01	1599.22	1.3467	64.12	3.692	-22.87
0.0952	1060.47	1602.10	1.3474	64.42	3.674	-22.42
0.1337	1061.93	1604.97	1.3481	64.57	3.656	-22.06
0.1723	1063.35	1607.77	1.3487	64.84	3.638	-21.51
0.2112	1064.79	1610.65	1.3492	64.95	3.620	-21.30
L-serine+1.0 mol L^{-1} DST						
303.15 K						
0.0000	1120.96	1651.82	1.3610	-	3.270	-
0.0179	1121.60	1653.65	1.3616	65.26	3.260	-24.04
0.0539	1122.86	1657.31	1.3621	65.59	3.242	-23.62
0.0902	1124.10	1661.01	1.3635	65.86	3.224	-23.38
0.1268	1125.33	1664.75	1.3642	66.07	3.206	-23.20
0.1637	1126.53	1668.49	1.3655	66.34	3.189	-22.91
0.2010	1127.75	1672.20	1.3662	66.46	3.171	-22.60
308.15 K						
0.0000	1118.94	1655.92	1.3606	-	3.259	-
0.0179	1119.56	1657.73	1.3610	66.22	3.250	-22.98
0.0540	1120.78	1661.39	1.3618	66.59	3.232	-22.73
0.0903	1122.01	1665.02	1.3625	66.58	3.215	-22.49
0.1270	1123.19	1668.76	1.3632	66.94	3.197	-22.30
0.1640	1124.37	1672.47	1.3640	67.15	3.180	-22.03
0.2014	1125.55	1676.13	1.3648	67.31	3.162	-21.67
313.15 K						
0.0000	1117.68	1660.00	1.3598	-	3.247	-
0.0179	1118.28	1661.82	1.3610	67.16	3.238	-22.47
0.0540	1119.47	1665.47	1.3615	67.38	3.220	-22.13
0.0904	1120.65	1669.13	1.3621	67.55	3.203	-21.85
0.1272	1121.83	1672.83	1.3628	67.66	3.185	-21.67
0.1642	1122.99	1676.53	1.3635	67.82	3.168	-21.43
0.2016	1124.15	1680.23	1.3642	67.94	3.151	-21.18
L-serine + 1.5 mol L^{-1} DST						

0.0189	1060.73	1580.08	1.3490	62.84	3.776	-25.11
0.0568	1062.26	1583.01	1.3495	62.97	3.757	-24.79
0.0949	1063.77	1585.96	1.3501	63.18	3.737	-24.54
0.1333	1065.28	1588.88	1.3510	63.31	3.718	-24.20
0.1718	1066.76	1591.81	1.3514	63.51	3.700	-23.87
0.2105	1068.21	1594.66	1.3519	63.77	3.681	-23.35
308.15 K						
0.0000	1058.48	1586.74	1.3463	-	3.752	-
0.0189	1059.24	1588.19	1.3474	63.35	3.743	-23.96
0.0569	1060.74	1591.11	1.3479	63.70	3.724	-23.66
0.0951	1062.23	1593.99	1.3484	63.86	3.705	-23.21
0.1335	1063.70	1596.86	1.3488	64.07	3.687	-22.80
0.1720	1065.16	1599.75	1.3493	64.21	3.668	-22.55
0.2108	1066.61	1602.49	1.3500	64.37	3.651	-21.96
313.15 K						
0.0000	1056.77	1594.87	1.3456	-	3.720	-
0.0189	1057.52	1596.31	1.3460	63.87	3.711	-23.08
0.0570	1059.01	1599.22	1.3467	64.12	3.692	-22.87
0.0952	1060.47	1602.10	1.3474	64.42	3.674	-22.42
0.1337	1061.93	1604.97	1.3481	64.57	3.656	-22.06
0.1723	1063.35	1607.77	1.3487	64.84	3.638	-21.51
0.2112	1064.79	1610.65	1.3492	64.95	3.620	-21.30
L-serine+1.0 mol L^{-1} DST						
303.15 K						
0.0000	1120.96	1651.82	1.3610	-	3.270	-
0.0179	1121.60	1653.65	1.3616	65.26	3.260	-24.04
0.0539	1122.86	1657.31	1.3621	65.59	3.242	-23.62
0.0902	1124.10	1661.01	1.3635	65.86	3.224	-23.38
0.1268	1125.33	1664.75	1.3642	66.07	3.206	-23.20
0.1637	1126.53	1668.49	1.3655	66.34	3.189	-22.91
0.2010	1127.75	1672.20	1.3662	66.46	3.171	-22.60
308.15 K						
0.0000	1118.94	1655.92	1.3606	-	3.259	-
0.0179	1119.56	1657.73	1.3610	66.22	3.250	-22.98
0.0540	1120.78	1661.39	1.3618	66.59	3.232	-22.73
0.0903	1122.01	1665.02	1.3625	66.58	3.215	-22.49
0.1270	1123.19	1668.76	1.3632	66.94	3.197	-22.30
0.1640	1124.37	1672.47	1.3640	67.15	3.180	-22.03
0.2014	1125.55	1676.13	1.3648	67.31	3.162	-21.67
313.15 K						
0.0000	1117.68	1660.00	1.3598	-	3.247	-
0.0179	1118.28	1661.82	1.3610	67.16	3.238	-22.47
0.0540	1119.47	1665.47	1.3615	67.38	3.220	-22.13
0.0904	1120.65	1669.13	1.3621	67.55	3.203	-21.85
0.1272	1121.83	1672.83	1.3628	67.66	3.185	-21.67
0.1642	1122.99	1676.53	1.3635	67.82	3.168	-21.43
0.2016	1124.15	1680.23	1.3642	67.94	3.151	-21.18
L-serine + 1.5 mol L^{-1} DST						

303.15 K						
0.0000	1181.02	1725.85	1.3740	-	2.843	-
0.0170	1181.57	1727.97	1.3748	67.44	2.834	-22.18
0.0511	1182.57	1732.26	1.3760	67.71	2.818	-21.84
0.0856	1183.56	1736.58	1.3772	67.90	2.802	-21.58
0.1205	1184.53	1740.89	1.3780	68.10	2.786	-21.28
0.1554	1185.50	1745.05	1.3788	68.24	2.770	-20.72
0.1907	1186.46	1749.27	1.3800	68.37	2.754	-20.37
308.15 K						
0.0000	1179.59	1727.03	1.3729	-	2.842	-
0.0170	1180.08	1729.17	1.3740	68.35	2.834	-21.56
0.0512	1181.05	1733.45	1.3750	68.51	2.818	-21.26
0.0857	1182.01	1737.66	1.3770	68.66	2.802	-20.74
0.1205	1182.94	1741.88	1.3771	68.91	2.786	-20.32
0.1556	1183.89	1746.02	1.3781	68.98	2.771	-19.89
0.1910	1184.81	1749.99	1.3790	69.14	2.756	-19.24
313.15 K						
0.0000	1178.18	1730.31	1.3720	-	2.835	-
0.0170	1178.65	1732.42	1.3730	69.25	2.827	-20.51
0.0513	1179.58	1736.63	1.3745	69.45	2.811	-20.08
0.0858	1180.48	1740.82	1.3764	69.75	2.795	-19.66
0.1207	1181.37	1745.05	1.3770	69.97	2.780	-19.38
0.1558	1182.27	1749.10	1.3778	70.04	2.765	-18.87
0.1913	1183.13	1753.07	1.3785	70.26	2.750	-18.25

The density and ultrasonic velocity are used to calculate isentropic compressibility of solutions by using the Newton-Laplace's Equation.[27]

$$\kappa_s = \frac{1}{u^2 \rho} \qquad (1)$$

The calculated κ_s values are reported in Table 2. It is seen that the κ_s values decrease with amino acid concentration in each system at all the temperatures which is ascribed increase in number of incompressible amino acid zwitterions in solutions. The κ_s values also decrease with temperature and salt concentration.

Further, the apparent molar volumes, $V_{2,\phi}$ and apparent molar isentropic compressibilities, $\kappa_{S,2,\phi}$ have been computed from density and ultrasonic velocity data using fallowing relations[28]

$$V_{2,\phi} = \frac{M_2}{\rho} + \frac{1000}{m\rho\rho_0}(\rho_0 - \rho) \qquad (2)$$

$$\kappa_{S,2,\phi} = \frac{1000(\kappa_s\rho_o - \kappa_o\rho)}{m\rho\rho_o} + \frac{M \times \kappa_s}{\rho} \qquad (3)$$

Where, M is the molar mass ($g \cdot mol^{-1}$) and m is the molality ($mol \cdot kg^{-1}$) of solute, ρ and ρ_o is the densities ($kg \cdot m^{-3}$) of the solution and solvent respectively, κ_s and κ_{s0} are the isentropic compressibility of solution and solvent respectively. The $V_{2,\phi}$ and $\kappa_{S,2,\phi}$ for amino acids in aqueous solutions of DST at different temperatures T= 303.15, 308.15 and 313.15 K which are reported in Table 2.

The positive values of $V_{2,\phi}$ and negative values of $\kappa_{S,2,\phi}$ indicates strong ion-solvent/solute-solvent interaction between zwitterionic groups of amino acids (COO^- and NH_3^+) and ions of DST (Na^+ and $C_4H_4O_6^-$). The $V_{2,\phi}$ values increase with increase in concentration of solute and cosolute as well as with temperature. Negative $\kappa_{S,2,\phi}$ values indicate that water molecules around ionic charged groups of amino acids are less compressible than water in bulk which ascribed to strong ion-solvent interactions as similar case found in apparent molar volume.

Partial molar volume and transfer volume

Apparent molar volume at infinite dilution ($V_{2,\phi}^o$) have been calculated by least squares fitting method using Equation (4).

$$V_{2,\phi} = V_{2,\phi}^o + S_v m \qquad (4)$$

Where, $V_{2,\phi}^o$ is apparent molar volume at infinite dilution which is equal to partial molar volume and S_v is the experimental slope representing ion-ion or solute-solute interactions. The $V_{2,\phi}^o$ and S_v values are presented in Table 3 and Figure 1. The $V_{2,\phi}^o$ values are positive at all concentrations of DST and at all temperatures for studied amino acid. The $V_{2,\phi}^o$ values increase with increase in the concentration DST and temperature that is attributed to the release of some solvent molecules from loose hydration layer of solute (expansion).

At infinite dilution, solute-solute interactions are negligible and solvent molecules surround ions produced by DST and zwitterions of amino acids.

According to the co-sphere overlap model[29-30] overlap of co-sphere of two dipolar/ionic species interactions cause an increase in volume, while overlap of dipolar/ionic-hydrophobic and hydrophobic-hydrophobic species interactions cause decrease the volume. The observed

$V^{o}_{2,\phi}$ values suggested that ion-ion/hydrophilic interactions are dominant than ion-hydrophobic and hydrophobic-hydrophobic interactions.

Table 3. The partial molar volume ($V^{o}_{2,\phi}$) at infinite dilution, experimental slope (S_v) and volumes of transfer ($\Delta_t V^{o}_{2,\phi}$) of L-serine in aqueous solutions of DST at different temperatures.

303.15K			308.15K			313.15K		
$V^{o}_{2,\phi}$	S_v	$\Delta_t V^{o}_{2,\phi}$	$V^{o}_{2,\phi}$	S_v	$\Delta_t V^{o}_{2,\phi}$	$V^{o}_{2,\phi}$	S_v	$\Delta_t V^{o}_{2,\phi}$
L-serine in water								
60.84	4.17	-	61.24	5.80	-	61.89	6.46	-
L-serine in 0.5 mol·L^{-1} DST								
62.71	4.77	1.87	63.34	5.09	2.50	63.80	6.73	2.96
L-serine in 1.0 mol·L^{-1} DST								
65.21	6.60	4.37	66.16	5.83	5.32	67.13	4.14	6.29
L-serine in 1.5 mol·L^{-1} DST								
67.41	5.29	6.57	68.28	4.60	7.44	69.18	5.77	8.34

Foot note: $V^{o}_{2,\phi}$ =×10^{-6} $m^3 \cdot mol^{-1}$, S_v =10^{-6} $m^3 \cdot mol^{-1} \cdot kg^{-1}$, $\Delta_t V^{o}_{2,\phi}$ =10^{-6} $m^3 \cdot mol^{-1}$.

The $V^{o}_{2,\phi}$ values provide important information about solute-solvent interactions. The small positive S_v values indicate presence of weak solute-solute interactions. The S_v values are less as compared to $V^{o}_{2,\phi}$ which suggested that dominance of solute-solvent interactions over solute-solute interactions.

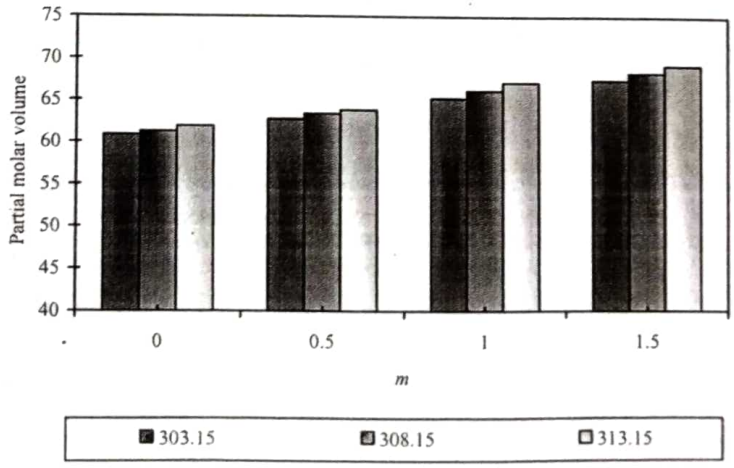


Figure 1: Partial molar volumes of L-serine in water and aqueous- Na_2Tar solutions at different temperatures.

Again, the transfer volume ($\Delta_t V^{o}_{2,\phi}$) have been calculated using following relation (5).

$$\Delta_t V^{o}_{2,\phi} = V^{o}_{2,\phi}(in\ aq.\ DST\ solution) - V^{o}_{2,\phi}(in\ water) \quad (5)$$

The $\Delta V^{o}_{2,\phi}$ values are reported in Table 3. $\Delta V^{o}_{2,\phi}$ values are positive and increase with an increase in the concentration of DST for present amino acid. On the other hand $\Delta V^{o}_{2,\phi}$ values do not observed regular trend with respective temperatures. Positive $\Delta V^{o}_{2,\phi}$ values indicate strong ion-ion interactions of amino acids (solute) and DST (cosolute) because these contain polar, ionic and hydrophilic groups. Observed $\Delta V^{o}_{2,\phi}$ values suggested structure making/promoting ability of solute amino acids due to solvophobic solvation as well as structural interactions for two co-spheres according to co-sphere overlap model.[29-30]

Partial molar isentropic compressibilities and transfer compressibility

Partial molar isentropic compressibilities ($\kappa^{o}_{s,2,\phi}$) at infinite dilution can be calculated by using Equation (6).

$$\kappa_{S,2,\phi} = \kappa^{0}_{S,2,\phi} + S_{\kappa}\, m \quad (6)$$

Where $\kappa^{o}_{s,2,\phi}$ is apparent molar isentropic compressibility at infinite dilution, which is equal to partial molar isentropic compressibilities and it is a measure of solute-solvent interactions. The S_k is experimental slope which represents solute-solute interactions in the solutions. The m is molality of solution. The $\kappa^{o}_{s,2,\phi}$ and S_k values are summarized in Table 4 and Figure 2.

Table 4: The partial molar isentropic compressibilities ($\kappa^{0}_{s,2,\phi}$) at infinite dilution, experimental slope S_k and transfer molar compressibilities ($\Delta_t\kappa^{0}_{S,2,\phi}$) of L-serine in aqueous solutions of DST at different temperatures.

303.15K			308.15K			313.15K		
$\kappa^{0}_{s,2,\phi}$	S_k	$\Delta_t\kappa^{0}_{S,2,\phi}$	$\kappa^{0}_{s,2,\phi}$	S_k	$\Delta_t\kappa^{0}_{S,2,\phi}$	$\kappa^{0}_{s,2,\phi}$	S_k	$\Delta_t\kappa^{0}_{S,2,\phi}$
L-serine in water								
-26.71	3.05	-	-25.26	2.93	-	-24.52	5.80	-
L-serine in 0.5 mol L^{-1} DST								
-25.32	8.67	1.39	-24.19	10.23	2.52	-23.34	9.91	3.37
L-serine in 1.0 mol L^{-1} DST								
-24.10	7.42	2.61	-23.11	6.89	3.60	-22.52	6.79	4.19
L-serine in 1.5 mol L^{-1} DST								
-22.40	10.45	4.31	-21.87	13.24	4.84	-20.75	12.47	5.96

Foot note: $\kappa^{0}_{s,2,\phi}$=10^{-14} $m^3 \cdot mol^{-1} \cdot pa^{-1}$, S_k =10^{-14} $m^3 \cdot mol^{-1} \cdot pa^{-1} \cdot kg^{-1}$, $\Delta_t\kappa^{0}_{S,2,\phi}$=$10^{-14}$ $m^3 \cdot mol^{-1} \cdot Pa^{-1}$.

The $\kappa^0_{s,2,\phi}$ values of L-serine in aqueous solution are good agreement with literature survey values[31-32] the $\kappa^0_{s,2,\phi}$ values become more negative at lower temperature which is due to strong solute-solvent interactions.[33]

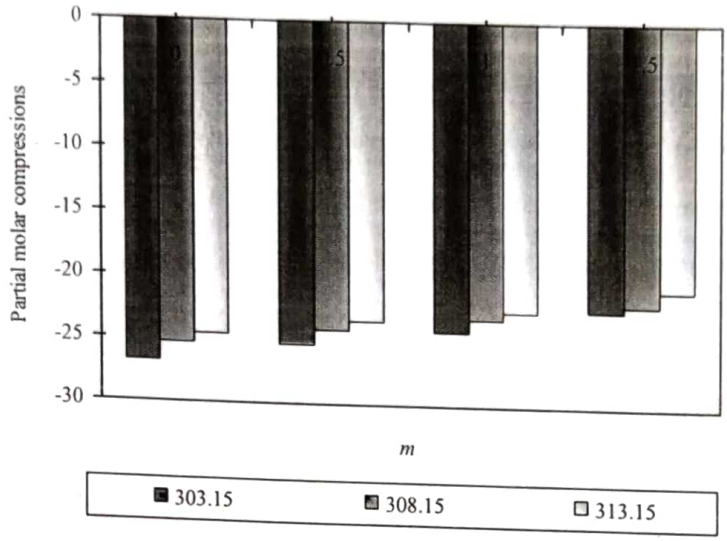


Figure 2: Partial molar compressions of L-serine in water and aqueous-Na_2Tar solutions at different temperatures.

With increase in the concentration of DST as well as temperature, the $\kappa^0_{s,2,\phi}$ value decreases (becomes less negative) which is attributed to the reduction in the electrostriction and release of some solvent molecules into the bulk. Effective interaction between ions of (DST) and water molecule induce the dehydration of amino acids, therefore at high concentration of DST; the solvent molecules around the amino acids are more compressible than at low concentration. S_k values are positive for both the amino acids in all the studied systems but magnitude of these values is less which is the sign of weak solute-solute interactions.

The transfer compressibility $\Delta_t\kappa^0_{S,2,\phi}$ is calculated by using Equation (7).

$$\Delta_t\kappa^0_{S,2,\phi} = \kappa^0_{S,2,\phi}(in\ aq.\ DST.\ solutions) - \kappa^0_{S,2,\phi}(in\ water) \qquad (7)$$

The $\Delta_t\kappa^0_{S,2,\phi}$ values (Table 4) are positive at all concentrations of DST and increase with increase in the concentration of DST for both the amino acids. The $\Delta_t\kappa^0_{S,2,\phi}$ values suggest that the effective interaction between zwitterionic end groups of amino acids and ions of DST which may be due to the structure making/promoting tendency of these ions.

CONCLUSION

Density, refractive index and ultrasonic velocity measurement for L-serine in (0.5 mol kg^{-1} 1.0 mol kg^{-1} and 1.5 mol kg^{-1}) aqueous DST solutions at temperatures T= (303.15, 308.15 and 313.15) K have been studied. The apparent molar volume, compressibility and volumes of transfer have been computed from experimental properties. The positive $V^{o}_{2,\phi}$ values suggested the existence of strong solute-solvent interactions. Partial molar volume increases with increase in concentration of DST and temperature suggesting the weakening of solute-solvent interactions due to release of solvent from hydration shell of amino acids. The positive ($\Delta V^{o}_{2,\phi}$) values indicate that ion-ion/hydrophilic and hydrophilic-hydrophilic interactions overcome the ion-hydrophobic and hydrophobic-hydrophobic interactions in the solution. The $\kappa^{0}_{s,2,\phi}$ values of amino acids become more negative in pure solvent as compared to amino acids in DST solution and it become less negative as increase in the concentration of DST as well as temperatures of studied system. The negative $\kappa^{0}_{s,2,\phi}$ values suggested that water molecule around the amino acids are less compressible than the bulk water. The positive $\Delta_t\kappa^{0}_{S,2,\phi}$ values indicate that interaction between zwitterions and ions of DST and solvation decrease with an increasing in the concentration of salt.

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REFERENCES

1. Makhatadze GI, Privalov PL. Contribution of hydration to protein folding thermodynamics: I. the enthalpy of hydration. J Mol Biol., 1993; 232: 639-9.
2. Privalov PL. Cold denaturation of proteins. Biochem Mol Bio, 1990; 25: 281-6.
3. Peter HH, Schleich T. Ion effects on the solution structure of biological macromolecules. Accounts Chem Res., 1969; 2: 257-5.
4. Franks F. Protein stability: the value of 'old literature'. Biophys Chem., 2002; 96: 117–7.
5. Zhao H. Viscosity B-coefficients and standard partial molar volumes of amino acids, and their roles in interpreting the protein (enzyme) stabilization. Biophys Chem., 2006; 122: 157–3.

Kumar H, Singla M, Jindal R. Studies of interionic interactions of L-serine/L-threonine in aqueous trilithium citrate solutions using density and speeds of sound measurements at different temperatures. J Mol Liq., 2015; 208: 170–2.

7. Usmani MA, Riyazuddeen. Interactions in (L-alanine/L-threonine + aqueous glucose/aqueous sucrose) systems at (298.15–323.15) K. Thermochim Acta, 2012; 527: 112-7.
8. Zhao C, Ma P, Li J. Partial molar volumes and viscosity B-coefficients of arginine in aqueous glucose, sucrose and l-ascorbic acid solutions at T =298.15K. J Chem Thermodyn, 2005; 37: 37–2.
9. Ali A, Shahjahan. Volumetric and viscometric behavior of some amino acids and their group contributions in aqueous tetramethylammonium bromide at different Temperatures. Z Phys Chem., 2008; 222: 1519–2.
10. Bolen DW, Yang M. Effects of guanidine hydrochloride on the proton inventory of proteins: implications on interpretations of protein stability. Biochem., 2000; 39: 15208-6.
11. Hagihara Y, Aimoto S, Fink AL, Goto Y. Guanidine hydrochloride-induced folding of proteins. J Mol Bio., 1993; 231: 180-4.
12. Badarayani R, Kumar A. Densities and speed of sound of glycine in concentrated aqueous NaBr, KCl, KBr and $MgCl_2$ at T= 298.15 K. J Chem Thermodyn, 2003; 35: 897–8.
13. Chauhan S, Chaudhary P, Sharma K, Kumar KK. Temperature-dependent volumetric and viscometric properties of amino acids in aqueous solutions of an antibiotic drug. Chem Pap, 2013; 67: 1442-2.
14. Sinha B, Dakua VK, Roy MN. Apparent molar volumes and viscosity B-coefficients of some amino acids in aqueous tetramethylammonium iodide solutions at 298.15 K. J Chem. Eng Data., 2007; 52: 1768-2.
15. Singh SK, Kishore N. Partial molar volumes of amino acids and peptides in aqueous salt solutions at 25^0C and a correlation with stability of proteins in the presence of salts. J Solution Chem., 2003; 32: 117–5.
16. Banipal TS, Kaur D, Banipal PK, Singh G. Thermodynamic and transport properties of L-serine and L-threonine in aqueous sodium acetate and magnesium acetate solutions at T = 298.15 K. J Chem Thermodyn, 2007; 39: 371–4.
17. Banipal TS, Kaur J, Banipal PK. Interactions of some amino acids with aqueous manganese chloride tetrahydrate at T = (288.15 to 318.15) K: A volumetric and viscometric approach. J Chem Thermodyn, 2012; 48: 181–9.
18. Lide DR. Handbook of Chemistry and Physics. Boca Raton, FL: CRC Press. 1998: 502.

19. Zafarani-Moattar MT, Hosseinzadeh S. Refractive index, viscosity, density, and speed of sound of aqueous sodium tartrate solutions at various temperatures. J Chem Eng Data, 2006; 51: 1190-3.
20. Berger SE, Kirk-Othmer I. Encyclopedia of Chemical Technology, Wiley-Interscience: New York, 1984; 13: 103-1.
21. Deosarkar SD, Shaikh UB. Physico-chemical properties and components interaction in the solutions of para-substituted benzoic acids in aqueous ethanol. Russ J Gen Chem., 2013; 83(12): 2392–4.
22. Deosarkar SD, Pandhare VV, Kattekar PS. Densities and refractive indices of potassium salt solutions in binary {ethanol + water} mixture of different compositions, J Eng, 2013; 2013: 1-4.
23. Deosarkar SD, Deoraye SM, Kalyankar TM. Temperature and concentration dependences of density and refraction of aqueous duloxetine solutions, Russ. J Phy Chem A., 2014; 88(7): 1129–2.
24. Syal VK, Lal G, Bisht P, Chauhan S. Ultrasonic measurements of some 1:1 electrolytes in chlorobenzene + methanol mixtures. J Mol Liq., 1995; 63: 317-8.
25. Syal VK, Gautam R, Chauhan S. Ultrasonic velocity measurements of carbohydrates in binary mixtures of DMSO+ H2O at 25^0C. Ultrasonics, 1998; 36: 619-3.
26. Riyazuddeen, Khan I. Interactions in L-alanine–/L-proline–/L-valine–/L-leucine–aqueous KCl/KNO3 systems at different temperatures: An isentropic compressibility study. Thermochim Acta, 2009; 483: 45-8.
27. Banipal TS, Kaur J, Banipal PK, Sood AK, Singh K. Volumetric and viscometric studies of some amino acids in aqueous solutions of cadmium chloride at T = (288.15 to 318.15) K and at atmospheric pressure. J Chem Eng Data, 2011; 56: 2751–0.
28. Pal A, Kumar S. Volumetric and ultrasonic studies of some amino acids in binary aqueous solutions of $MgCl_2 \cdot 6H_2O$ at 298.15 K. J Mol Liq, 2005; 121: 148–5.
29. Mishra AK, Ahluwalia JC. Apparent molal volumes of amino acids, n-acetylamino acids, and peptides in aqueous solutions. J Phy Chem., 1984; 88: 86-2.
30. Iqbal MJ, Chaudhary MA. Effect of temperature on volumetric and viscometric properties of some non-steroidal anti-inflammatory drugs in aprotic solvents. J Chem Thermodyn, 2010; 42: 951–6.
31. Rajagopal K, Gladson SE. Partial molar volume and partial molar compressibility of four homologous □-amino acids in aqueous sodium fluoride solutions at different temperatures. J Chem Thermodyn, 2011; 43: 852–7.

32. Nain AK, Lather M. Study of solute–solute and solute–solvent interactions of L-serine in d-xylose/l-arabinose + water solutions using volumetric, ultrasonic and viscometric methods at different temperatures. Phys Chem Liq, 2015; 53: 599-8.

33. Zafarani-Moattar MT, Sarmad S. Effect of tri-potassium phosphate on volumetric, acoustic, and transport behavior of aqueous solutions of 1-ethyl-3-methylimidazolium bromide at T = (298.15 to 318.15) K. J Chem Thermodyn, 2010; 42: 1213-1.