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Ultrasonic Investigation of Molecular Interaction in Salicylic Acid Solution at Different Frequencies†

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Salicylic acid is a basic nucleus used for the synthesis of different antipyretic, analgesic and antibiotic drugs which are widely used in medicinal field. Various techniques have been used to study intermolecular interactions, one such technique is the measurement of ultrasonic velocity. Ultrasonic parameters provide valuable information about various intermolecular interactions in solution. Measurements of ultrasonic velocity, density and viscosity of 0.01 M solution of salicylic acid in ethanol have been carried out at 303.15 K at different frequencies. The experimental data was used to calculate various acoustical parameters such as adiabatic compressibility (β), apparent molar compressibility (Φ_k), specific acoustic impedance (Z), relative association (R_A), relaxation time (τ) and intermolecular free length (L_f). The results are interpreted in terms of solute - solvent interactions occurring in the solution.

Key Words: Salicylic acid, Ultrasonic velocity, Acoustic parameters, Intermolecular interactions.

INTRODUCTION

Ultrasonic technique is the most important and universally accepted technique to study the physical and chemical properties of solution[1-4]. The measurements of ultrasonic velocity in liquid and liquid mixtures provide valuable information about the physico-chemical parameters and the nature of molecular interaction in them[5-7].

Ultrasonic velocity measurements have been widely used in the field of molecular interactions and structural aspects. A number of workers[8-11] has carried out ultrasonic studies of liquid in aqueous as well as non aqueous medium. The molecular interactions between salicylic acid with ethanol as a solvent at 303.15 K have been investigated in the present paper. This also gives idea about solubility of salicylic acid in solvents like ethanol. By the measurement of ultrasonic velocity, density and viscosity of the solution at 303.15 K at 2 MHz, 4 MHz and 6 MHz frequencies and computing the data the acoustic properties like adiabatic compressibility (β), apparent molar compressibility (Φ_k), apparent molar volume (Φ_v), specific acoustic impedance (Z), relative association (R_A), intermolecular free length (L_f) and relaxation time (τ) are determined.

EXPERIMENTAL

All the chemicals used were of analytical grade. Double distilled water was used for the preparation of solutions. Pure ethanol was used as a solvent to prepare 0.01 M solutions of salicylic acid.

Ultrasonic velocity and density measurements are necessary to determine the acoustic parameters of solutions. Ultrasonic velocity through 0.01 M salicylic acid solution in ethanol was measured with the Mittal type (Model-M-83, Mittal enterprizes) multifrequency ultrasonic interferometer at different frequencies with an accuracy of ±2 m/s. All the readings were taken at 303.15 K, viscosity of solution was measured by Ostwald's viscometer and density of solution was measured by specific gravity bottle. Elite thermostatic water bath was used in which continuous stirring and circulation of water was carried out with the help of electric stirrer and temperature was maintained with an accuracy of 0.1 ºC. All the weighing were made on digital electronic balance (Model CB/CA/CT-series) having an accuracy of 0.001 g.

By using ultrasonic velocity, following acoustic parameters were calculated.

Adiabatic compressibility:

$\beta_S = 1/v^2d$, where, v-ultrasonic velocity, d-density.

Specific acoustic impedance:-

$Z = v.d_s$, wher, d_s - density of solution.

Intermolecular free length:

$L_f = K. \sqrt{\beta_S}$, where, K-Jacobson's constant

Apparent molar compressibility :

$\Phi_k = [1000(\beta_S d_o - \beta_o d_s)/m d_s d_o] + (\beta_s M/d_s)$

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TABLE-1
ACOUSTIC PARAMETERS OF SALICYLIC ACID IN ETHANOL AT 303.15 K

Frequency MHz	Velocity (V_s m/s)	Adiabatic compressibility ($\beta \times 10^{-11}$ (pa^{-1}))	Specific acoustic impedance $Z \times 10^5$ (Kgm^{-2} Sec^{-1})	Intermolecular free length (m) $L_f \times 10^{-3}$	Relative association R_A	Acoustic relaxation time $\tau \times 10^{-14}$	Apparent molar compressibility (Φ_K) $\times 10^{-12}$
2	4672	5.6053	38.1874	4.7542	1.0447	8.1097	-1503.75
4	11408	0.9401	93.2457	1.947	1.0278	1.3601	-382.167
6	22802	0.2353	186.3868	0.974	1.0037	0.3404	-154.791

where, β_S = adiabatic compressibility of solution; β_o = adiabatic compressibility of solvent.

Relative association:

$$R_A = d_o/d_s(v_o/v_s)^{1/3}$$

Relaxation time:

$$\tau = 4/3\ \beta_S\ \eta;\ \text{where}\ \eta = \text{viscosity of solution}$$

RESULTS AND DISCUSSION

The experimentally determined values are listed in following Table-1.

Concentration of salicylic acid solution = 0.01 M, Density = 817.4 Kgm^{-3}, Viscosity = 1.0851 × 10^{-3} Kgm^{-1} s^{-2}, molecular weight of salicylic acid = 138.12.

The ultrasonic velocity of 0.01 M salicylic acid solution in ethanol was measured at 303.15 K at 2 MHz, 4 MHz and 6 MHz frequency. It is observed that at constant concentration if frequency increases, ultrasonic velocity also increases. Again it is observed that with the increase in frequency there is no effect on the value of apparent molar volume. Specific acoustic impedance increases with increase in frequency. Adiabatic compressibility decreases with increase in frequency. It is observed that intermolecular free length (L_f) decreases with the increase in frequency. Alcohols are polar in nature and hence associate strongly through hydrogen bonding. From the structure of the drug and the solvent, the interaction is mainly between -OH group of solvent and carboxyl group of drugs. Hydrogen bonds between solute- solvent strengthen the intermolecular forces resulting in the decrease of adiabatic compressibility with the increase of frequency.

Increase in the acoustic impedance is an indication of strong interaction between salicylic acid and solvent[12]. From the above findings, it is observed that molecular association between drug-solvent molecule arising from intermolecular hydrogen bonding and the variation of acoustical parameters with frequency at 303.15 K strongly supports the molecular association occurring in these systems.

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