Study of physico chemical properties of Spectinomycin hydrochloride in different solvent system at 298.15º

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Abstract

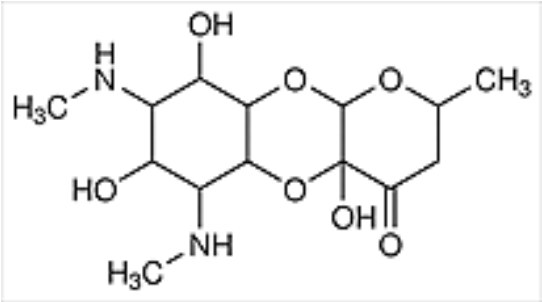
In solution chemistry, the way for proper understanding of the different phenomena regarding the molecular interactions on the basis of quantitative influence of the solvents and the extent of interactions of ions in solvents. Here in this study, the acoustical properties have been investigated from the ultrasonic velocity and density measurements of substituted heterocyclic drug (Spectinomycin hydrochloride) in Methanol+water , Acetonitrile +water and 1, 4-Dioxane + water at 298.15º. The measurements have been performed to evaluate acoustical parameters such as Density, viscosity and ultrasonic velocity , Excess viscosities and excess molar volume ,Excess molar free energy , Coefficient of viscosity (ηr), Apparent molar volume (V_ϕ) & Solvation number (Sn), Ultrasonic velocity , Apparent molar compressibility , Relative association , Adiabatic compressibility , Intermolecular free length Specific acoustic impedance .

Key word: Ultrasonic velocity, Spectinomycin hydrochloride, apparent molar volume.

1. Introduction

In the recent years, Measurement of density, viscosity & ultrasonic velocity are helpful to interpret ion-ion, ion-solvent, solvent-solvent interaction in aqueous and non aqueous medium. The interaction helps in better understanding the types of solute and solvent i.e. whether the added solute modifies or distorts the structure of solvent. Apparent molar volume gives valuable information about ion-ion and ion-solvent interaction in solution. The addition of organic solvent to an aqueous solvent of drugs brings about the change in ion solvation that result a large change in reactivity of dissolved drugs [1-4].

Since the discovery of the antibiotic action in 1947, a large number of derivates has been synthesized and successfully applied[1]. Recently, the use of many of them has been reduced, because of the fact that bacteria developed efficiency for resistance decreases[2]. The microbial resistance to anti-infective agents is now a growing problem that to develop new synthetic antimicrobial agents. So three important antibiotics were studied i.e the hydrochloride forms of Tetracycline hydrochloride[3], ciprofloxacin[4] and spectinomycin[5]. The structures of the studied antibiotics are presented in Figure.1 The presence of both the carboxylic and the amine groups make the acid-base behaviour of these drugs may be influenced by the physicochemical properties of the solvents [5].



Structure of spectinomycin

Figure.1. structure of spectinomycin hydrochloride

Spectinomycin hydrochloride (SH) are most important broad spectrum antibiotic is bright yellow, crystalline salt that is stable in air but darkens on exposure to strong sunlight. The hydrochloride salt is used most commonly in medicine. One gram of hydrochloride salt dissolves in about 10 ml of water and in 100 ml of alcohol [5].

It is official India, A few analytical method have been reported for its quantitative estimation in pharmaceutical formulations which includes biological fluids using HPLC, UV spectrophotometry, liquid chromatography and electrophoresis methods. In view of the above fact, some rapid and sensitive analytical methods are in need its quantitative estimation [6-10].

Although there is a substantial amount of characterization work from the molecular point of view for spectinomycin, only a limited amount of solubility data is available and no data at all were observed for acoustic parameter, ultrasonic velocity and physical parameter in water, Methanol+water, Acetonitrile +water and 1, 4-Dioxane + water .

The present investigation is related to ion solvent interaction of antibiotic drugs in binary solvent system. In this work, we are interested in studying the acoustical properties, ultrasonic velocity and physical properties of spectinomycin in aqueous medium, Methanol+water, Acetonitrile +water and 1, 4-Dioxane + water medium.

2. Material and method

2.1. Material

Analytical grade methanol (E.Merck, India,) Acetonitrile (E.Merck, India),and 1,4-Dioxone (E.Merck, India), ware used for preparing the solvent mixture. The purity of all the solvents was > 99.5%. All these organic solvents were further dried over molecular sieve and freshly distilled before use. All solutions were prepared in doubly distilled water, the final distillation being made from alkaline potassium permanganate solution in all glass distillation apparatus.

2.2. Preparation of stock solution

Stock solution (0.01M) of all drugs was prepared by dissolving the calculated weighed amounts of the drug in known volume of the solvent mixture. This is diluted successively to different concentration by adding appropriate solvent from micro burette. The same procedure is adopted using aqueous organic mixture (10-50% v/V) of different compositions.

2.2. Experimental

The antibiotics used were of analytical grade and their characterisation was done from C.H.N analysis (CDRI, Lucknow) ,Spectral analysis and Physico-chemical properties . The required quantity of antibiotic drug is dissolved in solvents of different mole fractions of water, Methanol+water, Acetonitrile +water and 1, 4-Dioxane + water to prepare required solutions. These solutions are used to calculate their densities using pycnometer. For viscosity measurements Ostwald viscometer was used with accuracy nearly 0.3%. The viscometer was calibrated frequently with distilled water. The flow time was also measured by using digital clock (0.01 sec). Precautions regarding prevention of evaporation of solvent were also taken. The ultrasonic velocity of such solutions was determined by ultrasonic interferometer(Mittal) by maintaining constant temperature at 298.15^0K.These parameters include adiabatic compressibility, intermolecular free length, acoustic impedance, apparent molar compressibility, apparent molar volume, limiting apparent molar compressibility, limiting apparent molar volume and the associated constants S_k and S_v.

3. Instrumentation

3.1. Thermostat

A constant temperature bath (INSREF India) is used to maintain the temperature constant. The accuracy of the bath temperature is ± 0.2^0c. An ice bath equipped with a mechanical stirrer is used to keep the temperature below the room temperature.

3.2. Pycnometer

The densities of solvent mixtures are measured using a double stem pycnometer with a bulb of 10 cm^3 capacity. A mark is made at the middle of each stem with equal distance from the ends of the stems. The liquid level in the stem is read with reference to this mark. The volume of the pycnometer is calculated from the weight of the water by filling the pycnometer with a hypodermic syringe without air bubbles and weighing using an analytical balance with an accuracy of 0.1 mg. By dividing the weight of water thus obtained by the density of water at required temperature, the exact volume of the pycnometer between the marks is calculated. The same procedure is repeated by filling the pycnometer with solvent mixture and determining their weights. The weight of the solvent mixture thus obtained in each case is divided by the volume of the pycnometer (volume of the liquid taken) to obtain the density. Thus the densities of different aqueous solution and aqua-organic solvent mixture are measured.

3.3. Viscometer

The viscosities of the solvent system used in the present study are determined using Ostwald's viscometer. This is filled with appropriate liquid and the thermostat is required for constant temperature. After thermally equilibrating the liquid is allowed to flow and efflux time is measured. This is repeated three times and using the arithmetic mean of the efflux times, using the arithmetic mean of the efflux time the viscosity (η) is calculated using the equation,

$$\frac{\eta_1}{\eta_2} = \frac{t_1 d_1}{t_2 d_2}$$

where t_1 and t_2 are the time of flow of pure solvent and that of solution. d_1 and d_2 are the densities of pure solvent and solution respectively. η_1 and η_2 are the viscosities of pure solvent and that of solution respectively.

3.4. Ultrasonic interferometer

An ultrasonic interferometer (Mittal, M-81) is used to determine the ultrasonic velocity in solution with a high degree of accuracy. The knurled cap of the cell was opened in the middle portion of it the solution was poured and the knurled cap was screwed. Excess liquid overflowing from the cell is wiped out. The cell is inserted in the socket and clamped it with the help of a screw provided on its side. High frequency generator is connected to the cell using co-axial cables. The micrometer is moved slowly in either clockwise or anticlockwise direction till the anode current on the ammeter on the high frequency generator shows a maximum or minimum. The readings of a few consecutive maximum and minimum are taken. The difference between two consecutive readings will give $\frac{\lambda}{2}$. From this value ultrasonic velocity (U) is calculated as

$$U = \lambda \times f$$ (Where f is the frequency of ultrasonic wave)

4. Results and discussion

4.1. Density, viscosity and ultrasonic velocity

The density, viscosity and ultrasonic velocity data of spectinomycin are shown in figure 2 and table-1.We observed maximum density and viscosity around 10-50% of water, Methanol+water, Acetonitrile +water and 1; 4-Dioxane + water at 298.15^0K.These values are used to calculate various physico- chemical parameters of the mixture [11-13]. The density & viscosity are increased with increase in concentration of SH due to increase electrostriction present in the system. But ultrasonic velocity decreases with increase in concentration of these drugs.

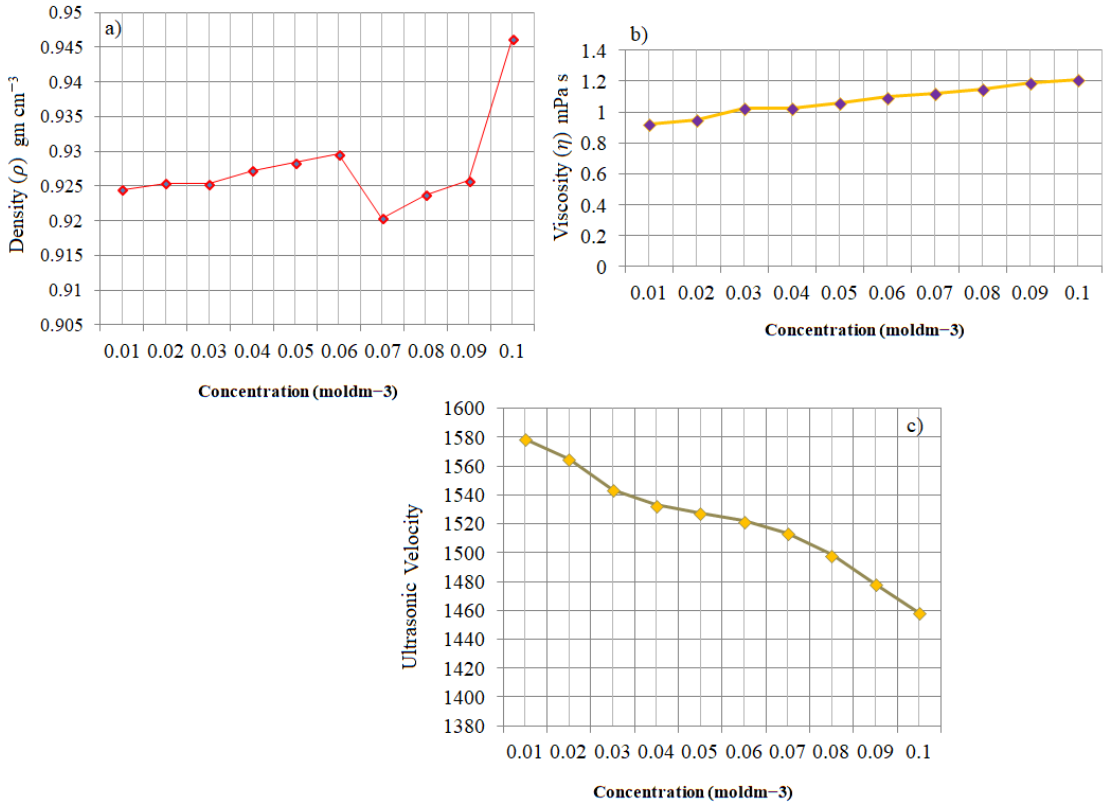


Fig. 2: Density, viscosity& ultrasonic velocity of SH in water system at 298.15°K.

The excess viscosities of the solutions were calculated from the viscosity data reveals that the values vary with percentage of water with Methanol, acetonitrile, 1, 4-Dioxane with maxima at 50% shown in table-1 which may be attributed to the association between drugs with solvent.

Table.2. Density& viscosity of SH in different % (v/v) of methanol+water system, Acetonitrile+water and 1, 4-Dioxane+water at 298.15°K (concentration of 0.05mol.dm^{-3})

SH	**Methanol+water**		**Acetonitrile +water**		**1, 4-Dioxane + water**	
	Density (ρ) gm cm^{-3}	Viscosity (η) mPa s	Density (ρ) gm cm^{-3}	Viscosity (η) mPa s	Density (ρ) gm cm^{-3}	Viscosity (η) mPa s
10%	0.9595	1.1444	0.9582	1.1454	0.9472	1.1443
20%	0.9593	1.1455	0.9583	1.1453	0.9473	1.1447
30%	0.9604	1.1452	0.9594	1.1462	0.9487	1.1454
40%	0.9613	1.1461	0.9591	1.1464	0.9485	1.1453
50%	0.9621	1.1463	0.9593	1.1471	0.9493	1.1454

4.2. Excess viscosities and excess molar volume

The excess viscosities of the solutions were calculated from the viscosity data reveals that the values vary with percentage of water with Methanol, acetonitrile, 1, 4-Dioxane with maxima at 50% shown in table- 2 which may be attributed to the association between drug with solvent.

Table. 3. Excess molar volume (V^E) and Excess viscosity (η^E) of SH in different % (v/v) of methanol+water system, Acetonitrile+water and 1, 4-Dioxane + water at 298.15°K (concentration of 0.05mol.dm^{-3})

SH	Methanol+water		Acetonitrile +water		1, 4-Dioxane + water	
	Excess molar volume (V^E)	**Excess viscosity (η^E)**	**Excess molar volume (V^E)**	**Excess viscosity (η^E)**	**Excess molar volume (V^E)**	**Excess viscosity (η^E)**
10%	0.21	0.21	0.19	0.17	0.21	0.16
20%	0.23	0.22	0.21	0.19	0.23	0.17
30%	0.24	0.23	0.22	0.20	0.25	0.19
40%	0.25	0.24	0.24	0.21	0.27	0.20
50%	0.26	0.21	0.25	0.22	0.29	0.22

4.3. Excess molar free energy

There are several semi-empirical relations used to correlate the viscosity of binary liquid mixtures. The Gruenberg-Nissan interactions parameter (d) which is regarded as a measure of the strength of interactions between two dissimilar molecules were calculated in table-4 and figure 3. The Gruenberg-Nissan parameter provides the best measure to ascertain the strength of interaction for water with Methanol, acetonitrile, 1, 4-Dioxane binary solvent mixture. The Free energy of activation & Gruenberg-Nissan constant increase with increase in percentage of solvent mixture.

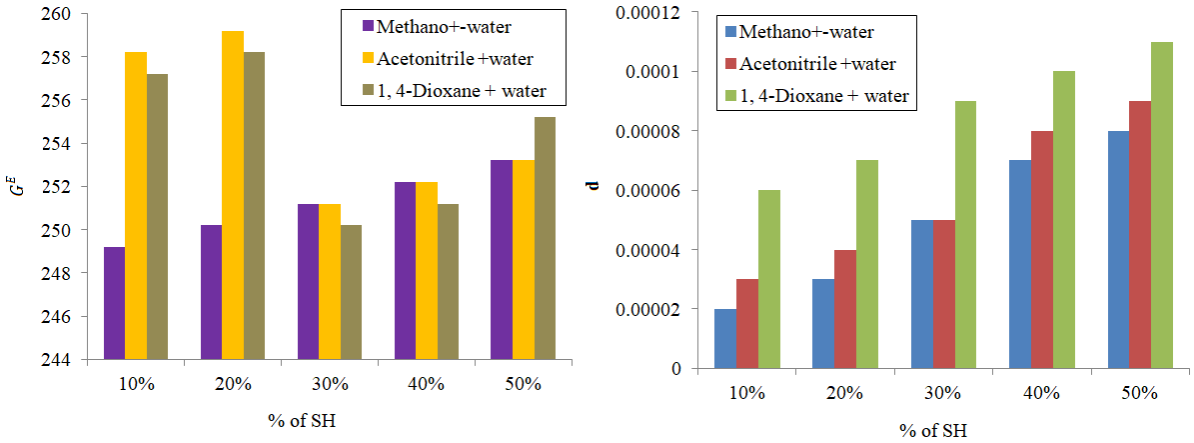


Fig.3 Excess molar free energy of activation of flow (G^E) and Grunberg and Nissan constant (d) of SH in different % (v/v) of methanol+water system, Acetonitrile+water and 1, 4-Dioxane+water at 298.15°K (concentration of 0.05mol.dm^{-3})

4.4. Coefficient of viscosity (ηr), Apparent molar volume (V_ϕ) & Solvation number (Sn)

From fig.4, it is observed that apparent molal volume increases with increase in percentage of water with Methanol, Acetonitrile, 1, 4-Dioxane binary solvent mixture in all system indicates the existence of weak

ion-solvent interaction. The apparent molar volume (V_ϕ) independent of ion-ion interaction and provides information concerning ion-solvent interaction.

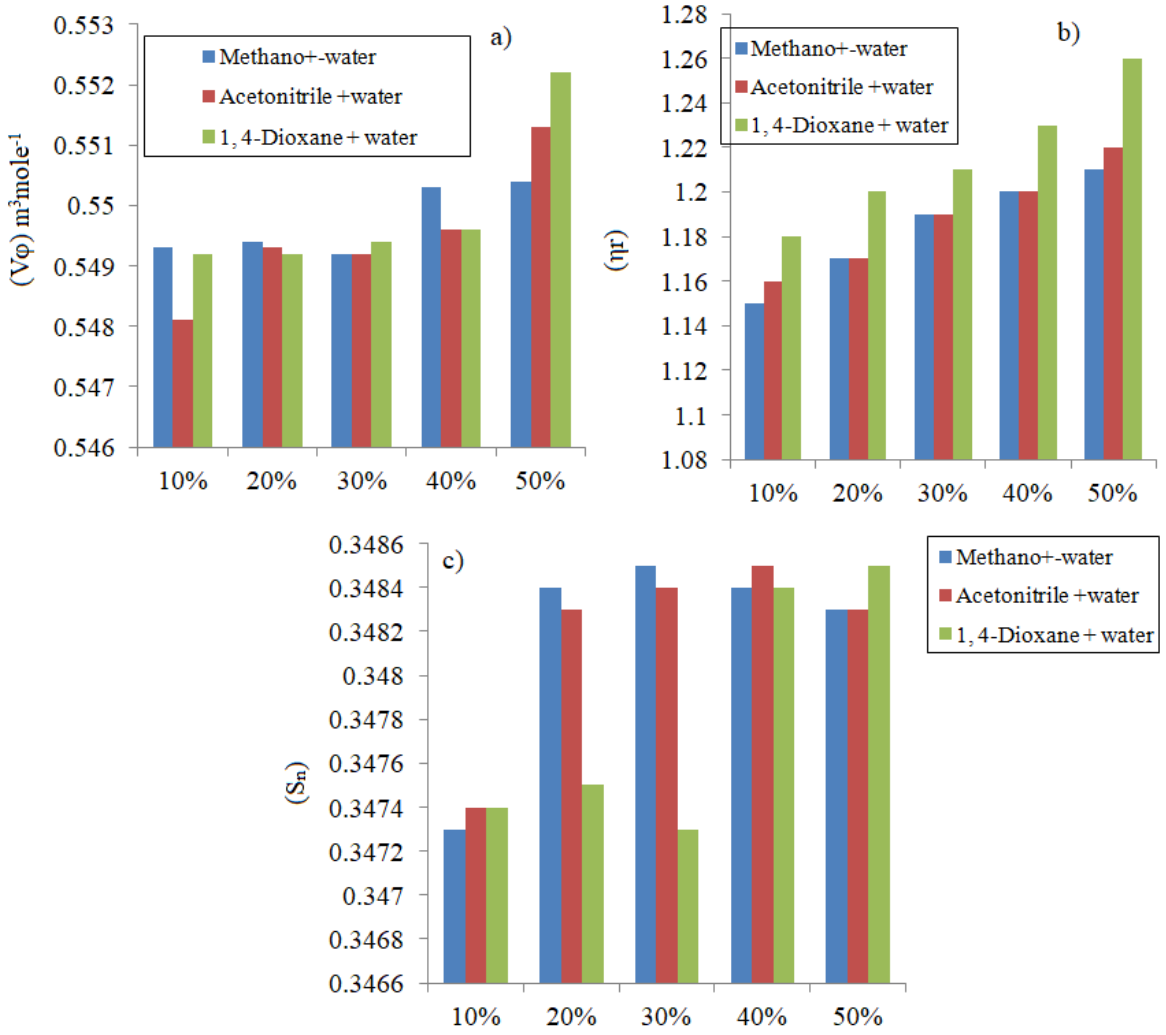


Fig.4. Coefficient of viscosity (ηr), Apparent molar volume (V_ϕ) & Solvation number (Sn) of SH in different % (v/v) of methanol+water system, Acetonitrile +water and 1, 4-Dioxane + water at 298.15°K (concentration of 0.05mol.dm^{-3})

4.5. Limiting apparent volume

The values of limiting apparent volume ($V\phi^0$) are positive for methanol, Acetonitrile and 1,4 Dioxane shown in table -4.and .This suggests the existence of ion –solvent interaction. From Table-4, it was observed that the value of 'A' (Falkenhagen coefficient) is positive in all systems. 'A' measures of ionic interaction. It indicates that there is a strong solute-solute interaction in solute molecules. The Jones–Dole coefficient measures solute –solvent interaction. The value of "B" coefficient is negative as shown in table-4 which measures the solute-solvent interactions.

Table.4. Limiting Apparent molar volume (V_ϕ^0) Limiting Apparent molar compressibility (K_ϕ^0) ,S_v, S_k, A and B of SH in different % (v/v) of methanol+water system, Acetonitrile+water and 1, 4-Dioxane+water at 298.15^{0}K (concentration of 0.05mol.dm^{-3})

%	Methanol+water					
	V_ϕ^0	K_ϕ^0	S_v	S_k	A	B
10%	0.5152	1.0321	6.221	51.784	10.401	-55.352
20%	0.5152	1.0322	6.224	51.785	10.404	-55.350
30%	0.5153	1.0324	6.226	51.787	10.406	-55.347
40%	0.5155	1.0325	6.227	51.789	10.408	-55.345
50%	0.5162	1.0326	6.229	51.790	10.409	-55.343
%	Acetonitrile +water					
10%	0.5143	1.0324	6.223	51.781	10.401	-55.349
20%	0.5152	1.0325	6.225	51.782	10.404	-55.346
30%	0.5154	1.0327	6.227	51.784	10.405	-55.344
40%	0.5156	1.0328	6.229	51.785	10.407	-55.342
50%	0.5154	1.0331	6.230	51.790	10.410	-55.338
%	1, 4-Dioxane + water					
10%	0.5153	1.0323	6.222	51.784	10.404	-55.346
20%	0.5154	1.0324	6.224	51.786	10.405	-55.345
30%	0.5155	1.0325	6.235	51.787	10.407	-55.342
40%	0.5159	1.0330	6.236	51.794	10.409	-55.336
50%	0.5160	1.0331	6.236	51.796	10.412	-55.335

4.6. Ultrasonic velocity , Apparent molar compressibility , Relative association , Adiabatic compressibility , Intermolecular free length Specific acoustic impedance

In the present investigation, different acoustical parameters such as Relative association(R_A) adiabatic compressibility (β), intermolecular free length (Lf), specific acoustic impedance (Z), are calculated from ultrasonic velocity measurement(listed in table-5 .The relative association increases with increase in percentage of Methanol+water, acetonitrile+water 1, 4-Dioxane+water binary solvent mixture in antibiotic drugs. It is found that there is strong interaction between solute and solvent. .It was found that the ultrasonic

velocity is decreased with the increase in concentration[14]. Variation of ultrasonic velocity in solution depends upon the increase or decrease of molecular free length after mixing the component. Intermolecular free length increased linearly on increase in concentration of SH drugs in water with Methanol, acetonitrile, 1, 4-Dioxane binary solvent mixture. Hence, decrease in ultrasonic velocity with increase in concentration of drugs was significant interaction between ions and solvent molecules suggesting a structure promoting behaviour of the added drugs. The specific acoustic impedance (Z) decreased with the increase in concentration of drugs in water with Methanol, acetonitrile, 1, 4-Dioxane binary solvent mixture. When concentration of drugs is increased, the thickness of oppositely charged ionic atmosphere increases due to decrease in ionic strength. This is suggested by decrease in acoustic impedance with concentration in all systems. It was seen that the intermolecular free length increased with the increase in concentration in both system. The intermolecular free length increased due to greater force of attraction between solute and solvent by forming hydrogen bonding. The adiabatic compressibility increased with the increase in concentration of solution. It is happened due to collection of solvent molecule around ions, this supporting weak ion-solvent interaction. This indicates that there is significant solute-solvent interaction.

Table-5:Ultrasonic velocity (Us) m s^{-1}, Apparent molar compressibility ($K_\phi \times 10^{-9}$) m^2 N^{-1}, Relative association (R_A), Adiabatic compressibility ($\beta \times 10^{-10}$)m^2N^{-1}, Intermolecular free length ($L_f \times 10^{-11}$)m, Specific acoustic impedance ($Z \times 10^6$) kg m^{-2} s^{-1} of SH in different % (v/v) of methanol+-water system, Acetonitrile +water and 1, 4-Dioxane + water at 298.15° K(concentration of 0.05mol.dm^{-3})

%	Ultrasonic velocity	Apparent Molar compressibility	Relative association	Adiabatic compressibility	Intermolecular free length	Specific acoustic impedance
Methanol+water						
10%	1301.13	3.455	1.004	5.586	4.7286	1.4193
20%	1299.14	3.456	1.005	5.588	4.7287	1.4192
30%	1297.15	3.457	1.06	5.589	4.7288	1.4191
40%	1295.16	3.458	1.017	5.591	4.7289	1.4189
50%	1294.12	3.459	1.018	5.592	4.7291	1.4188
Acetonitrile +water						
10%	1202.13	3.453	1.009	5.583	4.7284	1.4192
20%	1201.15	3.455	1.010	5.584	4.7285	1.4190
30%	1199.19	3.458	1.011	5.586	4.7287	1.4188
40%	1196.13	3.459	1.03	5.587	4.7288	1.4186
50%	1194.15	3.461	1.04	5.588	4.7289	1.4185

1, 4-Dioxane + water						
10%	1299.11	3.451	1.004	5.583	4.7281	1.4191
20%	1295.15	3.453	1.006	5.584	4.7285	1.4189
30%	1294.12	3.455	1.007	5.585	4.7285	1.4184
40%	1292.14	3.457	1.008	5.587	4.7286	1.4183
50%	1289.11	3.459	1.009	5.588	4.7287	1.4182

5. Conclusion

In the conclusion, volume and compressibility data have been determined for Spectinomycin hydrochloride in aqueous water, Methanol+-water, Acetonitrile +water and 1, 4-Dioxane + water at 298.15^{0}K and the results have been used to study the ion-solvent interactions present in the mixtures. From the magnitude of $K_\phi^{\,0}$,$V_\phi^{\,0}$, S_k and S_v, it can be concluded that the larger ion-solvent interaction will exist in Acetonitrile +water and 1, 4-Dioxane + water solvents than Methanol+water system. Thus SH are effective structure maker in aqueous Acetonitrile +water and 1, 4-Dioxane + water solutions over Methanol+water system.

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