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Study of Ultrasonic Velocity, Density, Viscosity and Derived Acoustic Parameters of L-arginine at Different Temperature

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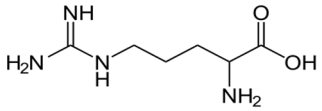
Abstract: ***The measurement of ultrasonic velocity, adiabatic compressibility, free length and acoustic impendence are novel tools for investigation of properties of compound, nature of intermolecular interaction between components in homogeneous solution. The density, viscosity and ultrasonic velocity of different concentration of aqueous solution L-arginine have been studied at different temperature. From experimental data different thermo acoustic parameters like adiabatic compressibility, free length and acoustic impendence have been evaluated. The nature of solute, solute-solvent interactions in this system was also studied.***
Keywords: L-arginine, ultrasonic velocity, adiabatic compressibility, free length, acoustic impendence

I. INTRODUCTION

L-Arginine is non-essential amino acid having amino group, carboxylic acid group and a side chain of three carbons ending with a guanido group (Structure 1). It is involved in various metabolic pathways[1]. It is used for chest pain, high blood pressure and erectile dysfunction. It behaves as good oxidant and plays an important role in cardiovascular disorder [2-3]. Arginine gets converted into nitric oxide a powerful neurotransmitter that helps blood vessels relax and improves blood circulation[4].



Structure 1

Ultrasonic study have great significance in obtaining knowledge of inter and intra-molecular interactions of solute and solvent, structural and physiochemical behavior solute and verifying different theories which explains properties of solution[5-9].
In the present work, attempt has been made to determine ultrasonic velocity, adiabatic compressibility, free length and acoustic impendence of aqueous solution of L-arginine at 301.15, 306.15 and 310.15 K temperature and studied molecular interaction and variation of above parameters with concentration at different temperature.

II. EXPERIMENTAL

The analytical grade of L-Arginine was obtained from SD fine chemicals. The double distilled water was used to prepare 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09 and 0.1 molar solution. All the weighing was made by digital balance having an accuracy of ± 0.0001g. The density (ρ) of solutions was measured by specific gravity bottle with accuracy ± 0.0001 g/cm^3. The viscosity (η) was measured by Oswald's viscometer. All the measurements were carried out at 301.15, 306.15 and 310.15 K temperature. The ultrasonic velocity was measured by multi-frequency (1-10MHz) ultrasonic interferometer supplied by Mittal enterprises New Delhi at 2 MHz with accuracy ±2 m/s accuracy. The interferometer was filled with test solution and water was circulated around the cell. The temperature of system was maintained by thermostat**.**

III. THEORY

The different empirical relations were used to derive acoustic and thermodynamic parameters and they are discussed as follows.

1) *Ultrasonic Velocity (U):* Ultrasonic velocity is the speed in which sound travels through a given material and it is given by U = f × λ where λ and f is wavelength and frequency of the ultrasonic wave respectively.
2) *Adiabatic Compressibility (β_s):* The adiabatic compressibility was be calculated by from ultrasonic velocity and density of solution and given by.

$$\beta s = 1/ U^2 \rho s$$

Where- U and ρs is ultrasonic velocity and density of solution.

3) *Intermolecular Free Length (L_f):* The intermolecular free length is temperature dependent measures distance between the surfaces of the molecules in the liquid medium. According to Jacobson K value, intermolecular free length (L_f) can be given by the formula:

$$L_f = K \sqrt{\beta_s}$$

Where K and β_s are Jacobson's constant and adiabatic compressibility

4) *Specific Acoustic Impedance (Z):* It is a product of ultrasonic velocity (U) and density (ρs) given by following equation

$$Z = U \times \rho_s$$

Where U and ρ_s are ultrasonic velocity and density of the solution

5) *Relative Association (R_A):* The relative association determines extent of association of components in the medium. It is given by following equation.

$$R_A = \rho_s / \rho_0 (U_0 / U_s)^{1/3}$$

Where U_s, U_0, ρ_s and ρ_0 are ultrasonic velocity and density of solution and solvent respectively

6) *Relaxation Time (τ):* It is the characteristic time in which a system relaxes under certain changes under external conditions. It is calculated by using equation

$$\tau = 4/3\ \beta_s \times \eta s$$

Where β_s and ηs are adiabatic compressibility and viscosity of the solution

IV. RESULT AND DISCUSSION

The experimentally measured values of ultrasonic velocity, density, viscosity and acoustic parameters like adiabatic compressibility, free length and acoustic impendence etc. of aqueous solution of L-Arginine at 301.15K, 306.15K, and 310.15K temperature at 2MHz frequency are given in Table 1. The derived acoustic parameters were presented in fig 4-8. The density of L-arginine solution increases with increasing in concentration of the solution at different temperature. However density was found to decreases with rise in temperature for same concentration (Table 1). The rise in density with concentration is due to aggregation of solute particle in the solution [10-11]. The decreasing trends of density with rise in temperature might be due to weakening of intermolecular cohesive forces between solute and solvent (fig.1)[12]. From table 1, viscosity of solution increases with increases in concentration of solution. The trend of linear increase of viscosity with concentration (fig. 2) suggested strong cohesive forces due molecular interactions and decrease of viscosity with temperature indicated weakening of cohesive forces between solute and solvents[13-14]. The linear rise of ultrasonic velocity with temperature (table 1, fig. 3) showed solute solvent interaction and molecular association in the solution[15-17]. When L-arginine is added to water, it attracts water molecules toward itself by wrenching the molecule from the bulk of solvent due to force of electrostriction. Due to this volume available in solvent molecule for the next incoming ions gets decreases[18]. From table 1 and fig. 4 it is clear that adiabatic compressibility decrease with increase in concentration. The variation in intermolecular free length with concentration is shown in table 1 and fig. 5. Increase in concentration leads to decrease the gap between two solutes which is defined by intermolecular free length. As concentration of solute increases intermolecular free length goes on decreasing[19-20]. In the present study, intermolecular free length decreases linearly with increasing concentration. This trend indicates that there is significant interaction between L-arginine and water molecule and subsequently shows structure forming behavior between them. The variation of acoustic impedance with concentration is shown in table 1 and fig. 6. Acoustic impedance is found to inverse relation to adiabatic compressibility. It shows increase trend with increase in concentration which can be explained in the term of intermolecular interaction in the given system[21-22]. This indicates the strong molecular interaction like hydrogen bond formation and dipole-dipole interactions between the components molecules in the system. The variation in R_A with concentration is shown in table 1 and fig. 7. The property is useful to study and understand the molecular interactions in the system[23]. It is mainly influenced by breaking up of the associated solvent molecules on addition of solute in it and the salvation of solute molecules with water. The former leads to decrease and later to the increase of relative association. In the present study, relative association increases linearly with increase in concentration indicated that significant intermolecular interaction takes place between components of the system. The variation of acoustic relaxation time (t) is given in table 1; fig. 8. It increases with increases with concentration in the system. This trend may due to salvation processes suggesting solute solvent interaction in the system[24-25].

V. CONCLUSION

In the present investigation, the observed trends and variation of density, viscosity and ultrasonic velocity and some thermo-acoustical parameters of aqueous solution of L-arginine with molar concentration at 2MHz frequency at different temperature was studied. The measured and derived thermo-acoustic parameters are helpful for understanding nature of L-arginine and solvent and type and strength of interaction between L-arginine and water.

VI. ACKNOWLEDGEMENT

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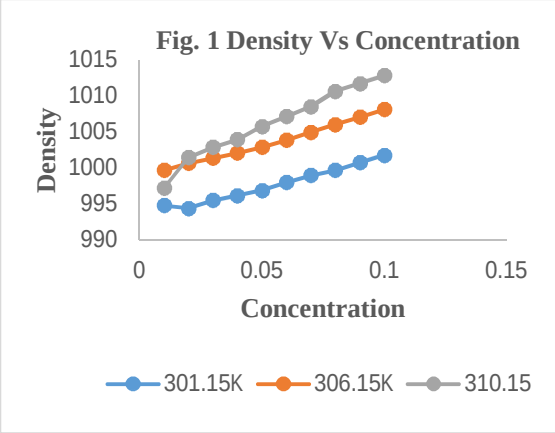
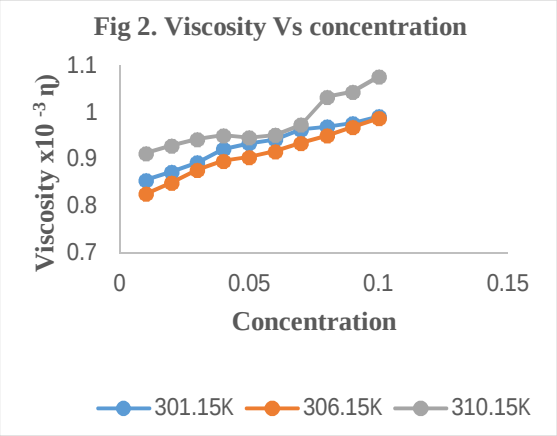
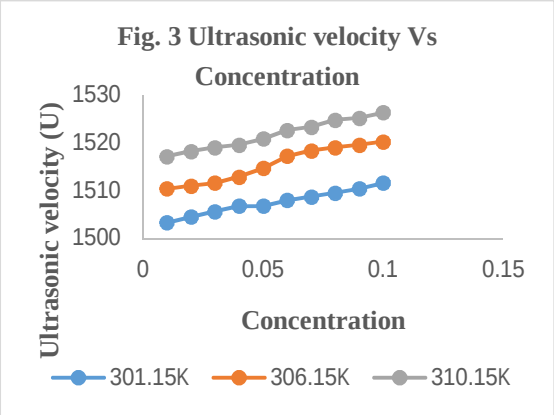
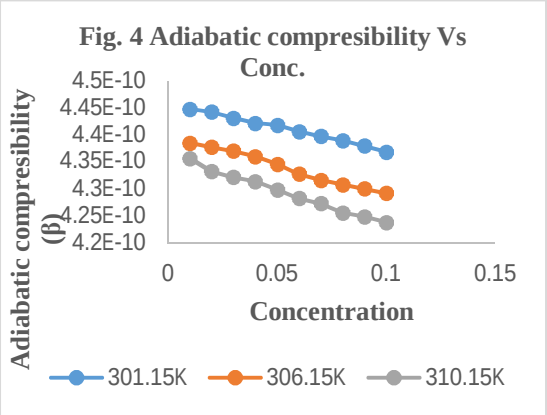
Table 1. Measured value of temperature, Concentration (M), Density (ρ), Viscosity (η) ultrasonic velocity (U) and Some derived thermo acoustic parameters such as adiabatic compressibility (β), free length (Lf), acoustic impedance (Z), Relative association (RA) and relative time (τ)

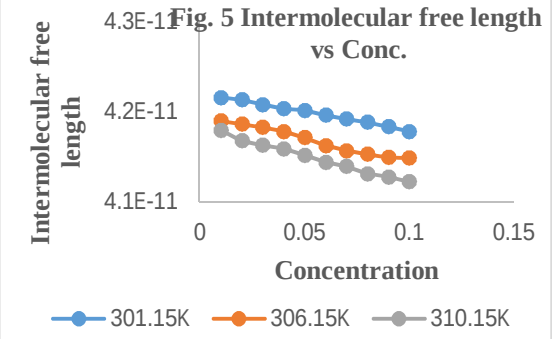
Temp. (K)	Conc. (M)	ρ_s (Kg/M^3)	η $kgm^{-1}/_S$	U (m/s)	$\beta x10^{-10}$	$Lf\ x10^{-11}$	$Z\ x10^{-6}$	RA	$\tau\ x\ 10^{-10}$
301.15	0.01	994.8	0.8555	1503.34	4.44785	4.2164	1.4955	0.3311	5.075
	0.02	994.4	0.8734	1504.535	4.44257	4.2139	1.4961	0.3307	5.1735
	0.03	995.5	0.8929	1505.669	4.43098	4.2084	1.4988	0.3308	5.2752
	0.04	996.2	0.9219	1506.778	4.42135	4.2038	1.501	0.3308	5.4347
	0.05	996.9	0.9343	1506.823	4.41798	4.2022	1.5021	0.331	5.5036
	0.06	998	0.9425	1507.993	4.40627	4.1966	1.5049	0.3311	5.5372
	0.07	999	0.9635	1508.737	4.39752	4.1925	1.5072	0.3313	5.6493
	0.08	999.7	0.9695	1509.556	4.38967	4.1887	1.5091	0.3314	5.6743
	0.09	1000.8	0.9771	1510.429	4.37978	4.184	1.5116	0.3315	5.7059
	0.1	1001.8	0.9915	1511.65	4.36834	4.1785	1.5143	0.3316	5.7749
306.15	0.01	999.7	0.8257	1510.429	4.3846	4.1902	1.5099	0.3349	4.8271
	0.02	1000.7	0.8501	1510.989	4.37697	4.1866	1.512	0.3351	4.9611
	0.03	1001.4	0.8774	1511.65	4.37009	4.1833	1.5137	0.3352	5.1124
	0.04	1002.1	0.8966	1512.883	4.35992	4.1784	1.516	0.3351	5.2121
	0.05	1002.9	0.9047	1514.711	4.34593	4.1717	1.5191	0.335	5.2423
	0.06	1003.9	0.9171	1517.253	4.32707	4.1627	1.5231	0.3347	5.2911
	0.07	1005	0.9348	1518.4	4.3158	4.1572	1.5259	0.3349	5.3792
	0.08	1006.1	0.9507	1519.017	4.30758	4.1533	1.5282	0.3351	5.4602
	0.09	1007.1	0.9688	1519.583	4.3001	4.1497	1.5303	0.3353	5.5545
	0.1	1008.2	0.9873	1520.252	4.29163	4.1487	1.5327	0.3355	5.6495
310.15	0.01	997.2	0.9125	1517.169	4.35662	4.18	1.5129	0.3338	5.3
	0.02	1001.5	0.9291	1518.229	4.33186	4.1681	1.5205	0.335	5.3663
	0.03	1002.9	0.9429	1519.017	4.32133	4.163	1.5234	0.3353	5.4327
	0.04	1004	0.9513	1519.559	4.31351	4.1593	1.5256	0.3356	5.4712
	0.05	1005.8	0.9464	1520.87	4.29837	4.1519	1.5296	0.3359	5.4239
	0.06	1007.2	0.9315	1522.679	4.28221	4.1441	1.5336	0.3359	5.3185
	0.07	1008.6	0.8734	1523.348	4.27251	4.1394	1.5364	0.3363	4.9754
	0.08	1010.7	1.0332	1524.779	4.25563	4.1313	1.541	0.3367	5.8625
	0.09	1011.8	1.0442	1525.212	4.24859	4.1278	1.5432	0.3369	5.9151
	0.1	1012.9	1.076	1526.323	4.2378	4.1226	1.546	0.337	6.0798

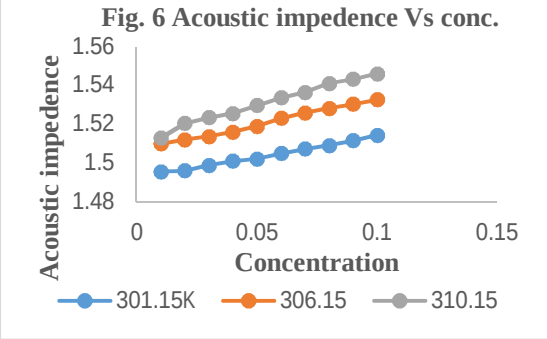


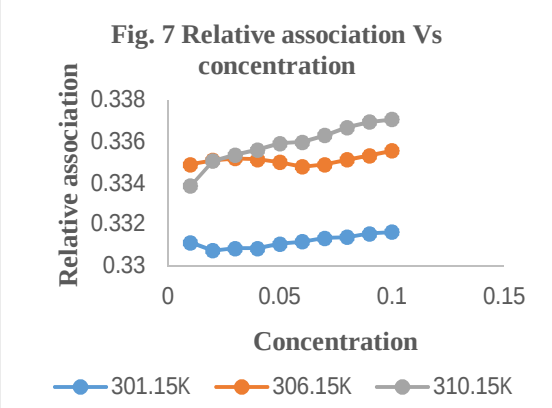


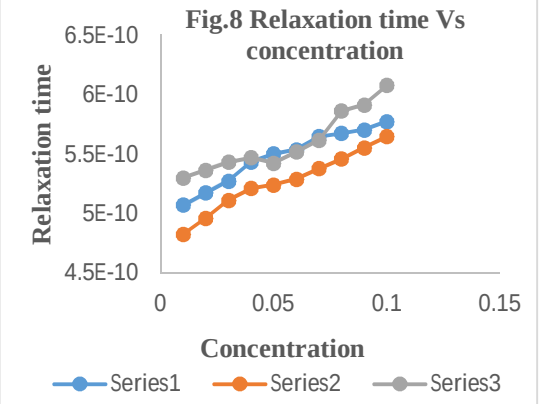












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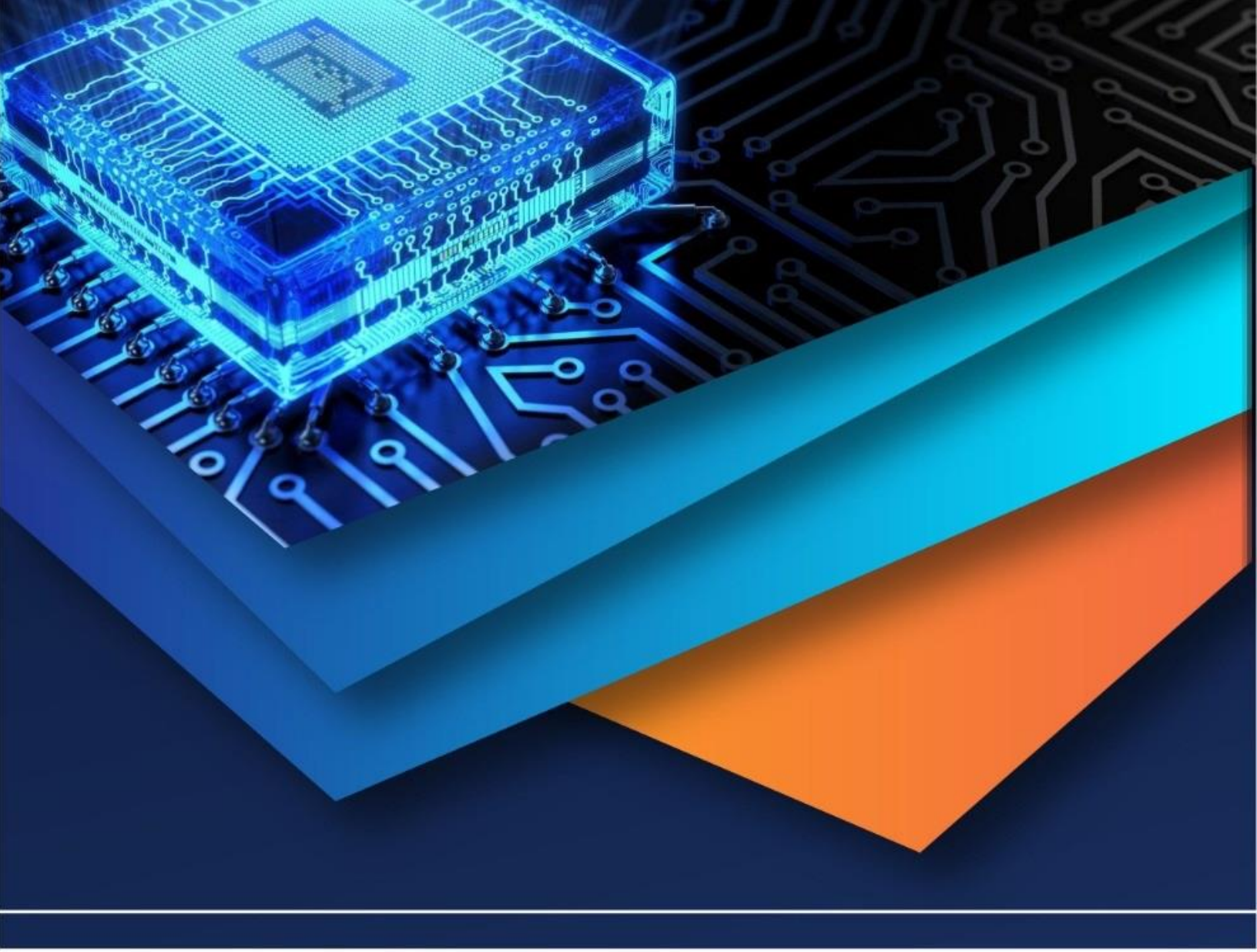

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