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Adiabatic compressibility, intermolecular free length and acoustic relaxation time of aqueous antibiotic cefotaxime sodium

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ABSTRACT

Ultrasonic velocity measurement provides an important tool to study the liquid state. The measurement of ultrasonic velocity in liquid mixture provides valuable information about their physico-chemical properties and nature of molecular interaction in them. Ultrasonic parameters provide valuable information about various inter and intra molecular interactions in solution. Cefotaxime sodium is used as an antibiotic in pharmaceutical. It is antibacterial, β-lactum; third generation cephalosporin. Ultrasonic velocity, density and viscosity of aqueous solution of cefotaxime sodium at different concentrations, temperatures and different frequencies such as 2MHz, 4MHz and 6MHz have been experimentally determined. Ultrasonic parameters such as adiabatic compressibility, intermolecular free length and relaxation time of these solutions are computed on the basis of these measurements. Various molecular interactions in these solutions have been analyzed on the basis of the variation of these parameters with concentration, temperature and frequency.

Key words: cefotaxime sodium, ultrasonic velocity, viscosity, acoustic parameters.

INTRODUCTION

The investigation of reasonable molecular interactions for antibiotic resistance have been attempted by many researchers.[1,2] Ultrasonic is an area of intense scientific and technological research. Science and technology of ultrasonic is widely sought in the recent years for industrial and medical applications. The study of behavior of propagation of ultrasonic waves in liquid system and solids is now rather well established as an effective means for examining certain physical properties of the materials. It is particularly well adapted to examine changes in such physical properties while they occur. The ultrasonic studies provide a wealth of information about state of liquids. It explains many properties of liquids, solutions. The measurement of ultrasonic velocity in pure liquids and mixtures is an important tool to study the physico-chemical properties and also explains the nature of molecular interactions. The parameters obtained in such a study are used in tern to derive an insight into the molecular interaction in such solutions. A number of researchers[3,4] have investigated the molecular interaction in aqueous solution of antibiotic. Cefotaxime sodium is used as an antibiotic in pharmaceuticals.

In continuation of work[5-9], in the present study, ultrasonic velocity, density and viscosity measurement of aqueous solution of antibiotic cefotaxime sodium at different temperatures, concentrations and frequencies was carried out. The data obtained is used to calculate various acoustical parameters. The data and the results obtained during this

investigation may give detail information regarding molecular interactions, drug absorption and transmissions activity.

EXPERIMENTAL SECTION

Antibiotic drug cefotaxime sodium obtained from Alkem laboratories limited was used. Double distilled water was used for making solutions. Densities were measured with the help of density bottle. Weighing was done on CB/CA/CC Conpech Digital Balance CCB-124, (± 0.0001 g). A special thermostatic water bath arrangement was made for density, viscosity and ultrasonic velocity measurements in which there is continuous stirring of water with the help of electric stirrer and temperature variation was maintained within ± 0.1°C. All the ultrasonic velocities were measured by multi frequency interferometer (Mittal Enterprises, Model F-83) with accuracy of ± 0.03% at frequencies 2, 4 and 6MHz. Viscosities of the solutions were measured by Oswald's viscometer.

RESULTS AND DISCUSSION

In the present investigation, measurements of densities, viscosities and ultrasonic velocities of solvent water and an antibiotic cefotaxime sodium solution have been made.

The adiabatic compressibility (β) is evaluated by using equation.

$$\beta = 1 / v^2.d \quad \ldots\ldots (1)$$

Intermolecular free length has been evaluated from adiabatic compressibility (β) by Jacobson's formula,

$$L_f = K\sqrt{\beta_s} \quad \ldots\ldots (2)$$

Where, K is the temperature dependent constant known as Jacobson's constant.

Relative Viscosity of Solution is calculated by equation

$$\eta_2 = \eta_1.t_2.ds/t_1.d_0 \quad \ldots\ldots (3)$$

Where, η_1=viscosity of water, η_2= viscosity of experimental liquid, t_1=time flow of water, t_2=time flow of experimental liquid, d_0=density of water and ds=density of experimental liquid.

Relaxation time is evaluated by equation

$$\tau = 4/3\beta.\eta \quad \ldots\ldots (4)$$

The values of ultrasonic velocities, densities and viscosities at different frequencies, concentrations and temperatures are tabulated in table 1, 2 and 3.

Table 1: Acoustic parameters of aqueous solution of Cefotaxime sodium at 2MHz.

Temperature (K)	Concentration (M)	Ultrasonic Velocity (m/s)	Density (Kg/m^3)	Viscosity $\eta x10^{-3}$ (NSm^{-2})	Adiabatic compressibility $\beta x10^{-10}$	Intermolecular free length L_f (A^0)	Acoustic relaxation time $\tau x10^{-10}$sec
303.15	0.001	1489.33	1016.16	0.8699	4.43	0.01320	5.146
	0.01	1491.21	1025.55	0.9301	4.38	0.01313	4.438
	0.1	1524.10	1043.55	1.1765	4.12	0.01273	6.471
308	0.001	1526.54	1006.14	0.9168	4.27	0.01304	5.213
	0.01	1527.13	1016.52	0.9262	4.22	0.01297	5.209
	0.1	1564.90	1039.00	0.9467	3.93	0.01251	4.961
313	0.001	1563.38	999.53	0.7559	4.09	0.01286	4.125
	0.01	1528.29	1010.52	0.7642	4.24	0.01309	4.317
	0.1	1637.99	1038.66	0.7855	3.59	0.01204	3.758

Table 2: Acoustic parameters of aqueous solution of Cefotaxime sodium at 4MHz.

Temperature (K)	Concentration (M)	Ultrasonic Velocity (m/s)	Density (Kg/m^3)	Viscosity $\eta x10^3$ (NSm^{-2})	Adiabatic compressibility $\beta x10^{-10}$	Intermolecular free length L_f (A^0)	Acoustic relaxation time $\tau x10^{-10}$sec
303.15	0.001	1525.52	1016.16	0.8699	4.22	0.01289	4.905
	0.01	1523.95	1025.55	0.9301	4.19	0.01284	5.207
	0.1	1527.27	1043.55	1.1765	4.10	0.01270	6.444
308.15	0.001	1599.44	1006.14	0.9168	3.89	0.01244	4.749
	0.01	1593.29	1016.52	0.9262	3.88	0.01243	4.785
	0.1	1599.81	1039.00	0.9467	3.76	0.01224	4.747
313.15	0.001	1596.21	999.53	0.7559	3.93	0.01260	3.692
	0.01	1597.07	1010.52	0.7642	3.88	0.01252	3.953
	0.1	1672.37	1038.66	0.7855	3.44	0.01180	3.605

Table 3: Acoustic parameters of aqueous solution of Cefotaxime sodium at 6MHz.

Temperature (K)	Concentration (M)	Ultrasonic Velocity (m/s)	Density (Kg/m^3)	Viscosity $\eta x10^3$ (NSm^{-2})	Adiabatic compressibility $\beta x10^{-10}$	Intermolecular free length L_f (A^0)	Acoustic relaxation time $\tau x10^{-10}$sec
303.15	0.001	1633.63	1016.16	0.8699	3.68	0.01204	4.277
	0.01	1643.56	1025.55	0.9301	3.60	0.01191	4.476
	0.1	1636.14	1043.55	1.1765	3.57	0.01186	5.615
308.15	0.001	1635.60	1006.14	0.9168	3.72	0.01217	4.541
	0.01	1638.54	1016.52	0.9262	3.66	0.01208	4.525
	0.1	1639.92	1039.00	0.9467	3.58	0.01194	4.517
313.15	0.001	1640.79	999.53	0.7559	3.72	0.01226	3.738
	0.01	1643.10	1010.52	0.7642	3.67	0.01217	3.735
	0.1	1738.32	1038.66	0.7855	3.19	0.01135	3.337

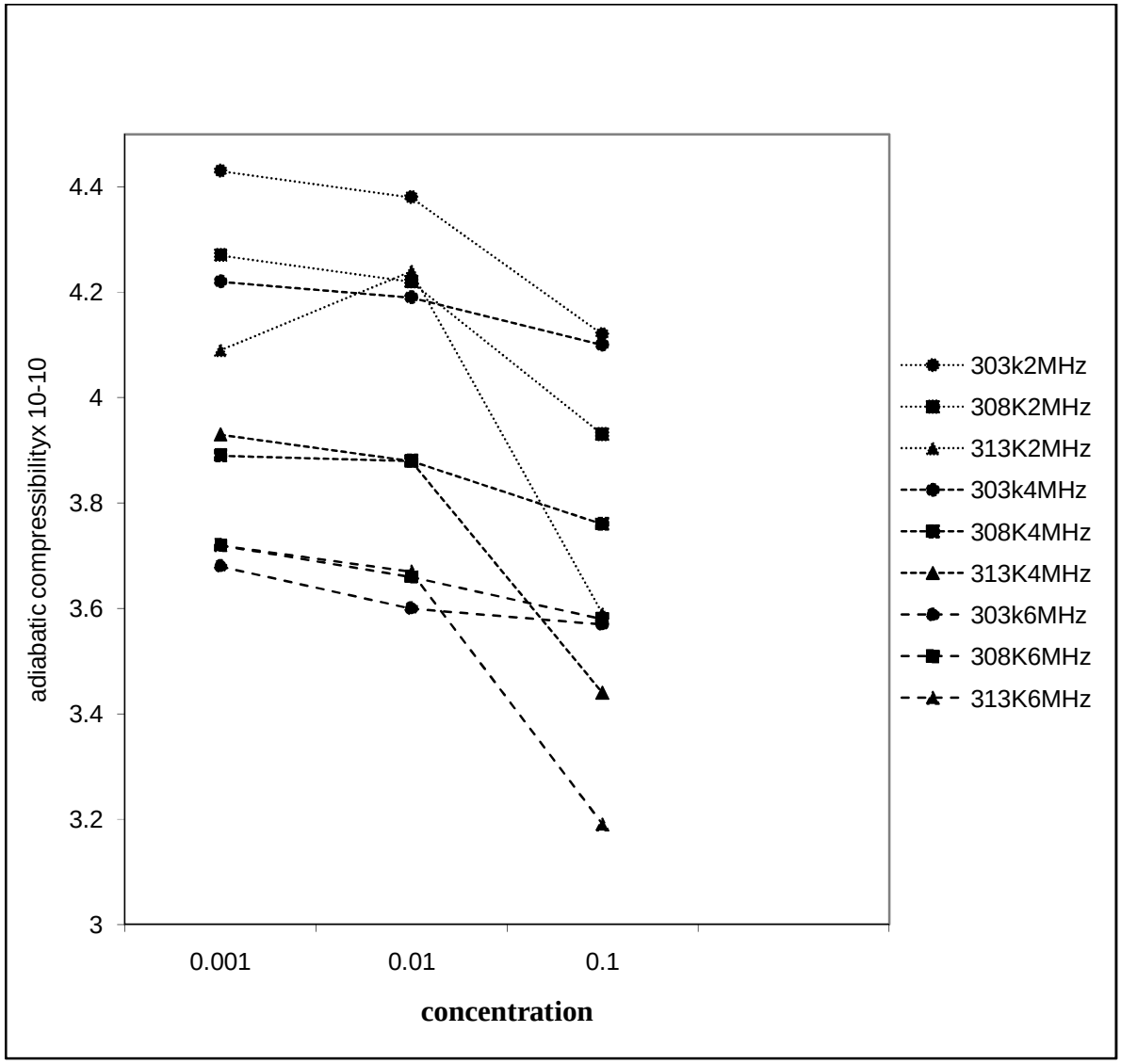
From the experimentally determined values of density, viscosity and ultrasonic velocity of aqueous solution of cefotaxime sodium at different concentrations, temperatures and at different frequencies such as 2MHz, 4MHz and 6MHz, various acoustical parameters like adiabatic compressibility, intermolecular free length and acoustic relaxation time have been evaluated. From this data molecular interaction in aqueous solution of cefotaxime sodium will be predicted.

A keen look at the Table 1, 2 and 3 suggest that the experimentally calculated values of ultrasonic velocity of aqueous solution of cefotaxime sodium increases with increases in concentration, temperature as well as frequency such as 2MHz, 4MHz and 6MHz where as the values of density and viscosity increase with increases concentration and the same is deceases with increases of temperature. The increasing values of density, viscosity and ultrasonic velocity show that there is moderate attraction between solute and solvent molecule. The decrease in values of density and viscosity with increase in temperature shows decrease in intermolecular forces due to increasing the thermal energy of the system.

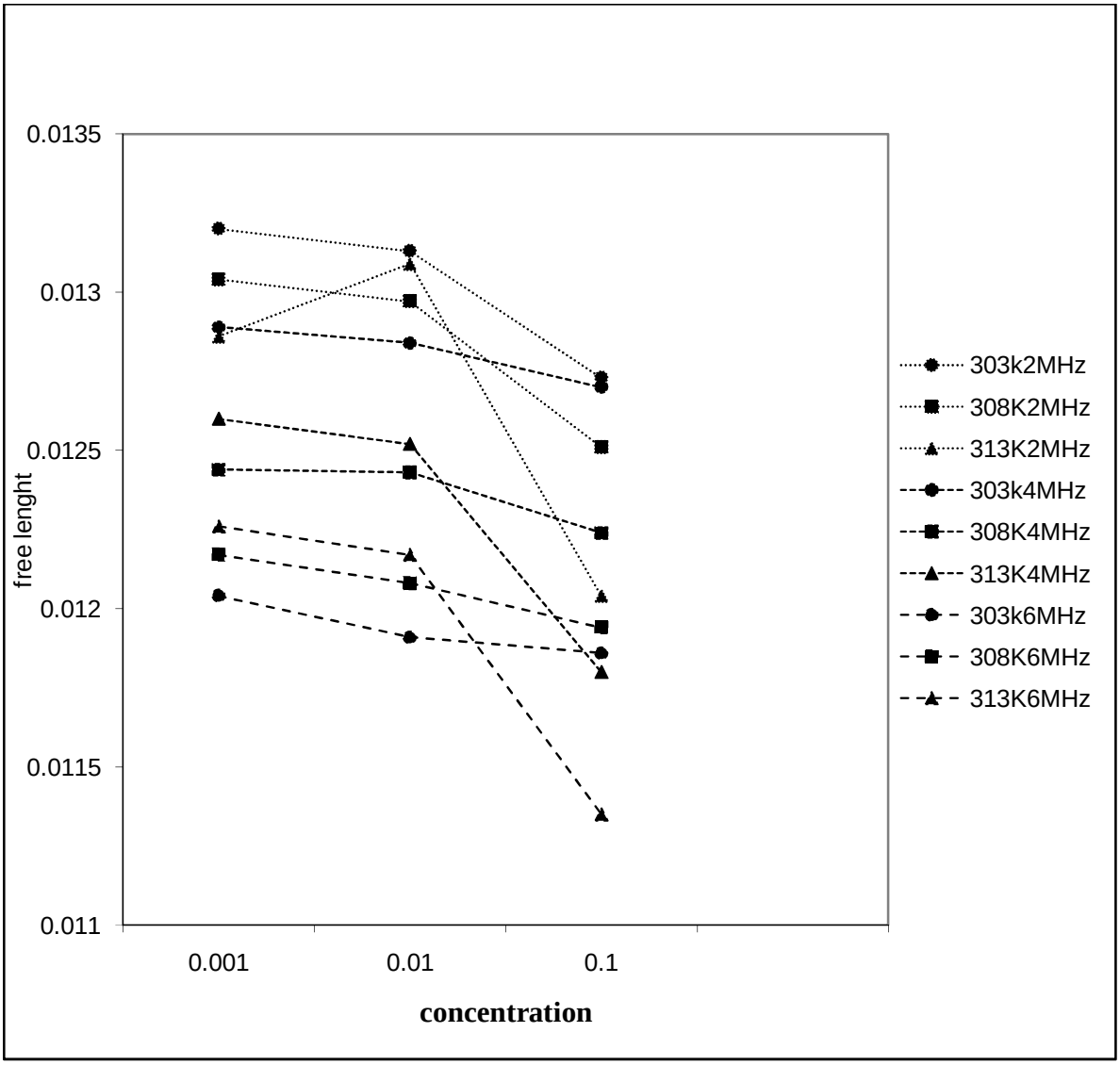
Adiabatic compressibility exhibits reverse trend to that of ultrasonic velocity as shown in Table-1, 2 and 3. Adiabatic compressibility decreases gradually with increase in concentration, temperature and frequency, because this depends on electron donor and acceptor capacity/nature. Water is polar solvent when antibiotic cefotaxime sodium is added the association of solute and solvent molecules occur resulting in close packing and clinging of molecules. Because of this, solution become less compressible and hence values of adiabatic compressibility decrease. The decreased values of adiabatic compressibility indicate strong intermolecular association between cefotaxime sodium and water molecules. This strong intermolecular interaction indicates the hydrogen bond formation in aqueous solution. This observation is similar to that of study of aqueous solution of cefodroxil where strong intermolecular interaction is attributed to the hydrogen bond formation.[1]

The intermolecular free length depends on adiabatic compressibility and shows similar behavior to that of adiabatic compressibility and inverse to that of ultrasonic velocity. The intermolecular free length decreases with increases of concentration, temperature as well as frequency. This indicates possibility of breaking dipole in cefotaxime sodium by mixing water and gets associated in the structure by electrostriction thus decreasing the free space available. This prevails that specific strong intermolecular interaction between cefotaxime and water molecules takes place. Decreased value of free length indicates structure promoting behavior of solute molecule.

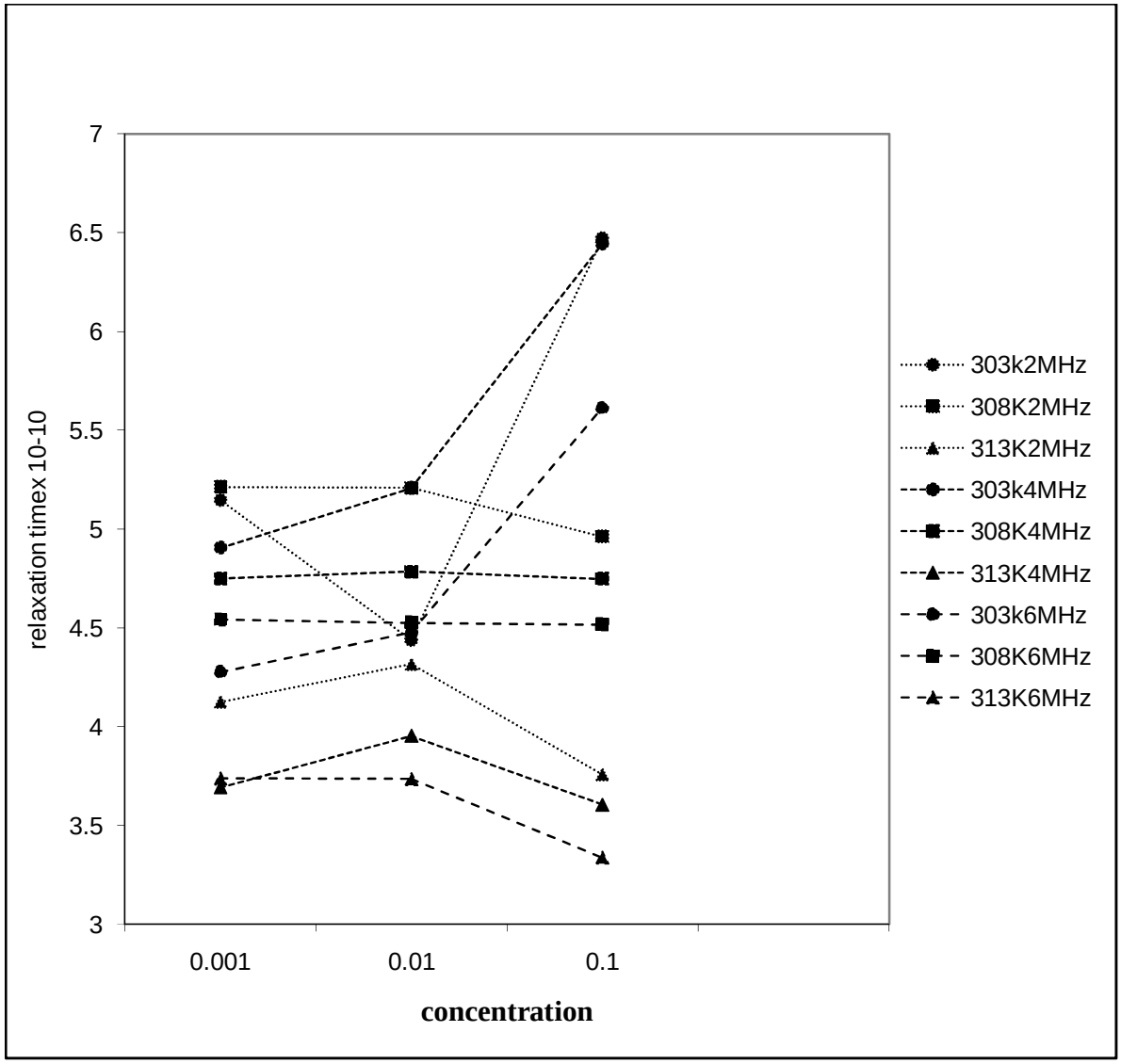
Relaxation time increases with increase in concentration and same decreases with rise in temperature as well as frequency. Relaxation time, which is of the order of 10^{-12} sec, is due to structural relaxation process[10] and in such situation it is suggested that the molecules gets rearranged due to co-operative process.[11]



Fig;1 adiabatic compressibility at different concentration, temperature and frequencies.



Fig;2 free length at different concentration, temperature and frequencies.



Fig;3 relaxation time at different concentration, temperature and frequencies.

CONCLUSION

The present study of aqueous solution of cefotaxime, a specific behavior of acoustical parameters reflects strong interaction of solute-solute and solute-solvent resulting from hydrogen bond formation in aqueous solution of cefotaxime sodium, which may be responsible to increase drug absorption and transmission at higher concentration, temperature and frequency.

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