THERMOACOUSTICAL STUDIES OF MOLECULAR INTERACTION IN THE SOLUTION OF ALPRAZOLAM DRUG AT DIFFERENT TEMPERATURES AND CONCENTRATIONS

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A B S T R A C T

In the present study, the ultrasonic velocity, density and viscosity of the aqueous solution of Alprazolam drug with different concentration and at three different temperatures 297.15K, 307.15K, 317.15K has been measured. Based on the data obtained, various derived acoustical parameters like adiabatic compressibility, intermolecular free length, acoustic impedance, relaxation time, Rao's constant, Wada's constant and Gibb's free energy have been calculated. From the result obtained it can be concluded that there is a strong intermolecular interaction of Alprazolam drug with water due to strong hydrogen bonding.

Keywords: Acoustical Parameters, Ultrasonic velocity; Alprazolam; Intermolecular Interaction; Hydrogen bonding

1. Introduction

In recent years ultrasonic velocity measurements have been widely used to detect molecular interactions in binary mixtures. This study is non-destructive
and have found to be effectively applicable to the various field viz., medicinal, agricultural, industrial, polymer chemistry etc. Researchers use the ultrasonic velocity to estimate the thermodynamics properties and predict the intermolecular interactions between drug and the solvent. [1-2].

The ultrasonic velocities (U), viscosity (η) and Density (ρ) measurements find wide applications in characterizing the physico - chemical behavior of the liquid mixtures [3-6]. These properties are extensively used to estimate the thermodynamics properties and predict the intermolecular interactions. Further, the measurements of excess thermodynamic properties are found to be greatly significant in studying the structural changes associated with the liquids. These measurements are highly sensitized to molecular interactions and can be used to provide qualitative as well as quantitative information about the physical nature and strength of molecular interaction in solutions. [7-8]. Due to the great importance of ultrasonic velocity in the determination of solute-solvent interactions, it is used to determine the percentage of adulterant added in the sample of milk, fuels, fruit juices and drinks[9-10].

The ultrasonic velocity is also used to determine the enthalpy of dissolution in a mixture of solid-liquids and liquid-liquid [11-13]. The changes in the ultrasonic velocity and thus calculated acoustical parameters with respect to varying temperature and concentration are used by scientists to find out structural changes associated with interacting components present in the solution [14-16]. Researchers studied the nature of interaction present between various drugs and solvent [17-18].

Alprazolam is an antianxiety drug that is used in the treatment of panic and anxiety disorders. The literature survey reveals that a lot of work has been done to investigate intermolecular interactions of pure liquid and liquid mixture using ultrasonic measurement but molecular interaction of Alprazolam drug with water has not been studied. The chemical name of alprazolam is 8-chloro-1-methyl-6-phenyl-4H-s-triazolo [4,3-α] [1,4] benzodiazepine [Fig 1]. In the present work, molecular interactions of Alprazolam drug in

water at different temperatures over a wide range of concentrations have been studied. The ultrasonic velocity, density and viscosity and derived acoustical parameters viz. adiabatic compressibility, acoustic impedance, relaxation time, intermolecular free length, Rao's constant, Wada constant and Gibb's free energy have been calculated. The variation of these parameters with concentration was found to be useful in understanding the nature of interactions between the components.

Experimental section:

All AR grade chemicals were used in the experiments. Also, these chemicals used in the same form as received from market without further purification. The solutions were prepared in double distilled water.

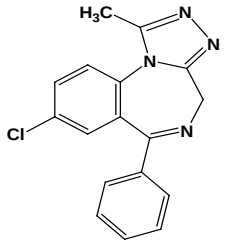

Fig. 1 : Structure of Alprazolam drug ($C_{17}H_{13}ClN_4$)

Thermoacostical study of the Alprazolam Drug

The solutions of different concentration (W/V %) of Alprazolam drug (Molar mass = 308.765 g) were prepared in distilled water as the solvent. The densities (ρ) of these binary solutions were measured accurately using 25 mL specific gravity bottle in an electronic balance with an accuracy of ±0.0001g. The basic parameter ultrasonic velocity (U) has been measured on Digital Ultrasonic Pulse Echo Velocity Meter (Vi Microsystems Pvt. Ltd. Model VCT-70 at 2MHz) with an accuracy of 0.1%. The viscosities (η) of solutions were determined using Ostwald's viscometer by calibrating with doubly distilled water with an accuracy of ±0.001 Pa.sec. The basic parameter U, η and ρ of various concentrations of drug i.e. 0.1, 0.05, 0.025, 0.0125, 0.00625 and 0.003125 % were measured at 297.15 K, 307.15 K and 317.15 K. Thermostatically controlled water circulation system is used to maintain the temperature with an accuracy of 0.05^0C. For all mixtures and pure components, triplicate measurements were performed. The various acoustical parameters were calculated from U, η and ρ values using standard formulae.

Adiabatic compressibility: $\beta = {}^{1}/_{U^2\rho}$ (1)

Acoustic impedance (Z): $Z = U \times \rho$ (2)

Intermolecular free length: $L_f = K_T\sqrt{\beta}$ (3)

Where K_T is temperature dependent constant known as Jacobson's constant

$K_T = (93.875+0.375T) \times 10^{-8}$, where T = Absolute temperature in Kelvin

Relaxation time : $\tau = {}^{4\eta\beta}/_{3}$ (4)

Rao's costant: $R_a = \left(\frac{M}{\rho}\right) \times (U)^{\frac{1}{3}}$ (5)

Wada constant: $W = \frac{M(B)^{\frac{-1}{7}}}{\rho}$ (6)

where M = Molecular weight of solute

Gibb's free energy

$\Delta G^* = -2.303kTlog\left[{}^{h}/_{kT\tau}\right]$ (7)

Where,

k = Boltzmann's constant (1.3806×10^{-23} JK^{-1})

h = Planck's constant (6.6250×10^{-34} J.Sec.)

Results & Discussion

The measured values of ultrasonic velocity, viscosity, density and derived acoustical parameters for different concentration of Alprazolam drug solution at different temperatures are plotted as shown by Fig 2(A-I).

The variations of acoustical parameters of various concentrations of Alprazolam drug solution are studied at different temperatures. The results have been discussed in terms of various interactions observed and nature of bonding present in different solutions of Alprazolam drug. It has been observed that value of ultrasonic velocity increases with increase in the concentration as well as temperature of solutions. The increase in density and ultrasonic velocity may be due to cohesive forces and molecular association of solute. This shows a stronger interaction between solute and solvent molecules [Fig 2(A)]. The increase in the value of ultrasonic velocity is due to strong solute-solvent interactions which may be due to transfer of sound energy from one molecule to other. It has been observed that the values of the densities and viscosities increase continuously with rising concentration of solution as mentioned in [Fig 2(B-C)].

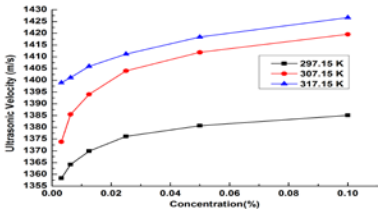

Fig.2(A): Variation of ultrasonic velocity of Alprazolam drug solution with concentration and temperature

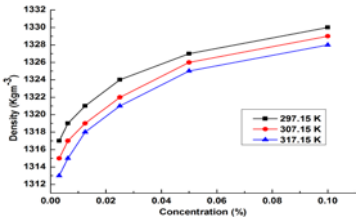

Fig.2(B):Variation of density of Alprazolam drug solution with concentration and temperature

The increase in the values of density may be due to the association of solute particles in the solution which indicates stronger attraction of unlike molecules whereas linear increase in the value of viscosity may be due to increase in the movement of molecules and ions present in the solution which decreases the solute solvent interaction hence indicates the strong Van der Waal forces of attraction and strong hydrogen bonding. As temperature increases, density and viscosity of various solutions decrease due to breaking of forces between solute and solvent molecules.

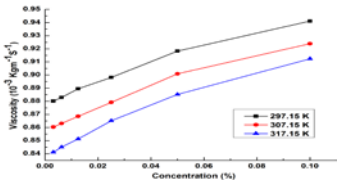

Fig. 2(C): Variation of viscosity of Alprazolam Alprazolam drug solution with concentration and temperature

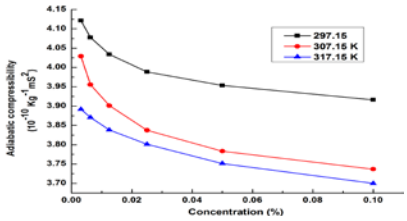

Fig. 2(D): Variation of adiabatic compressibility of drug solution with concentration and temperature

Adiabatic compressibility and intermolecular free length shows opposite behaviour compared to the ultrasonic velocity. As the concentration of Alprazolam drug solutions increase from 0.003125 to 0.1 %, then values of the adiabatic compressibility and intermolecular free length decreases continuously [Fig 2(D) and 2(F)]. The decrease in the value of intermolecular free length and adiabatic compressibility supports the existence of strong solute-solvent interaction which may be due to presence of strong intermolecular hydrogen bonding between Alprazolam drug and water molecules. Whereas nonlinear trends in the values of intermolecular free length and adiabatic compressibility with increase in temperature is due to weak solute-solvent interaction. Acoustic impedance is the product of density and ultrasonic velocity. The values of the acoustic impedance increases with the increasing concentration of solute and temperature as mentioned in [Fig 2(E)].

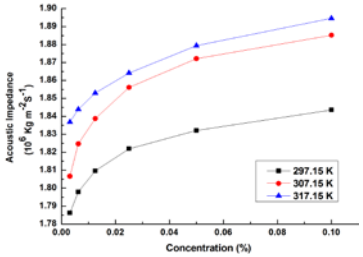

Fig.2(E): Variation of acoustic impedance of Alprazolam Alprazolam drug solution with concentration and temperature

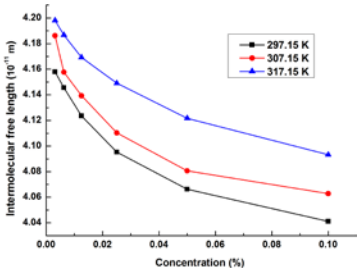

Fig. 2(F): Variation of intermolecular free length of drug solution with concentration and temperature

These values reveal that the molecular interactions are associative in nature. Increase in the value of the acoustical impedance with rise in temperature may be due to strong interactions between the solute-solvent molecules, whereas a nonlinear trend in the value of acoustical impedance is due to weak molecular interaction between the solute-

solvent molecules. The values of relaxation time increases with the concentration of solute whereas these values decreases by increasing the temperature which supports the stronger interactions between solute-solvent [Fig. 2(G)]. The Gibb's free energy reveals the closer packing of the molecules due to H- bonding of unlike molecules in the solution. The increase in Gibb's free energy with increasing Alprazolam drug concentration indicates strong complex formation between solute and solvent molecules. These trends of Gibb's free energy support the stronger hydrogen bonding interactions between solute and solvent molecules [Fig.2 (J)]. The values of Rao's constant and Wada constant with increase in the concentration of solution shows same trends. These values decrease with increase in concentration which is due to the presence of good intermolecular interaction between solute and solvent molecules [Fig. 2(H-I)].

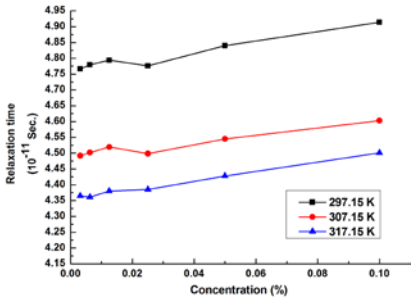

Fig. 2(G): Variation of relaxation time of Alprazolam drug solution with concentration and temperature

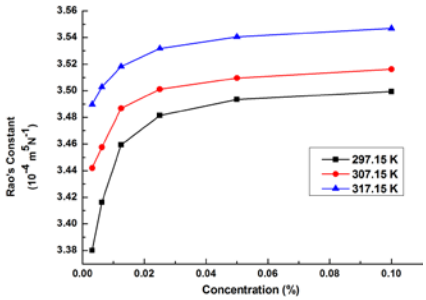

Fig. 2(H): Variation of Rao's constant of Alprazolam drug solution with concentration and temperature

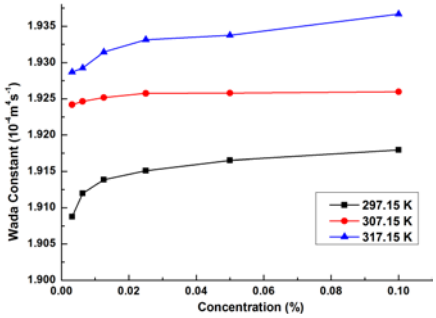

Fig. 2(I): Variation of Wada constant of Alprazolam drug solution with concentration and temperature

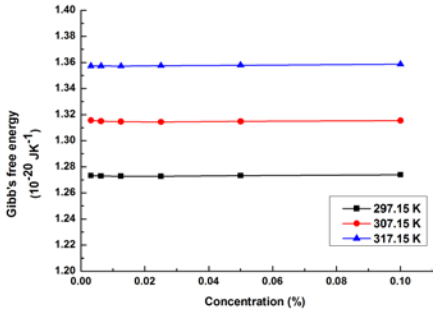

Fig.2(J): Variation of Gibb's free energy of Alprazolam drug solution with concentration and temperature

It is concluded that the increase in values of ultrasonic velocity and decrease in values of intermolecular free length with increase in percentage concentration of Alprazolam drug in water may be due to existence of strong intermolecular interaction of drug molecules and water molecules. This strong intermolecular interaction is may be due to intermolecular hydrogen bonding and dipole-dipole interactions.

Conclusion-

In the present study, ultrasonic studies of Alprazolam drug in water with varying concentrations and at different temperatures have been studied. The ultrasonic velocity, viscosity and density of the Alprazolam drug solutions has been determined at 297.15 K, 307.15 K and 317.15 K and hence the derived acoustical parameter such as adiabatic compressibility, acoustic impedance, intermolecular free length, relaxation time, Rao's constant, Wada constant and Gibb's free energy are calculated. The study of acoustical parameters provides the fruitful information regarding the nature of molecular interaction present in the solution. With the increase in concentration of solution, the ultrasonic velocity increases while intermolecular free length decreases which reveals the strong intermolecular association through hydrogen

bonding.

Conflict of interests:

The authors declare that there is no conflict of interest regarding the publication of this paper.

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