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Ultrasonic, Volumetric and Viscometric Studies of substituted antibiotic Streptomycin in various percentage of aqueous ethanol

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Research Paper - Physics

ABSTRACT

Ultrasonic, volumetric, and viscometric studies on antibiotic streptomycin have been carried out in 10%, 20% and 30% aqueous ethanol at 303oK. Various thermodynamic parameters such as adiabatic compressibility, apparent molal volume, apparent molal compressibility and intermolecular free length have been determined. Results are discussed in terms of solute solvent interaction. Study indicates maximum interaction at lower concentration of the solvent.

Introduction:

In recent years, measurement of ultrasonic velocity have been adequately employed in understanding the nature of molecular interactions in pure liquid mixtures. Ultrasonic propagation parameters result valuable information regarding the behaviour of binary liquid systems, because intramolecular and intermolecular association, dipolar interactions, complex formation and related structural changes affect the compressibility of the system which in turn produces corresponding variations in the ultrasonic velocity. Ultrasonic velocities, densities, viscosities and derived thermodynamic and acoustical parameters are of considerable interest in understanding the molecular interactions in



binary [1-3] and ternary [4-7] liquid mixtures. Various thermodynamic and acoustical parameters of polar liquid mixtures are reported in the literature [8-12]. Ultrasonic, viscometric and volumetric studies of some substituted acetophenons and acetic acid in THF water, DMF water and dioxane water at 303.15 oK are reported by Aswar et al [13-14]. Hedao et al [15] reported adiabatic compressibility, apparent molal volume, apparent molal compressibility and solvation number of 2,3-Dihydroquinazolin-4 (1H)-one derivatives in 27% DMF water. Chaudhari et al [16-17] reported thermodynamic and acoustic parameters of substituted ampicillin and ciprofloxacin in aqueous ethanol at 303 oK. In the present paper thermodynamic and acoustic parameters such as adiabatic compressibility, apparent molal volume, apparent molal compressibility and intermolecular free length of the mixture of substituted streptomycin in aqueous ethanol at 303 oK is reported.

Experimental :

All the chemicals used are of analytical grade. Different compositions were made using double distilled water having specific conductance of less than 1×10^{-6} S cm^{-1} . Solutions of different concentrations were prepared by dissolving known weights of solutes. Density measurements were performed using 10 ml specific gravity bottle. All the weighing were done on a single pan digital balance with an accuracy of ± 0.001 gm. Ultrasonic velocities of the solutions were measured using multi frequency ultrasonic interferometer at a frequency of 2 MHz obtained from Mittal Enterprises-Model M81. The accuracy in the measurement of ultrasonic velocity was within ± 0.01 ms^{-1} .

Theory :

Sound speeds can be measured by using single frequency ultrasonic interferometer. The ultrasonic waves of known frequency produced by a quartz crystal are reflected by a movable metallic plate kept parallel to the quartz plate. When the state of acoustic resonance is reached due to formation of standing waves, an electrical reaction occurs on the generator driving the quartz plate and its anode current becomes maximum. Micrometer is slowly moved until the anode current meter on high frequency generator shows a maximum. The distance D thus moved by the micrometer between 2 consecutive maxima gives the value of the wavelength [18] by the relation $\lambda = 2 D$.



Knowing wavelength λ , ultrasonic velocity U can be determined by the relation $U = \lambda \nu$ where ν is the frequency of the generator. Various formulas used for calculation are as follows.

Adiabatic compressibility [19-20] of the solution (β_s) = $1/(U_s \lambda \nu)$

Adiabatic compressibility of the solvent (β_o) = $1/(U_o \lambda \nu)$

Apparent molal volume (v_a) and Apparent molal compressibility (β_a) [21-22] are given by the following equations.

Apparent molal volume (v_a) = $M/d_s + ((d_o - d_s) \times 10^3)/(m d_s)$

Apparent molal compressibility (β_a) = $(1000(\beta_o d_o - \beta_s d_s))/(m d_s) + \beta_s M/d_s$

Where d_o and d_s are the densities of the pure solvent and the solution respectively. m is the molality and M is the molecular weight of the solute.

According to studies, intermolecular free length (L_f) [23] is given by

Intermolecular free length (L_f) = $K \beta_a$

Where K is Jacobson's constant and is given by

$K = (93.875 + 0.375 \times T) \times 10^{-8}$

Where T is the temperature at which the experiment is carried out.

Result and discussion:

Streptomycin is soluble in water and insoluble in ethanol. Ethanol is a polar molecule. From the computed properties, streptomycin has 15 hydrogen bond acceptor count, 12 hydrogen bond donor count and 9 rotatable bond count. This shows high probability of formation of hydrogen bond with water molecule. Formation of the bond gives a packed structure to the solution. This certainly should increase the density (d_s) of the solution and thereby increase the ultrasonic velocity (U_s). The data for increase in density and ultrasonic velocity with the increase in the concentration of the solute and solvent is presented in table 1. Keeping the concentration of ethanol fixed in water, density increases with the concentration of the solution. As the concentration of the solvent is increased, density further increases with concentration. Figures 1 and 2 shows the graphs of variation of density and ultrasonic velocity with concentration respectively.

Table 2 shows the computed values of intermolecular free length (L_f) and adiabatic compressibility (β_s) with the concentration of the solution. Figures 3 and 4



shows the graphs of their variation with concentration respectively. Both show decreasing trend. Intermolecular free length decreases with increase in concentration of the solution. It further decreases with increase in concentration of the solvent. This can be attributed to the fact that, as the concentration of the solution and the solvent increases, formation of hydrogen bond between solute-solute molecules increases.

The values of apparent molal volume Δv and apparent molal compressibility Δk at different concentration of Streptomycin in 10%, 20% and 30% of ethanol in water are presented in table 3. Figures 5 and 6 shows the graphs of their variation with concentration respectively. All the values of Δv and Δk are negative for the concentration range under study. Both Δv and Δk increases with the concentration of the solution, at fixed concentration of the solvent. But they decrease as the concentration of the solvent is increased.

Limiting values of Δv and Δk are shown table 4. The nature of Δv and Δk as obtained from the data in table 3, together with the positive values of S_v obtained from Masson's equation [24] support the structure making tendency of the solution. The values of limiting parameters, Δv_0 and Δk_0 for different concentration of ethanol in water show the following order. 30% ethanol water < 20% ethanol water < 10% ethanol water. Hence solute solvent interactions are higher in 10% ethanol-water solvent than in the other 2 cosolvents.

Viscosity data were analysed using Jones-Dole equation [25]

$$\frac{\eta}{\eta_0} - 1 = Am^{1/2} + Bm$$

A and B are Falkenhagen and Jones-Dole coefficients respectively, and the other terms have their usual meaning. Positive values of B for all the concentrations of ethanol in water under consideration suggest strong ion solvent interaction.

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**Table 1 : Density and ultrasonic velocity at different concentration of Streptomycin in various percentage of ethanol in water**

concentration C (moles/Ltr)	Density d_s			Ultrasonic velocity U_s		
	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin
0.002	0.99692	1.00112	1.00309	1449	1590	1614
0.004	0.99806	1.00233	1.00362	1460	1604	1630
0.005	0.99834	1.00261	1.00395	1471	1614	1660
0.006	0.99885	1.00305	1.00407	1480	1621	1680
0.008	1.00004	1.00329	1.00436	1490	1634	1698
0.01	1.00040	1.00365	1.00464	1521	1650	1715

Table 2: Intermolecular free length L_f and Adiabatic compressibility β_s at different concentration of Streptomycin in various percentage of ethanol in water

concentration C (moles/Ltr)	Intermolecular free length L_f			Adiabatic compressibility β_s		
	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin
0.002	1.4340E-09	1.3039E-09	1.2835E-09	4.78E-07	3.95E-07	3.83E-07
0.004	1.4224E-09	1.2920E-09	1.2705E-09	4.70E-07	3.88E-07	3.75E-07
0.005	1.4122E-09	1.2837E-09	1.2474E-09	4.63E-07	3.83E-07	3.61E-07
0.006	1.4025E-09	1.2783E-09	1.2323E-09	4.57E-07	3.80E-07	3.53E-07
0.008	1.3924E-09	1.2676E-09	1.2195E-09	4.50E-07	3.73E-07	3.45E-07
0.01	1.3639E-09	1.2550E-09	1.2075E-09	4.32E-07	3.66E-07	3.39E-07

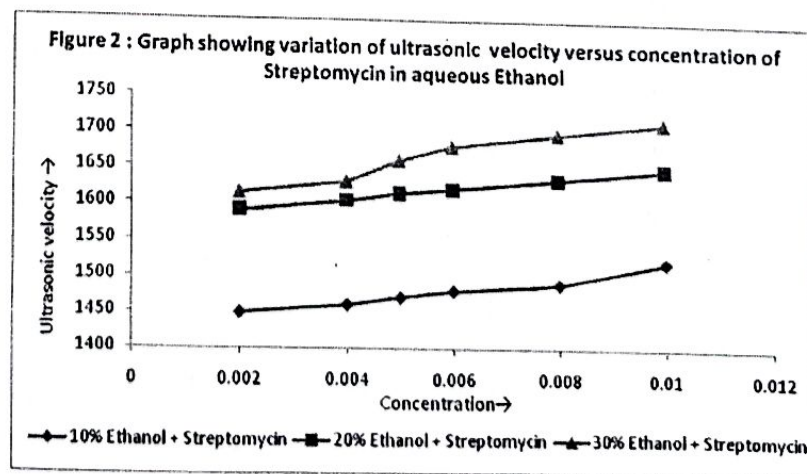
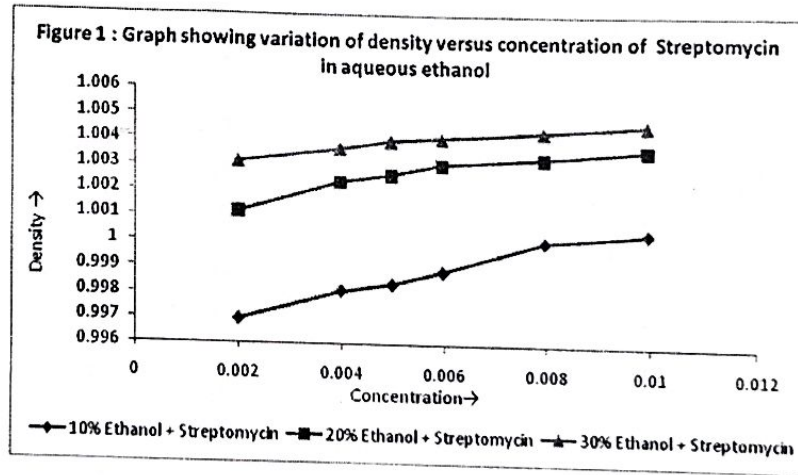
Table 3 : Apparent molal volume v and Apparent molal compressibility k at different concentration of Streptomycin in various percentage of ethanol in water

concentration C (moles/Ltr)	Apparent molal volume			Apparent molal compressibility		
	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin	10% Ethanol + Streptomycin	20% Ethanol + Streptomycin	30% Ethanol + Streptomycin
0.002	-5202	-15519	-23740	-5.14E-3	-13.34E-3	-28.00E-3
0.004	-2598	-7770	-11712	-4.51E-3	-8.48E-3	-15.86E-3
0.005	-2017	-6156	-9318	-4.93E-3	-7.75E-3	-15.37E-3
0.006	-1670	-5106	-7689	-5.16E-3	-6.98E-3	-14.22E-3
0.008	-1256	-3715	-5657	-4.70E-3	-5.99E-3	-11.54E-3
0.01	-924	-2892	-4438	-5.55E-3	-5.50E-3	-9.88E-3



Table 4: Limiting values of ϕ_v and ϕ_k for Streptomycin in various percentage of ethanol in water

Medium	ϕ_v^0	ϕ_k^0	S_v	S_k
10% E A + Amp	-7771.5	-0.1061	73976	0.0005
20% E A + Amp	-23144	-0.3044	219286	0.0238
30% E A + Amp	-35265	-0.3534	334483	0.0275



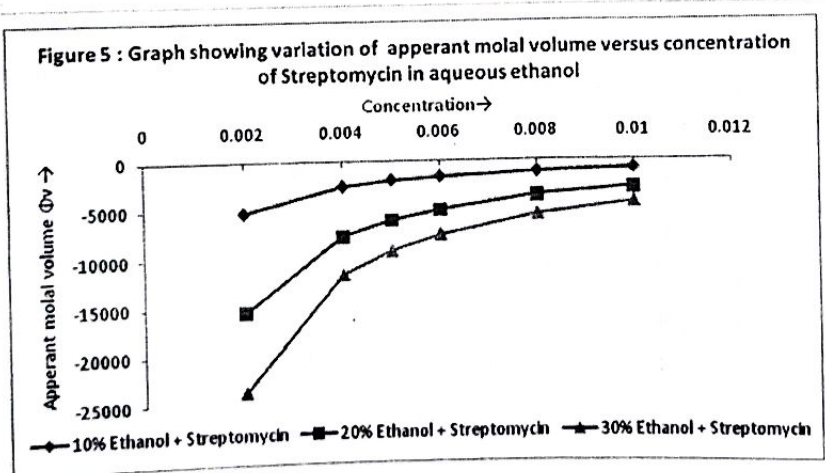
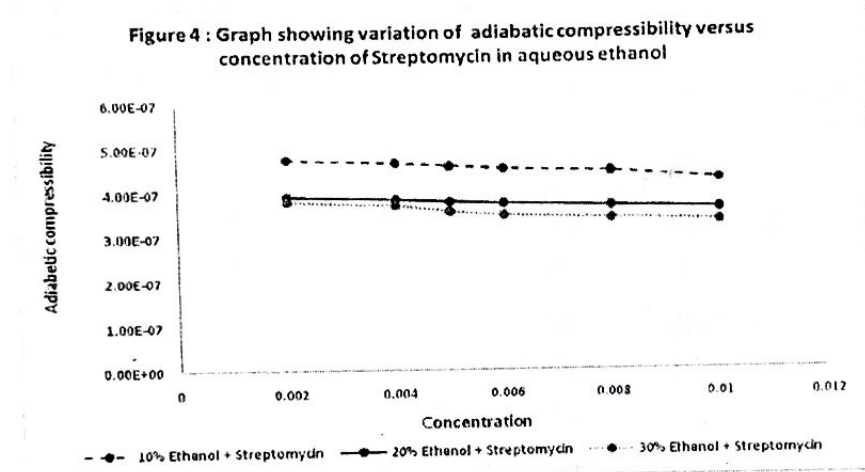
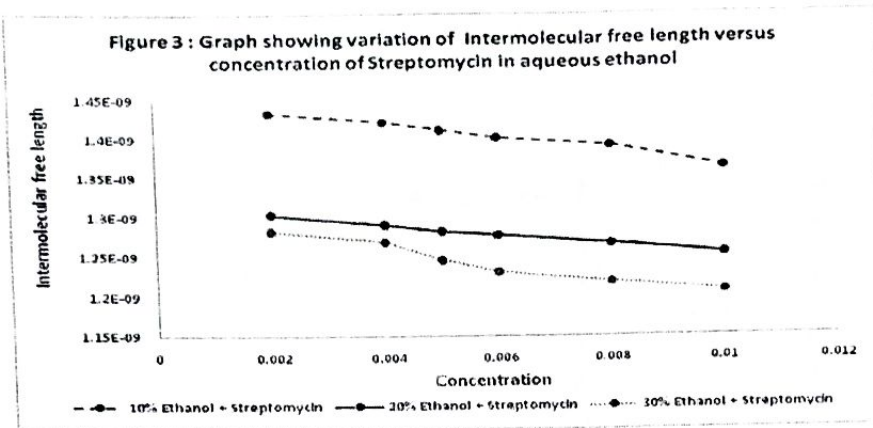
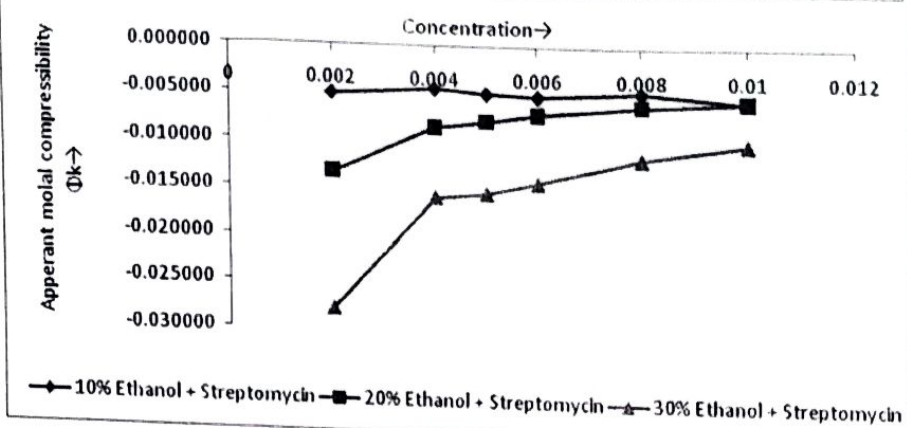




Figure 6 : Graph showing variation of Apperant molal compressibility versus concentration of Streptomycin in aqueous ethanol



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