Orbital
The electronic journal of chemistry

the electronic journal of chemistry

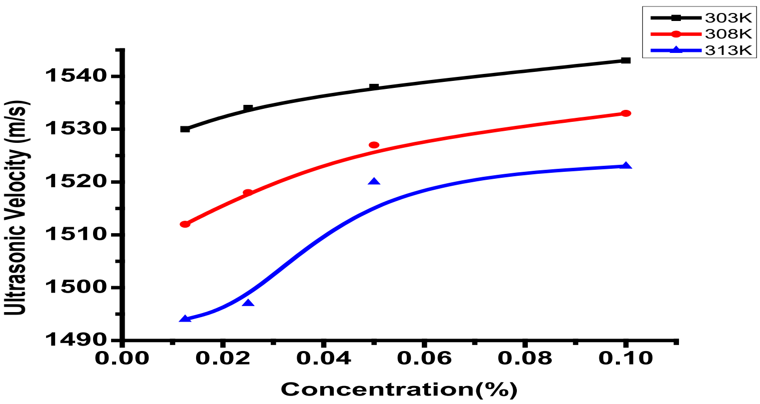
Full Paper | http://dx.doi.org/10.17807/orbital.v13i4.1465

Acoustical Studies of Molecular Interactions in the Solution of Streptomycin Drug at Different Temperatures and Concentrations

Ritesh Ramdasji Naik

Streptomycin is an antibiotic medication used to treat a number of bacterial infections. In the present study ultrasonic velocity (U), density (ρ) and viscosity (η) have been measured at frequency 1 MHz in the binary mixtures. The binary mixtures of streptomycin with water in the concentration range (0.1 to 0.0125%) at 303 K, 308 K, and 313 K using a multifrequency ultrasonic interferometer. The measured value of ultrasonic velocity, density and viscosity have been used to estimate the acoustical parameters namely adiabatic compressibility (βa), relaxation time (τ), acoustic impedance (z), free length (Lf), free volume (Vf) and internal pressure (Pi), Wada's constant(W), Rao's constant (R) to investigate the nature and strength of molecular interaction in the binary mixture with water. The obtained results support the occurrence of complex formation, molecular association through intermolecular hydrogen bonding in the binary liquid mixtures.

Graphical abstract



Keywords
Streptomycin
Free volume
Acoustical parameters
Ultrasonic velocity
Adiabatic compressibility
Acoustic impedance

Article history
Received 26 December 2019
Revised 03 August 2021
Accepted 26 August 2021
Available online 25 September 2021

Handling Editor: Grégoire J. F. Demets

1. Introduction

In present day applications of ultrasonic are emerging in the field of forensic sciences, space research and also in wars. Ultrasonic waves are used in studying the properties of matter on the basis of interaction between the waves and constituents of the medium through which they pass. Determination of ultrasonic velocity and absorption coefficient has furnished methods for studying molecular and structural properties of liquids. Ultrasonic waves are used in many applications including plastic welding, medicine, jewelry cleaning, pipe inspection, and nondestructive test. Within nondestructive test, ultrasonic waves give us the ability to 'see through' solid/opaque material and detect surface or internal flaws without affecting the material in an adverse manner. It had been identified, about 200 years ago, that dogs could hear

Department of Chemistry, D.D. Bhoyar College of Arts and Science Mouda, Nagpur, 441104, MS, India. *Corresponding author. E-mail: **ritunaik912@rediffmail.com**

[1]. In the field of technology, the waves are being used to measure depth of sea, directional signaling in submarine, and mechanical cleaning of surface soldering [3], and to detect shoals of fish. Acoustic sonograms have become an important medicinal diagnostic tool which is widely used nowadays [4-5]. Ultrasonic waves are used for both diagnosis and therapy. It includes the detection of wide variety of anomalies, such as tumor, bloodless surgery, proper extraction of broken teeth, cardiology, and stone fragmentation [6]. Ultrasound is more sensitive than X-rays in distinguishing various kinds of tissues. It is believed to be less hazardous than X-rays, although possible hazards of ultrasound have not yet been thoroughly explored [7]. The unique feature of sound wave property is that it gives direct and precise information of the adiabatic properties of solution. The data of velocity of sound in very few liquids were available up to 1930. The discovery of interferometer and optical diffraction method improved the investigation, both qualitatively and quantitatively. Most of the information extracted from ultrasonic study of fluids is confined to the determination of hydration number and compressibility [8-9]. The successful application of acoustic methods to physicochemical investigations of solution becomes possible after the development of adequate theoretical approaches and methods for precise ultrasound velocity measurements in small volumes of liquids [10-12]. In the present paper, acoustical studies have been studied in water at different temperatures over a wide range of streptomycin concentrations. From the experimental values a number of thermodynamic parameters namely ultrasonic velocity, adiabatic compressibility, acoustic impedance, relaxation time, free length, free volume, internal pressure, Rao's constant, ultrasonic attenuation, cohesive energy, and molar volume, Wada's constant has been calculated. The variation of these parameters with concentration was found to be useful in understanding the nature of interactions between the components [13-16].

2. Results and Discussion

The measured values of ultrasonic velocity, density and related thermo-acoustical parameters like adiabatic compressibility (βad), intermolecular free length (Lf), relaxation time (Ţ), free volume (Vf), internal pressure (Πi), acoustic impedance (Z), Wada's constant (W), ultrasonic attenuation (α/f2), Rao's constant (R), molar volume (Vm), cohesive energy (CE) of streptomycin with water at 303 K, 308 K, 313 K in different concentrations are shown in Figures 1–14. Ultrasonic velocity and density of the binary mixtures along with thermodynamic values such as adiabatic compressibility, free length, and impedance at different temperature were determined. It is observed that ultrasonic velocity increases with increase in concentration which may be due to solute-solvent interaction. The adiabatic compressibility decreasing with an increase in concentration shows that there is strong solute-solvent interaction. Acoustic impedance shows nonlinear increasing variation with an increase in molar concentration. This indicates the complex formation and intermolecular weak association which may be due to hydrogen bonding. Thus, complex formation can occur at these molar concentrations between the component molecules. The opposite trend of ultrasonic velocity and adiabatic compressibility indicates the association among interacting streptomycin and water molecules. In the present system of streptomycin, free length varies nonlinearly with increase in molar concentration which suggests the significant interaction between solute and solvent due to which structural arrangement is also affected. Relaxation time decreases with an increase in concentration. Nonlinear trend of density with concentration indicates the structure-making and breaking property of solvent due to the formation and weakening of H-bonds. The free volume decreases while internal pressure increases with an increase in molar concentration, indicating that there is a weak interaction between solute and solvent molecules. Rao's constant and Wada's constant decrease with increasing concentration, which indicates that there is a weak interaction between solute and solvent molecules.

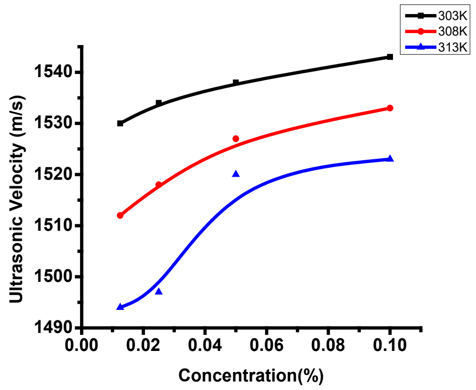


Fig. 1. Variation of ultrasonic velocity with concentration and temperature.

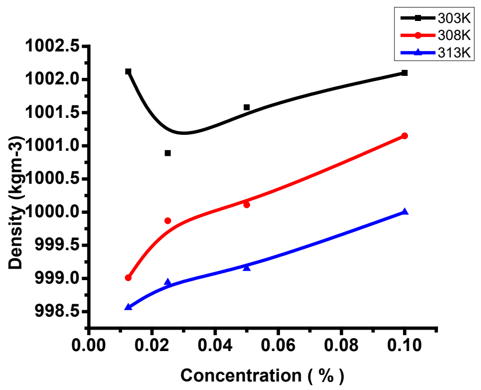


Fig. 2. Variation of density with concentration and temperature.

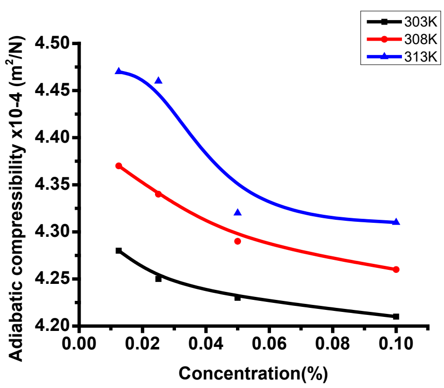


Fig. 3. Variation of adiabatic compressibility with concentration and temperature.

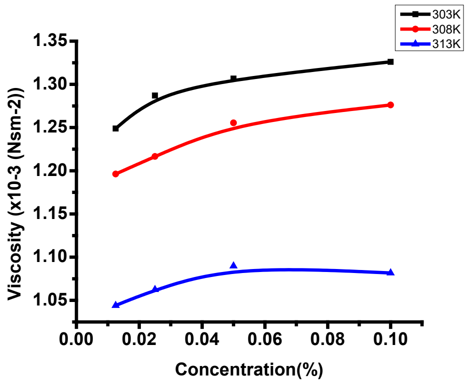


Fig. 4. Variation of viscosity with concentration and temperature.

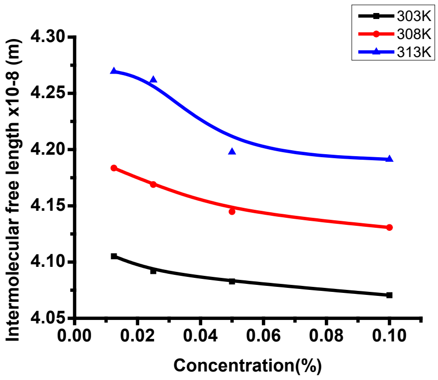


Fig. 5. Variation of intermolecular free length with concentration and temperature.

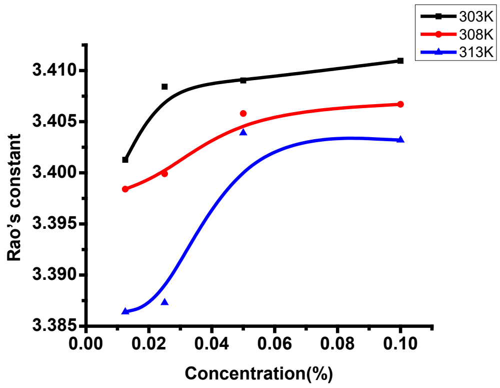


Fig. 6. Variation of Rao's constant with concentration and temperature.

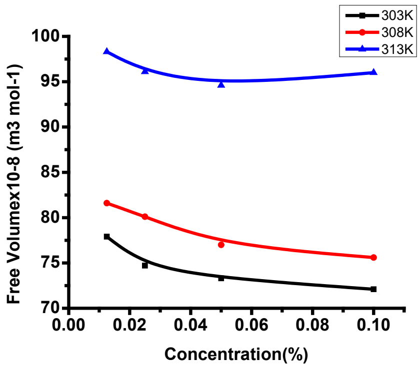


Fig. 7. Variation of free volume with concentration and temperature.

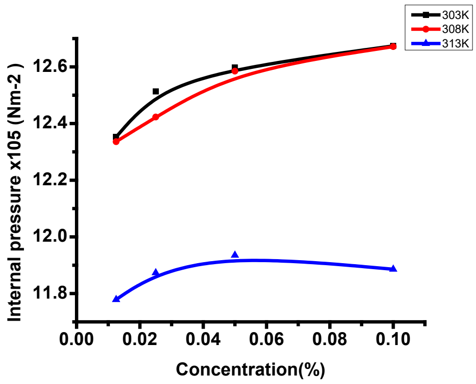


Fig. 8. Variation of Internal pressure with concentration and temperature.

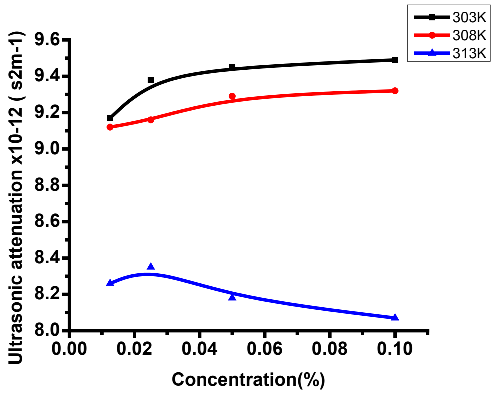


Fig. 9. Variation of ultrasonic attenuation with concentration and temperature.

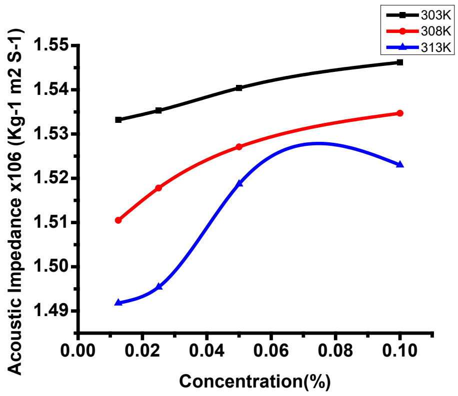


Fig. 10. Variation of acoustic impedance with concentration and temperature.

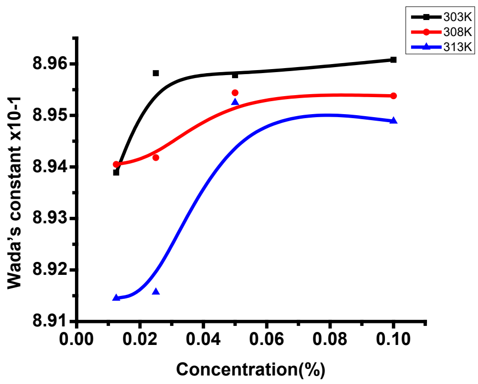


Fig. 11. Variation of Wada's constant with concentration and temperature.

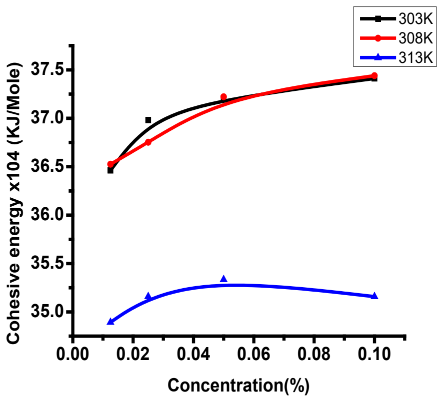


Fig. 12. Variation of cohesive energy with concentration and temperature.

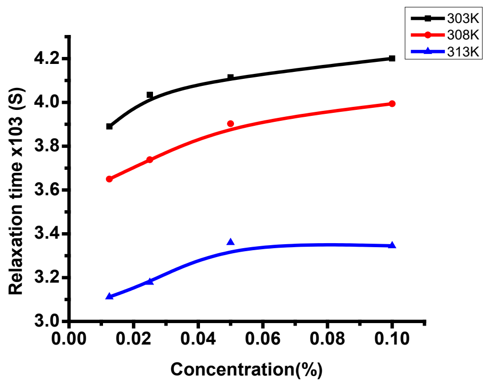


Fig. 13. Variation of relaxation time with concentration and temperature.

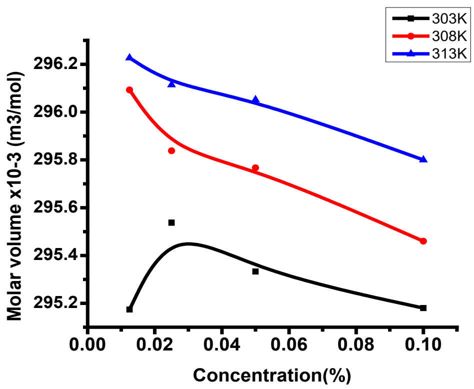


Fig. 14. Variation of molar volume with concentration and temperature.

3. Material and Methods

Chemicals were purchased from local commercial suppliers and are of laboratory grade. Streptomycin used in the present work was of analytical reagent (AR) grade with a minimum assay of 99.9%. Solution of different concentration of streptomycin were prepared by water as solvent. The ultrasonic velocity (U) has been measured in ultrasonic interferometer Mittal Model-F-05 with an accuracy of 0.1%. The viscosities (η) of binary mixtures were determined using Ostwald's viscometer by calibrating with doubly distilled water with an accuracy of ±0.001 PaSec. The density (ρ) of these binary solutions were measured accurately using 25 mL specific gravity bottle in an electronic balance, precisely and accurately. The basic parameters U, η, and ρ were measured at various concentrations (0.0125% to 0.1%) and temperatures (303 K, 308 K, 313 K). The various acoustical parameters were calculated from U, η, and ρ values using standard formulas. On using ultrasonic velocity, density and viscosity the following acoustical parameters like adiabatic compressibility (κ) [17], intermolecular free length (Lf) [18], relaxation time (Ʈ) [19], free volume (Vf) [20], internal pressure (Πi) [21], acoustic impedance (Z) [22], Wada's constant (W) [23], ultrasonic attenuation (α/f2) [24], Rao's constant (R) [25-28], molar volume (Vm), and cohesive energy (CE) were calculated by applying the following expressions (Eq. 1–12). Origin Pro and spss statistical software was used to described that there was interaction between the solute and solvent.

- **Ultrasonic velocity (υ):** The relation used to determine the ultrasonic velocity is given by

$$υ = f × λ \quad \textbf{(Eq. 1)}$$

where f - Frequency of ultrasonic waves, λ – Wavelength.

- **Adiabatic compressibility (κ):** Adiabatic compressibility is defined as

$$κ = (1/υ^2 ρ) \quad \textbf{(Eq. 2)}$$

where υ – Ultrasonic velocity, ρ – Density of the solution.

- **Free volume (V_f):** Free volume in terms of the ultrasonic velocity (υ) and the viscosity of the liquid (η) are calculated by formula

$$Vf = (M υ/kη)^{3/2} \quad \textbf{(Eq. 3)}$$

where M is the molecular weight and 'k' is a temperature-independent constant equal to 4.28× 10^9 for all liquids.

- **Acoustic impedance (Z):** The acoustic impedance is computed by the formula

$$Z = υ × ρ \quad \textbf{(Eq. 4)}$$

- **Free length (Lf):** It is calculated on using formula

$$L_f = (K\sqrt{κ}) \quad \textbf{(Eq. 5)}$$

K - Jacobson temperature dependent constant defined as K = (93.875 + 0.345T) ×10^{-8}, κ = Adiabatic compressibility.

- **Ultrasonic Attenuation ($α/f^2$):** It is calculated by

$$α/f^2 = 8π^2η/3ρυ^3 \quad \textbf{(Eq. 6)}$$

- **Viscous relaxation time (Ʈ):** It is calculated by using the relation

$$Ʈ = 4η/3ρυ^2 \quad \textbf{(Eq. 7)}$$

- **Rao's Constant (R):** Rao's constant is calculated by

$$R = \left(\frac{M}{\rho}\right)\ \upsilon^{\frac{1}{3}} \qquad \textbf{(Eq. 8)}$$

M = Molecular Weight.

- **Wada's constant (W):** It was calculated by formula

$$W=M.\ \kappa^{-1/7}/\ \rho \qquad \textbf{(Eq. 9)}$$

- **Internal pressure (Πi):** On using below-cited formula, internal pressure is calculated

$$\Pi i\ =\ b\ RT\left[\frac{k\ \eta}{v}\right]^2 \frac{\rho^{\frac{2}{3}}}{M^{\frac{7}{6}}} \qquad \textbf{(Eq. 10)}$$

- **Molar volume:** It is the ratio of density & molecular weight.

$$\mathrm{Vm} = \frac{\rho}{\mathrm{M}} \qquad \textbf{(Eq. 11)}$$

- **Cohesive energy** (CE) **:** Cohesive energy is calculated by formula quoted below.

$$CE = \Pi i \mathrm{Vm} \qquad \textbf{(Eq. 12)}$$

4. Conclusions

The acoustical parameters suggest the strong molecular interaction in the solution. Ultrasonic study of aqueous solution of Streptomycin at different concentrations give most useful information in understanding interaction of solute with solvent. In the present paper the ultrasonic velocity (υ), density and acoustical parameters adiabatic compressibility (βa), relaxation time (τ), acoustic impedance (z), free length (Lf), free volume (Vf) and internal pressure (Pi), Wada's constant(W), Rao's constant (R) have been measured at different concentrations. The parameters indicate that there is a strong molecular interaction.

Acknowledgments

The authors are thankful to Department of Chemistry, Jankidevi Bajaj College of Science, Wardha, for their kind support in the present research work.

References and Notes

[1] Gamow, G.; Clevel, J. M. Physics: foundation and frontier, 3rd ed. Delhi: Prentice-Hall, 1978, p. *155*.

[2] Duncan, T. Advanced physics, 2nd ed. London: John Murray, 1981, p. 215.

[3] Ameta, S. C.; Punjabi, P. B.; Swarnkar, H.; Chhabra, N.; Jain, M. *J. Indian Chem. Soc.* **2001**, *78*, 627.

[4] Frizzell, L. A. Encyl, Appl. Phys. Edr. G. L. Trigg, *VCH Publ.:* New York, **1998,** *22*, 475.

[5] Wells, P. N. T. Biomedical ultrasonics. London, New York: Academic Press, 1977.

[6] Shrivastava, S. K.; Kailash. *Bull. Mater. Sci*. **2004**, *27,* 383. **[Crossref]**

[7] Sears, F. W.; Zemansky, M. W.; Young, F. D. College physics, 4th ed. London: Addison-Wesley Pub. Co, 1974, p. 366.

[8] Shilo, H. *J. Am. Chem. Soc.* **1958**, *80,* 70.

[9] Bukin, V. A.; Sarvazyan, A. P.; Passechnic, V. I. *Biofizika* **1979**, *24*, 61.

[10] Sahai, R.; Pande, P. C.; Singh, V. *Indian J. Chem.* **1979**, *18A*, 217.

[11] Baluja, S.; Oza, S. *Fluid Phase Equilib.* **2001**, 178. **[Crossref]**

[12] Aswar, A. S. *Indian J. Chem.* **1997**, *36A*, 495.

[13] Ali, A.; Naine, A. K. *J. Pure Appl.Ultrason.* **1999**, *21*, 31. **[Crossref]**

[14] Aswale, S. S.; Aswale, S. R.; Dhote, A. B.; Tayade, D. T. *J. Chem. Pharm. Res.* **2011**, *3*, 233.

[15] Dabarse, P. B.; Patil, R. A.; Suryavanshi, B. M. *J. Pure Appl. Ultrason.* **2011**, 233.

[16] Praharaj, M. K.; Satapathy, A.; Mishra, S.; Mishra, P. R. *J. Chem. Pharm. Res.* **2012**, *4,* 1990.

[17] Varada Rajulu, A.; Mabu sab, P. *J. Mater. Sci.* ***1995,*** *18,* 247. **[Crossref]**

[18] Nikam, P. S.; Mehdi Hasan. *Asian J. Chem.* **1993**, *5,* 319.

[19] Aswale, S. S.; Aswale, S. R.; Dhote, A. B. *Int. J. Res. Chem. Environ.* **2012**, *2,* 154.

[20] Prasad, N.; Rajendra, H. *J. Pure Appl. Ultrason*. **2003,** *25*, 25.

[21] Suryanarayana, V. C.; Pugazhendhi, P. *Indian J. Pure Appl. Phys.* **1986**, *24*, 406.

[22] Aswale, S. S.; Aswale, S. R.; Dhote, A. B. *J. Nat. Sci.* **2013,** *1,* 13.

[23] Ekka, A. P.; Reddy, V. G.; Singh, P. R. *Acta Acust. united Acust.* **1980,** *46, 341.*

[24] Rajulu Varada, A.; Sreenivasulu, G.; Raghuraman, S. K. *Indian J. Chem. Technol.* **1994**, *1*, 302.

[25] Paladhi, R.; Singh, P. R. *Acta Acust. united Acust.* **1990**, *72*, 90.

[26] Kaur, R.; Chaudhary, S.; Kumar, K.; Gupta, M. K.; Rawal, R. K. *Eur. J. Med. Chem.* **2017**, *132*, 108. **[Crossref]**

[27] Dhote, A. B.; Bedare, G. R. *Int. J. Adv. Res. Sci. Eng.* **2017**, *6*, 548.

[28] Bedare, G. R.; Dhote, A. B. *Int. J. Life Sci.* **2018**, *Special Issue A 12*, 55.

How to cite this article

Naik, R. R. *Orbital: Electron. J. Chem.* **2021**, 14, 275.
DOI: **http://dx.doi.org/10.17807/orbital.v13i4.1465**