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# Intermolecular interactions identified with velocity of Ultrasound in Vanilin at different temperatures

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***Abstract-*** The thermodynamic and acoustical study elucidates the nature of interactions between molecules in liquids and solutions. Also ultrasonic parameters are directly related to a number of thermodynamic parameters. As the different liquid state theories are based on thermodynamic considerations, the study of propagation of ultrasonic waves in liquid systems is established as a simple and effective tool in determining the nature of interactions between molecules in liquids and solutions. Using ultrasonic velocity measurements, Adiabatic Compressibility, Rao's Constant, Wada's Constant, Specific Acoustic Impedance and Intermolecular Free Length are evaluated and the variations are analyzed. Structure making and Structure breaking nature of solution is studied using Internal Pressure variations.

***Index Terms-*** Velocity, Adiabatic compressibility, Internal Pressure, Free volume.

## I. INTRODUCTION

The structure of liquids is well established than that of gases or solids. Despite a great deal of research in this area, we still do not have a clear picture of the way in which molecules are arranged in even the most common liquid, water. Ultrasonic studies of electrolytic solutions yield valuable information about the nature and strength of molecular interactions. The estimation of ultrasonic velocity, help us to evaluate the Internal Pressure, Free Volume, Compressibility, Rao's Constant and Wada's Constant, which provides a wealth of information about the state of liquid. It explains many of the properties of liquids and solutions. Even microscopic changes occurring in the medium like in molecular orientations or in temperature will change the value of Internal Pressure. From the acoustic parameters the ultrasonic behaviour of Vanilin was assessed.

## II. EXPERIMENTAL STUDIES

The aqueous solution of Vanilin (AR Grade) is dissolved in double distilled water for making up different concentrations under study. A Mittal type fixed frequency Interferometer (2 MHz) is used for the determination of Ultrasonic Velocity. A circulating thermostat is used to maintain the temperature of the system at constant temperature variation studies.

## III. MATHEMATICAL FORMULAS

Ultrasonic Velocity (U) =$\lambda$ x f
$\lambda$ = wavelength f=frequency Where $\lambda$=2d/n

Adiabatic Compressibility: $\beta = (1/u^2\rho)$

Intermolecular free length ($L_f$): $$L_f = \left(\frac{K}{U_P^{1/2}}\right) = K\left(\beta_{ad}\right)^{1/2}$$

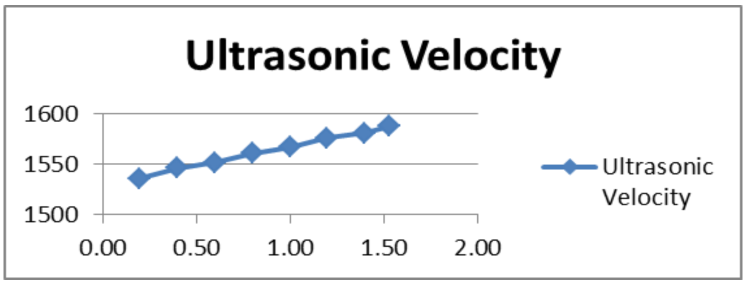
Relaxation time ($\iota$) = $4\eta/(3\rho U^2)$

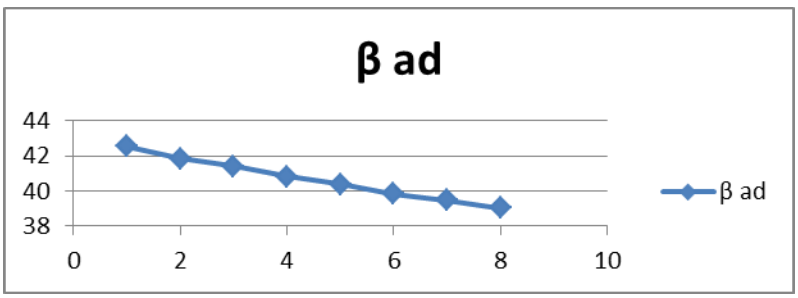
Specific Acoustic Impedance(z)= $\rho$*U

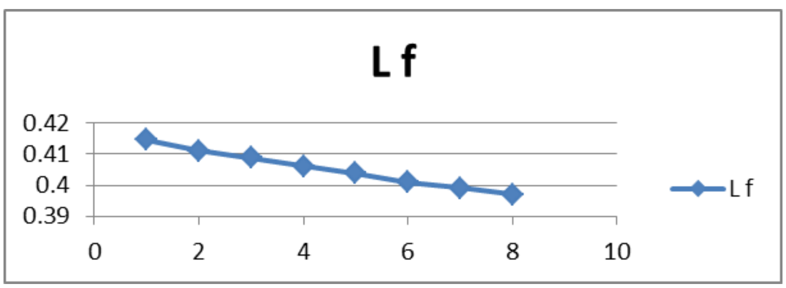
Rao's Constant(R)= $$R=\frac{M}{\rho}\bullet u^{1/3}$$

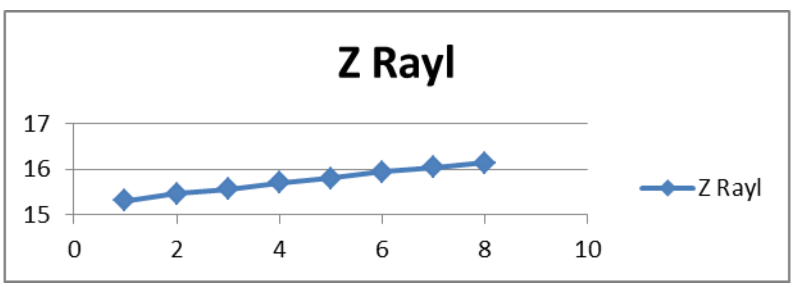
Wada's Constant(W)= $$\left[\frac{M}{\rho}\right]\left(\beta_{ad}\right)^{-1/7}$$

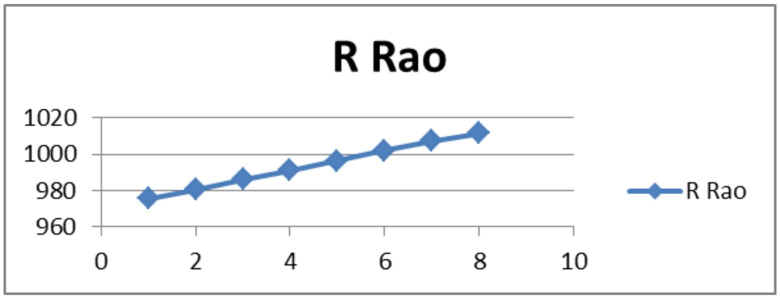
| Molality | Ultrasonic Velocity | β ad | L f | Z Rayl | R Rao | B Wada |
|---|---|---|---|---|---|---|
| 0.20 | 1536 | 42.52 | 0.4145 | 15.305 | 975.62 | 552.15 |
| 0.40 | 1546 | 41.83 | 0.4111 | 15.462 | 980.61 | 555.12 |
| 0.60 | 1552 | 41.38 | 0.4089 | 15.567 | 986.01 | 558.29 |
| 0.80 | 1561 | 40.81 | 0.4061 | 15.702 | 990.98 | 561.24 |
| 1.00 | 1567 | 40.38 | 0.4039 | 15.807 | 996.29 | 564.35 |
| 1.20 | 1576 | 39.81 | 0.4010 | 15.942 | 1001.98 | 567.64 |
| 1.40 | 1581 | 39.44 | 0.3992 | 16.034 | 1007.41 | 570.81 |
| 1.53 | 1588 | 39.03 | 0.3971 | 16.133 | 1011.34 | 573.07 |

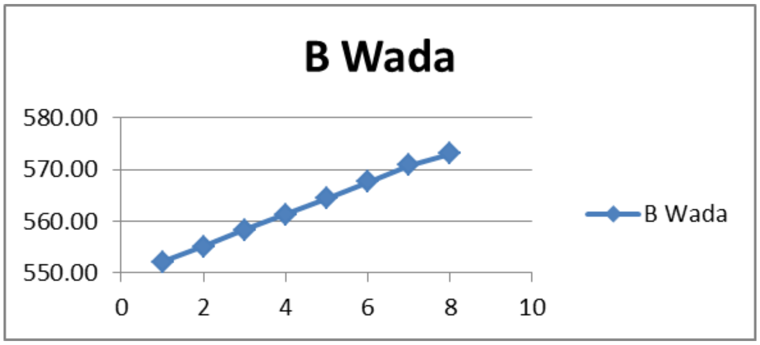





| Molality | internal pressure | free volume |
|---|---|---|
| 0.20 | 23662 | 0.03151 |
| 0.40 | 23582 | 0.03109 |
| 0.60 | 23431 | 0.03124 |
| 0.80 | 23317 | 0.03145 |
| 1.00 | 23202 | 0.03172 |
| 1.20 | 23028 | 0.03214 |
| 1.40 | 22939 | 0.03231 |
| 1.53 | 22827 | 0.03260 |

## IV. Results and Discussion

The experimentally determined values of Ultrasonic Velocity for Vanilin at different concentrations are summarized in the table.

The measurement of ultrasonic velocity is an important tool to study the physical & chemical properties of the liquid. Ultrasonic velocity and allied parameters of Vanilin for various concentrations are presented in tables and represented graphically in figures.

The parameters derived from ultrasonic measurements such as Adiabatic Compressibility, Intermolecular Free Length, Specific Acoustic Impedance, molar sound velocity and molar compressibility prove a better insight into molecular environment in liquid mixtures and solutions.

In this the ultrasonic velocity increases with increase in both temperature and concentration.

The plot between the ultrasonic velocity and concentration potential shows that the ultrasonic velocity is found to linearly increase with concentrations. This linear increase suggests that there are strong solute-solvent interactions in the liquid solution. These interactions are both concentration and temperature dependent. The effects of temperature on the interactions are more than that of concentration. At low concentrations, the number of hydrogen bonds formed may be less and at higher concentrations, it may be more due to solute-solute interactions [Graph1].

The compressibility is a macroscopic observable, which is sensitive to solute-solvent interactions. Any modifications induced by the solute on the local structure of the solvent generate changes in the Adiabatic Compressibility of the solutions and therefore compressibility can be used to characterize solvated properties of solute in dilute solutions. The decrease of Adiabatic Compressibility with Concentrations of all the solutions studied here indicates the formation of a more number of tightly bound systems. This implies, the $\beta$ is decreasing with Concentration[1]. This is seen from the fact that the Velocity is equal to the square root of the reciprocal of $\beta$ with density [Graph 2].

The intermolecular free length of the liquid systems decreases with increase in concentration. The free length is the distance between the surfaces of the neighboring molecules. It indicates significant interactions between the solute and solvent molecules, due to which the structural arrangement in the neighborhood of constituent solute particles is considerably affected. At lower concentrations, the molecules are not closer and then the Intermolecular Free Length will be high[2]. As the concentration increases, the molecules come closer, there by decreasing the intermolecular free length [Graph 3].

The usual behavior of the linear increase of Specific Acoustic Impedance with Concentration at a given temperature is observed in the system studied here. The Specific Acoustic Impedance in liquids can also be used to assess the strength of Inter-Molecular Attraction[3]. As the strength of the intermolecular attraction increases, the ultrasonic velocity also increases consequently, the acoustic impedance value also increases. Acoustic impedance is a characteristic property of the medium [Graph 4].

The variations of Molar Sound Velocity (Rao's constant) and Molar Compressibility (Wada's constant) show increasing trend with the variation of concentration at 303k as expected [Graph 5 & 6].

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