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Ultrasonic investigation of molecular interaction of L-Valine in mixed aqueous systems at different temperatures

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A B S T R A C T

The ultrasonic velocity (u), density (ρ) and viscosity (η) of L-Valine solutions (0.02-0.12 mol.dm-3) in 2% of NaI solutions have been investigated at 288.15, 293.15, 298.15 and 303.15K respectively. The acoustic parameters such as adiabatic compressibility (β), free length (Lf), acoustic impedance (Z), free volume (Vf) and relative association (RA) have been calculated. The variations of acoustic parameters with concentration and temperature indicated the existence of intermolecular interaction in the present systems.

Keywords: Ultrasonic velocity, compressibility, acoustic impedance, L-Valine

A R T I C L E I N F O

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1. Introduction

Proteins are the most abundant biomolecules of the living system. They are found in skin, hair, muscle, nerves, enzymes, antibodies and hormones. In order to understand its role played in the living organism, it is necessary to study the interaction of proteins with their surrounding environment like ions present in biological fluids in the form of salts [1-3]. An electrolyte, when dissolved in water perturbs the arrangement of water molecules with the strong electric field of its ions. This property of electrolyte known as structure maker or breaker has been widely used to understand the effect of electrolytes on the structure and function of both proteins and nucleic acids [4-5]. Due to complex structure of protein, direct study is somewhat difficult. Therefore the useful approach is to study simpler model compounds such as amino acids which are building blocks of proteins [6-7]. L-valine is an essential non-polar amino acid used by the muscles as a source of energy. It is helpful in the treatment of liver and gallbladder disease. As a branched chain amino acid, L-valine is important for optimal growth in infants and children and nitrogen balance in adults. Branched chain preparations are used in sports nutrition and health foods.

The variation of ultrasonic velocity and related parameters throw much light upon the structural changes associated with the liquid mixtures having strongly interacting components as well as weakly interacting components. Therefore, the present work mainly deals with velocity studies of different concentrations of L-Valine in 2% sodium iodide. These solutions/mixtures are of significant importance in physiological processes of life. Many physiological processes depend on the concentrations of electrolytes and their interactions with aqueous medium in protoplasm of the cell [8]. Nerve impulse also depends upon the concentration of aqueous solution of electrolytes. Hence, these electrolytes are chosen for the present investigation.

2. Experimental

All the chemicals used in this present work are analytical reagent (AR) grades; doubly distilled water has been used for preparing the solution of different concentrations of aqueous electrolytic solutions. 2% solution of NaI prepared as stock solution. It is used as a solvent for preparing the L-Valine solution of concentration range (0.02-0.12M). For weighing, an electronic digital balance having an accuracy of ±0.1mg was used. Densities were determined using specific gravity bottle by relative measurement method with accuracy of ±0.1 $kg.m^{-3.}$ An Ostwald's viscometer was used for viscosity measurement. An ultrasonic interferometer having the frequency 2MHz (VI Microsystems Pvt. Ltd. Perungudi, Chennai) with an accuracy of ±0.1% was used for velocity measurement. Constant digital temperature water bath was used to maintain the constant temperature with an accuracy of ±0.1K. Using the measured data some acoustical parameters have been calculated using standard relations as,

Adiabatic compressibility can be calculated from speed of sound (U) and density (ρ) of the medium:

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

Intermolecular free length can be determined as: $L_f = K\ \beta^{1/2}$

Where, K values for different temperatures were taken from the work of Jacobson.

The acoustic impedance is the product of the velocity of ultrasound in a medium and its density can be calculated by the relation.

$$Z = U\ \rho$$

The free volume (V_f) in terms of ultrasonic velocity (U) and the viscosity of liquid

$V_f = [M_{eff}.U / K\eta]$ M_{eff}. -effective molar mass, $K=4.28x10^9$, η-viscosity of solution.

Relative association (RA) = (ρ /ρo). (Uo /U) 1/3

3. Results and Discussion

Density:

Density is a measure of solvent-solvent and ion-solvent interactions. From table1, it is observed that density of L-Valine solutions in 2% aqueous solution of NaI is found to increase with increase in concentration of L-Valine and decrease with increase in temperature. Increase in density with concentration may be due to closed packing of the solute-solvent interactions among the constituent particles of the mixture [9]. The strength of interactions may be due to dipole-dipole or ion-dipole interaction.

Viscosity:

Viscosity is an important parameter in understanding the structure as well as molecular interactions occurring in the solutions. From table1, it is observed that viscosity of L-Valine solution in 2% aqueous solution of NaI are found to increase with increase in concentration of L-Valine and decrease with increase in temperature. Increase in viscosity of solution indicates the greater association among the molecules of solution [10]. The strong association in L-Valine solution may be due to the intermolecular hydrogen bonding, dipole-dipole and ion-dipole interactions between solute and solvent molecules. As the temperature of L-Valine solution increases, the cohesion and frictional forces have been diminished due to thermal motion of molecules and relative velocity increases and hence viscosity is found to decrease with increase in temperature.

Ultrasonic Velocity:

The ultrasonic velocity, for amino acid electrolytes solutions for different temperatures and various concentrations have been determined at 2MHz frequency and experimental values of U have been presented in Tables 1. From table1 it is observed that speed of sound of L-Valine solutions in 2% aqueous solution of NaI is found to increase with increase in concentration of L-Valine and increase with increase in temperature. The increase in ultrasonic velocity in any solution suggests the greater association among the components of the mixture [11]. The greater association is due to dipole-dipole, ion-dipole and hydrogen bonding between L-Valine and solvent (2% aqueous NaI) molecules. As temperature increases, the hydrogen bonds among water molecules dissociate and more water molecules are produced which fit in the cage like water structures and thus get 'trapped'. As a result, the number of close-packed water structures increases with increase in temperature. This increase in close-packed water structures forms the stiff material medium for the propagation of ultrasonic waves.

Adiabatic compressibility and free length: Increase in concentrations leads to decrease in gap between two species which is referred by intermolecular free length (Lf). From table1, it is observed that adiabatic compressibility and free length of L-Valine solution in 2% aqueous solution of NaI are found to decrease with increase in concentration of L-Valine and decrease with increase in temperature. Decrease in adiabatic compressibility and free length may due to the influence of the electrostatic field of solute molecules on the surrounding solvent molecules. Decrease in compressibility and free length indicates that there is enhanced molecular association in this system upon increment of solute [12]

Acoustic impedance:

From table1, it is observed that acoustic impedance of L-Valine solutions in 2% aqueous solution of NaI are found to increase with increase in concentration of L-Valine and increase with increase in temperature. The increase in acoustic impedance in any solution suggests the greater association among the components of the mixture [13]. The greater association is due to dipole-dipole, ion-dipole and hydrogen bonding between L-Valine and solvent molecules. This suggests that the strong intermolecular hydrogen bonding between solute and solvent molecule.

Relative Association:

The property which can be studied to understand the molecular interaction is the relative association (RA.). It is influenced by two factors: (i) Breaking up of the associated solvent molecules on addition of solute in it and (ii) The solvation of solute molecule [14]. The former leads to the decrease and later to the increase of relative association. From Table 1, it is observed that, RA increases with increase in the solute concentrations in the NaI solution.

Table 1: The values of density ,viscosity, ultrasonic velocity, adiabatic compressibility, free length, acoustic impedance and relative association of L-Valine solutions of concentration 0.02 to 0.12M in 2% aqueous NaI solution at temperature 288.15, 293.15 298.15 and 303.15K are reported in table 1.

Con. (Mol. dm^{-3})	ρ (Kg/m^3)	η x10^{-4} (Nm^{-2}s)	U (m/s)	βx10^{-10} (m^{2}N^{-1})	Lf x10^{-11} (m)	Z x10^6 (Kgs^{-1}m^{-2})	RA
303.15K							
0	995.85	7.97300	1499.286	4.4672	4.1936	1.4931	1.0000
2%	1003.03	8.12492	1499.973	4.4312	4.1766	1.5045	1.0071
0.02	1000.98	8.20265	1500.66	4.4362	4.1790	1.5021	1.0049
0.04	1001.19	8.29865	1502.036	4.4271	4.1747	1.5038	1.0048
0.06	1001.72	8.30308	1504.105	4.4126	4.1679	1.5067	1.0048
0.08	1002.55	8.40438	1505.487	4.4009	4.1623	1.5093	1.0054
0.1	1002.64	8.49958	1507.565	4.3884	4.1564	1.5116	1.0050
0.12	1003.07	8.50316	1509.649	4.3744	4.1498	1.5143	1.0049
298.15K							
0	997.89	8.90200	1490.419	4.5113	4.1774	1.4873	1.0000
2%	1004.81	8.96378	1491.097	4.4762	4.1611	1.4983	1.0068
0.02	1002.59	9.13832	1490.419	4.4902	4.1677	1.4943	1.0047
0.04	1003.04	9.23976	1492.456	4.4759	4.1610	1.4970	1.0047
0.06	1003.77	9.24641	1494.499	4.4604	4.1538	1.5001	1.0050
0.08	1004.07	9.34656	1495.863	4.4510	4.1494	1.5020	1.0050
0.1	1004.57	9.44865	1497.915	4.4365	4.1427	1.5048	1.0050
0.12	1004.83	9.54848	1499.419	4.4265	4.1380	1.5067	1.0049
293.15K							
0	998.29	1.0020	1480.987	4.5671	4.1652	1.4785	1.0000
2%	1005.25	0.9988	1480.987	4.5355	4.1507	1.4888	1.0070
0.02	1003.55	1.0276	1478.315	4.5596	4.1618	1.4836	1.0059
0.04	1003.86	1.0381	1480.317	4.5459	4.1555	1.4860	1.0057
0.06	1004.42	1.0489	1482.327	4.5310	4.1487	1.4889	1.0058
0.08	1004.66	1.0593	1484.342	4.5176	4.1426	1.4913	1.0056
0.1	1005.23	1.0599	1486.362	4.5028	4.1358	1.4941	1.0057
0.12	1005.39	1.0703	1488.388	4.4899	4.1298	1.4964	1.0054
288.15K							
0	999.63	1.1380	1463.743	4.6691	4.1753	1.4632	1.0000
2%	1006.45	1.1458	1470.352	4.5958	4.1425	1.4798	1.0053
0.02	1004.92	1.2210	1465.091	4.6360	4.1605	1.4723	1.0050
0.04	1005.30	1.2215	1468.375	4.6135	4.1504	1.4762	1.0046
0.06	1005.56	1.2328	1469.692	4.6040	4.1461	1.4779	1.0046
0.08	1006.21	1.2446	1471.012	4.5928	4.1411	1.4802	1.0049
0.1	1006.49	1.2560	1473.322	4.5772	4.1340	1.4829	1.0047
0.12	1007.03	1.2677	1475.65	4.5603	4.1264	1.4860	1.0047

4. Conclusion

It is concluded that strength of intermolecular interaction increases with increase in concentration of L-valine which indicates solute-solvent interactions.

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6. References

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