

Volumetric, ultrasonic and viscometric studies on L-lysine mono-hydrochloride in aqueous medium at different temperatures

K.C.Patil¹, Arti Gowardipe²

Department of Physics, Janata Mahavidyalaya Chandrapur-442401 (MS), India

kc.physics.chd@gmail.com

Abstract: At concentration range (0.001 to 0.06) mol/kg and temperature range T = (298.15, 303.15 and 308.15) K the densities (ρ), ultrasonic speeds (u) and viscosities (η) of aqueous solutions L-Lysine mono-hydrochloride were measured. From these experimentally measured values, the thermo-dynamical parameters such as apparent molar volume (ϕ_v), apparent molar compressibility ($K_{s\phi}$), isentropic compressibility (K_s), acoustic impedance (Z), relaxation time (τ) and classical absorption ($(\alpha/f^2)_{cl}$) have been evaluated. The results have been interpreted in terms of solute-solvent and solute-solute interactions in this system. It has been observed that there exist strong solute-solvent interactions in these systems and these interactions increases with concentration of solute in aqueous medium.

Keywords: Ultrasonic speed, l-lysine mono-hydrochloride, acoustic impedance, apparent molar volume, molecular interactions

1. INTRODUCTION

Nowadays, volumetric and ultrasonic characterization of biologically active materials in aqueous medium provides significant information about solute-solvent and solute-solute interactions that help us to understand several biochemical processes such as hydration, aggregation etc. The solute-solvent solutions have large effects on the structure and the properties of biologically important compounds like proteins, carbohydrates etc. L-lysine Mono-hydrochloride is an important α -amino acid which is used in biosynthesis of proteins. Lysine is often found buried with only the amino group exposed to solvent [1]. It is essential in human body and it must be obtained from the diet. It appears to help the body to absorb calcium and it plays an important role in the formation of collagen, a substance important for bones and connective tissues including skin, tendons and cartilage [2]. In many biological processes, lysine is an essential amino acid by including retention of endoplasmic reticulum, receptor, affinity, nuclear structure and function, protease cleavage points, chelation of heavy metals and muscles elasticity. It is an important for proper growth and it plays an essential role in the production of carnitine, a nutrient responsible for converting fatty acids into energy and helping to lower cholesterol [3, 4]. From the literature survey it has been observed that scanty work has been done on the study of molecular interactions such as solute-solvent, solute-solute etc. of L-lysine in aqueous medium. Therefore, in the present investigation, we have carried out the volumetric and acoustic characterization of L-lysine in aqueous medium at different concentration and temperature.

2. EXPERIMENTAL

L-Lysine mono-hydrochloride an amino acid, CAS No. 657-27-2, AR grade, 99% pure having molecular weight 182.65 was obtained from Sigma Aldrich chemicals Ltd. The appearance of this chemical is almost white powder. The aqueous solutions of L-lysine mono-hydrochloride of different concentrations was freshly prepared by using double distilled water. The required amount of solute was measured by using a digital weighing machine. The solutions were made on the basis of molality and stored in special airtight bottles to avoid contamination and evaporation. The densities measurements were done by using specific gravity bottle (10ml). Ultrasonic velocity was determined by using digital ultrasonic pulse echo velocity meter (VCT -70A). The viscosities of the solutions were measured by using Ostwald's type viscometer. The instruments were calibrated with double distilled water at certain temperature before taking measurements. The flow time has been measured with a digital stopwatch and average flow times were taken for each series of liquid solutions.

3. MATHEMATICAL FORMULATION

Apparent molar volume measurements (ϕ_v)

$$\phi_v = \frac{1000(\rho_0 - \rho)}{m\rho\rho_0} + \frac{M}{\rho}$$

Where, ρ , ρ_0 are density of solution and solvent respectively and 'm' is concentration of solution.

Apparent molar compressibility ($k_{s\phi}$)

$$K_{s,\phi} = \frac{1000(K_s\rho_0 - K_s^0\rho)}{m\rho\rho_0} + \frac{K_s M}{\rho}$$

Where, k_s and k_s^0 are the isentropic compressibility of the solution and solvent respectively.

Isentropic Compressibility

$$K_s = \frac{1}{u^2} \rho$$

Acoustic Impedance (Z)

The specific acoustic impedance is given by

$$Z = U \rho_s \quad \text{Kg } m^{-2} s^{-1}$$

Relaxation Time (τ)

$$\tau = \frac{4}{3\beta\eta}$$

Classical absorption ($(\alpha/f^2)_{cl}$)

$$(\alpha/f^2)_{cl} = \frac{8\pi^2\eta}{3\rho U^3}$$

Table 1: Experimental data of density, viscosity and ultrasonic velocity of aqueous L-lysine mono-hydrochloride at 298.15 K, 303.15 K and 308.15 K.

T(K)	c (mol.kg ⁻¹)	ρ (kg.m ⁻³)	η (m ⁻¹ .kg.s ⁻¹)	u (m.s ⁻¹)
298.15	0.001	997.130	9.179E-04	1491.752
	0.002	998.116	9.208E-04	1492.348
	0.003	998.116	9.210E-04	1491.752
	0.004	999.103	9.220E-04	1491.752
	0.005	1000.089	9.251E-04	1491.752
	0.006	1001.075	9.282E-04	1491.752
	0.007	1002.061	9.312E-04	1492.943
	0.008	1003.048	9.353E-04	1492.943
	0.009	1005.020	9.416E-04	1492.943
	0.010	1005.020	9.421E-04	1493.54
	0.020	1006.007	9.494E-04	1494.733
	0.030	1006.993	9.517E-04	1496.528
	0.040	1008.965	9.580E-04	1497.726
	0.050	1010.938	9.643E-04	1498.927
	0.060	1014.883	9.691E-04	1500.732
	303.15	0.001	995.710	7.585E-04
0.002		996.697	7.640E-04	1502.540
0.003		997.684	7.692E-04	1503.144
0.004		998.670	7.766E-04	1503.748
0.005		999.657	7.787E-04	1503.748
0.006		1000.644	7.865E-04	1503.748
0.007		1001.631	7.908E-04	1503.352
0.008		1002.618	7.954E-04	1503.748
0.009		1003.605	7.978E-04	1502.54
0.010		1004.591	8.046E-04	1503.748
0.020		1005.578	8.096E-04	1501.937
0.030		1006.565	8.165E-04	1506.171
0.040		1007.552	8.221E-04	1506.778
0.050		1009.526	8.273E-04	1509.210
0.060		1010.512	8.323E-04	1509.819
308.15		0.001	996.058	6.760E-04
	0.002	997.047	6.805E-04	1511.650
	0.003	998.037	6.862E-04	1511.429
	0.004	999.026	6.888E-04	1511.650
	0.005	1000.015	6.907E-04	1511.650
	0.006	1001.004	6.936E-04	1511.650
	0.007	1001.993	6.981E-04	1511.650
	0.008	1002.982	7.042E-04	1512.872
	0.009	1003.971	7.068E-04	1512.872
	0.010	1003.971	7.110E-04	1512.872
	0.020	1004.960	7.152E-04	1514.711
	0.030	1005.950	7.267E-04	1515.939
	0.040	1006.939	7.281E-04	1517.169
	0.050	1007.928	7.345E-04	1519.017
	0.060	1008.917	7.445E-04	1519.634

4. RESULT AND DISCUSSION

The experimentally measured and evaluated values of physical parameters of aqueous solution of L-lysine mono-hydrochloride of different concentrations at 298.15K, 303.15K and 308.15K are presented in Table-1, Table 2 respectively and their variation with concentration (0.001 - 0.06) mol.kg⁻¹ at different temperature (298.15, 303.15 and 308.15) K are shown in figure 1-9.

Table 2: Evaluated thermodynamic parameters of aqueous L-lysine monohydrochloride at 298.15 K, 303.15 K and 308.15 K.

T(K)	c (mol.kg ⁻¹)	K _s (Pa ⁻¹)	Z (kg.m ⁻² .s ⁻¹)	τ(s)	α/f _{cl} ² (m ³ .mol)	ϕ _v (m ³ .mol ⁻¹)	ϕ _{ks} (m ³ .mol ⁻¹ .Pa ⁻¹)
298.15	0.001	4.507E-10	1483056.182	5.532E-13	7.305E-15	1.832E-04	1.768E-08
	0.002	4.499E-10	1486593.087	5.534E-13	7.305E-15	-4.953E-01	9.281E-09
	0.003	4.502E-10	1490413.245	5.523E-13	7.294E-15	-3.301E-01	6.542E-09
	0.004	4.498E-10	1487470.672	5.540E-13	7.316E-15	-4.948E-01	4.589E-09
	0.005	4.493E-10	1490413.245	5.548E-13	7.326E-15	-5.932E-01	3.774E-09
	0.006	4.489E-10	1493355.818	5.555E-13	7.336E-15	-6.585E-01	3.230E-09
	0.007	4.477E-10	1498965.482	5.548E-13	7.321E-15	-7.049E-01	3.007E-09
	0.008	4.473E-10	1491603.176	5.600E-13	7.389E-15	-7.394E-01	2.307E-09
	0.009	4.464E-10	1494548.098	5.626E-13	7.424E-15	-8.746E-01	2.057E-09
	0.010	4.461E-10	1495145.74	5.625E-13	7.420E-15	-7.872E-01	1.896E-09
	0.020	4.449E-10	1503711.156	5.632E-13	7.422E-15	-4.423E-01	1.113E-09
	0.030	4.434E-10	1518800.911	5.583E-13	7.349E-15	-3.272E-01	9.207E-10
	0.040	4.418E-10	1511153.669	5.644E-13	7.423E-15	-2.939E-01	6.419E-10
	0.050	4.403E-10	1509408.71	5.683E-13	7.469E-15	-2.738E-01	5.091E-10
0.060	4.375E-10	1511225.325	5.698E-13	7.479E-15	-2.922E-01	4.257E-10	
303.15	0.001	4.454E-10	1503988.969	4.478E-13	5.875E-15	1.834E-04	2.849E-09
	0.002	4.444E-10	1497576.853	4.527E-13	5.935E-15	-4.970E-01	4.403E-10
	0.003	4.436E-10	1496695.512	4.559E-13	5.974E-15	-6.621E-01	1.455E-10
	0.004	4.428E-10	1497296.921	4.599E-13	6.025E-15	-7.441E-01	1.087E-10
	0.005	4.424E-10	1494329.038	4.620E-13	6.053E-15	-7.930E-01	-1.621E-10
	0.006	4.419E-10	1495812.98	4.662E-13	6.107E-15	-8.252E-01	-1.209E-10
	0.007	4.417E-10	1502836.823	4.667E-13	6.115E-15	-8.479E-01	1.266E-10
	0.008	4.411E-10	1492845.097	4.724E-13	6.189E-15	-8.647E-01	-2.910E-10
	0.009	4.414E-10	1494611.354	4.736E-13	6.210E-15	-8.776E-01	-2.795E-10
	0.010	4.402E-10	1495812.98	4.770E-13	6.248E-15	-8.877E-01	-2.153E-10
	0.020	4.408E-10	1498457.999	4.796E-13	6.291E-15	-4.926E-01	-7.645E-11
	0.030	4.379E-10	1499709.526	4.820E-13	6.304E-15	-3.608E-01	1.564E-11
	0.040	4.372E-10	1501800.854	4.844E-13	6.333E-15	-2.949E-01	4.098E-11

	0.050	4.349E-10	1507203.484	4.849E-13	6.330E-15	-2.747E-01	7.756E-11
	0.060	4.341E-10	1507811.674	4.874E-13	6.360E-15	-2.450E-01	7.674E-11
308.15	0.001	4.397E-10	1503588.27	3.967E-13	5.172E-15	-1.998E+00	7.141E-10
	0.002	4.389E-10	1501177.157	3.974E-13	5.179E-15	-1.497E+00	1.232E-09
	0.003	4.386E-10	1509956.372	4.009E-13	5.225E-15	-1.329E+00	6.592E-10
	0.004	4.380E-10	1511672.381	4.019E-13	5.238E-15	-1.245E+00	5.462E-10
	0.005	4.376E-10	1516158.056	4.018E-13	5.237E-15	-1.194E+00	6.261E-10
	0.006	4.372E-10	1511672.381	4.047E-13	5.275E-15	-1.160E+00	2.453E-10
	0.007	4.367E-10	1514662.831	4.066E-13	5.298E-15	-1.135E+00	2.836E-10
	0.008	4.356E-10	1509901.532	4.111E-13	5.353E-15	-1.116E+00	7.513E-11
	0.009	4.352E-10	1511397.966	4.122E-13	5.367E-15	-1.101E+00	7.589E-11
	0.010	4.352E-10	1512894.4	4.142E-13	5.393E-15	-9.909E-01	1.198E-10
	0.020	4.337E-10	1520726.437	4.140E-13	5.384E-15	-5.444E-01	2.181E-10
	0.030	4.326E-10	1518960.38	4.208E-13	5.468E-15	-3.955E-01	1.525E-10
	0.040	4.314E-10	1518692.147	4.213E-13	5.471E-15	-3.210E-01	1.305E-10
	0.050	4.300E-10	1531059.585	4.211E-13	5.461E-15	-2.762E-01	1.928E-10
	0.060	4.292E-10	1525668.988	4.282E-13	5.551E-15	-2.464E-01	1.443E-10

When the solution is heated, thermal energy of the solution increases due to which intermolecular separation between the molecules increases and this leads to decrease in density [5, 6] of aqueous L-lysine mono-hydrochloride with rise in temperature (fig.1) at a certain concentration. The viscosity variation of the solution with rise in temperature also indicates the molecular dissociation and supports the facts indicated by density variation with temperature [7-9]. The

increase in viscosity (fig.2.) with concentration at a certain temperature indicates molecular association through intermolecular hydrogen bonding. Figure 3 shows that the ultrasonic velocity of solution under the study increases with the increases with concentration as well as temperature. This may be attributed to the increase of compactness of the medium with the increase in solute in water solvent [10-12].

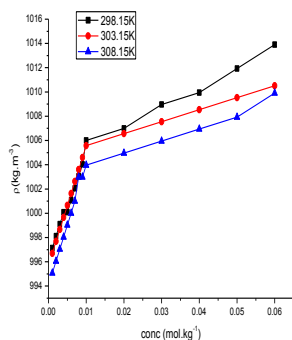


Fig.1. Variation of density with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine mono-hydrochloride solution

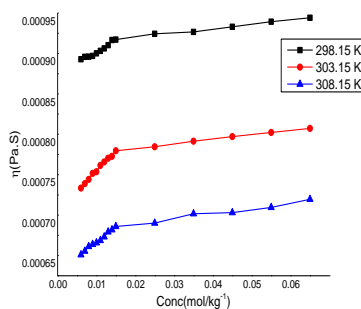


Fig. 2. Variation of viscosity with molality at 298.15K, 303.15K and 308.15K for aqueous L-lysine mono-hydrochloride solution

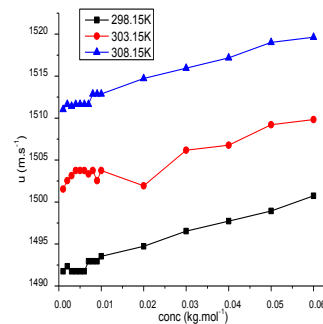


Fig.3. Variation of ultrasonic with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine mono-hydrochloride solution

Fig. (1-3): Effect of concentration and Temperature on Density, Viscosity, Ultrasonic Velocity of aqueous L-lysine mono-hydrochloride.

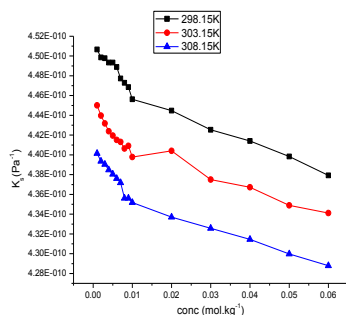


Fig.4. Variation of Isentropic compressibility with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

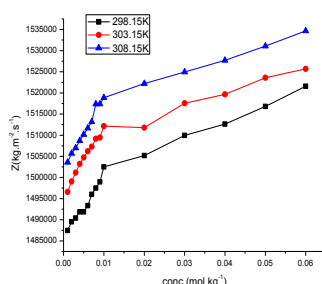


Fig.5. Variation of Acoustic impedance with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

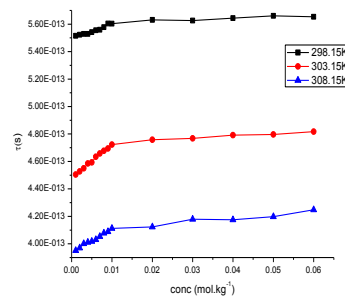


Fig.6. Variation of Relaxation time with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

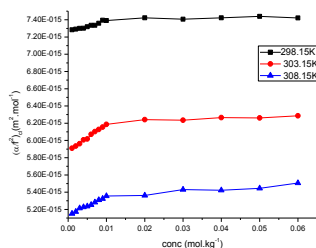


Fig.7. Variation of Classical absorption with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

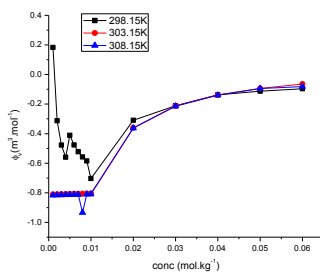


Fig.8. Variation of apparent molal volume with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

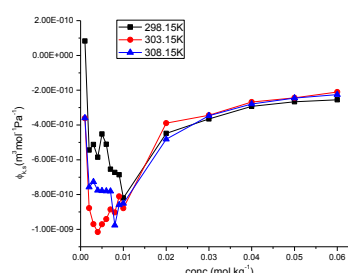


Fig.9. Variation of Apparent molal compressibility with molality at 298.15K, 303.15K, 308.15K for aqueous L-lysine monohydrochloride solution

Fig.(4-9) Variation of isentropic compressibility, Acoustic impedance, Relaxation time, Classical absorption, Apparent molal volume and Apparent molal compressibility of aqueous L-lysine mono-hydrochloride at different concentration and temperature.

Figure 4 shows that the isentropic compressibility $K_{s,\phi}$ of aqueous L-lysine mono-hydrochloride decrease with the increase in concentration and temperature. The $K_{s,\phi}$ values are positive and become smaller at higher concentration of aqueous solution and also with increase of temperatures $K_{s,\phi}$ decreases. The similar results are reported by S. J. Kharat [13].

The increase in acoustic impedance with rise in concentration and temperature in the present investigation shows that ultrasound wave has to face resistance to flow. The positive acoustic impedance is an evidential parameter for solute-solvent interaction [14-16]. Decrease in relaxation time (fig.6.) with increase in temperature indicates the weakening of hydrogen bonding in the present system [17]. The increase in relaxation time with concentration at a certain temperature supports the existence of strong interactions between the molecules of the mixtures [18-20]. The apparent molal volume, ϕ_v of L-lysine mono-hydrochloride in water solvent is calculated from the density data. The variation of apparent molal volume with molality of L-lysine monohydrochloride is graphically represented by figure 8. Figure shows that apparent molal volume is dependent on the concentration as well as on temperature. The values of apparent molal volume of aqueous solution are linearly increase with increase of concentration of amino acids and also increase with decrease in temperature. The apparent molal volume increases with an increase in the number of carbon in alkyl group present in amino acids and it leads to enhanced solute solvent interactions [21]. The apparent molal compressibility $\phi_{s,\phi}$ values of L-

lysine mono-hydrochloride in aqueous medium have been reported in table 2. The negative value of $\phi_{s,\phi}$ (loss of compressibility of medium) indicates enhanced solute solvent interactions. The increase in the values of apparent molal compressibility with concentration indicates strengthening of cohesive forces in the solution [22].

5. CONCLUSION

Volumetric and ultrasonic studies of L-lysine in aqueous medium (0.001-0.06) mol kg⁻¹ has been carried out with temperature range (298.15, 303.15 and 308.15) K with an interval of 5 K. The variation in apparent molal volume and apparent molal compressibility also strongly supports the facts indicated by other basic and derived parameters.

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