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Acoustic Study of Antimalarial Drugs: Artesunate and Clindamycin at Different Concentrations and Temperatures

S. H. Shrirame, A. B. Dhote, K. P. Jumde

Nilkanthrao Shinde Science and Arts College, Bhadrawati, Chandrapur

shrirame827528@gmail.com, dhoteaparna34@gmail.com

Abstract: *The acoustic characteristics of two antimalarial medications, Clindamycin and Artesunate, at various temperatures are compared in this study. Acoustic characteristics were assessed using ultrasonic velocity and density measurements, which revealed information on molecular association, structural changes, and solute-solvent interactions. The findings demonstrate a consistent change with temperature, underscoring the part that temperature plays in regulating molecular interactions. In pharmaceutical formulation, this might improve temperature-dependent medication stability and solubility.*

Keywords: Ultrasonic velocity, Acoustic parameters, Artesunate, Clindamycin, Solute–solvent interactions, Molecular association

I. INTRODUCTION

Ultrasonics refers to sound waves with frequencies above the upper limit of human hearing, typically greater than 20 KHz. These high-frequency waves possess unique physical properties such as short wavelength, high energy, and strong directional propagation, making them highly useful in scientific, medical, and industrial applications.The study of ultrasonics has gained significant importance due to its wide-ranging applications in fields such as non-destructive testing (NDT), medical imaging, cleaning processes, and material characterization. In medical science, ultrasonic waves are extensively used in diagnostic techniques like ultrasonography, enabling non-invasive visualization of internal body structures. Similarly, in industrial sectors, ultrasonics play a crucial role in detecting flaws in materials, measuring thickness, and ensuring product quality.A reliable and non-destructive method for examining the physicochemical behavior of liquids and solutions is the use of ultrasonic methods. Following the assessment of acoustic parameters, measurements of ultrasonic velocity, density, and viscosity yield important insights on solute–solvent interactions, molecular association, hydrogen bonding, and structural alterations. Since the stability, solubility, and bioavailability of medications are directly correlated with their molecular interactions in solution, these investigations are extremely important in the field of pharmaceutical sciences.[1-3].

Among the acoustic metrics, relative association, adiabatic compressibility, acoustic impedance, and intermolecular free length are especially helpful in determining the kind and intensity of molecular interactions. Because these characteristics are sensitive to changes in temperature and concentration, ultrasonic inquiry is a potent method for researching drug-solvent systems in a variety of settings.[4-5].

Clindamycin, a lincosamide antibiotic with antimalarial action, and artesunate, a semi-synthetic derivative of artemisinin, are frequently used in combination therapy to treat malaria. There hasn't been much research on the comparative assessment of their molecular interactions in solution using ultrasonic techniques, despite their therapeutic significance. Through its effects on viscosity, hydrogen bonding, and compressibility, temperature plays a critical role in modifying solute–solvent interactions, which in turn affects medication stability and pharmacological characteristics[6-7].

The current study compares the ultrasonic properties of clindamycin and artesunate in aqueous solutions at different temperatures. This work attempts to clarify how temperature affects the molecular relationships and structural behavior of these two medications by computing and examining acoustic metrics including adiabatic compressibility and intermolecular free length.

II. MATERIAL AND METHODOLOGY

Materials

Analytical grade samples of Artesunate and Clindamycin were obtained from a certified pharmaceutical supplier and used without further purification. Double-distilled water was employed as the solvent for all solutions. Stock solutions of known molarity were prepared using an electronic balance with an accuracy of ±0.1 mg, and serial dilutions were made to achieve the desired concentrations for ultrasonic and viscosity measurements.

Instrumentation

Ultrasonic Interferometer: A single-crystal ultrasonic interferometer operating at 2 MHz with an accuracy of ±0.1 m/s was used for ultrasonic velocity measurements.

Specific Gravity Bottle: Density measurements were carried out using a specific gravity bottle with an accuracy of ±0.001 g/cm³.

Viscometer: An Ostwald-type viscometer was used to determine viscosity.

Temperature Control: A thermostatically controlled water bath with an accuracy of ±0.1 K was used to maintain solution temperatures during all measurements.

Ultrasonic velocity Measurement

The ultrasonic interferometer was used to measure the ultrasonic velocity of the solutions of artesunate and clindamycin. To prevent air bubbles, solutions were carefully put into the interferometer cell. Maximum anode current was achieved by adjusting the micrometer screw, demonstrating resonance[8]. The distance (d) moved by the micrometer screw for n successive maxima was recorded, and the ultrasonic velocity (U) was calculated using the formula:

$$U = 2 \times f \times d \text{ ---1}$$

where f is the frequency of the ultrasonic wave (2 MHz). Measurements were conducted at different temperatures (298 K, 303 K, 308 K), and each experiment was repeated three times to ensure reproducibility.

Density Measurement

The density of each drug solution was measured using a specific gravity bottle. The bottle was first weighed empty and then filled with solution at the desired temperature. The density (ρ) was calculated as:

$$\rho = \text{mass of solution / volume of bottle} \text{ ---2}$$

All measurements were performed at the same temperatures as ultrasonic velocity measurements, and three readings were taken for each solution to obtain an average value.

Viscosity Measurement

Viscosity measurements were carried out using an Ostwald viscometer. The viscometer was cleaned, dried, and calibrated using double-distilled water. The flow time of pure solvent (t□) and drug solutions (t) through the capillary was recorded using a digital stopwatch[9]. The relative viscosity (ηr), specific viscosity (ηsp), and solution viscosity (η) were calculated using the relations:

ηr = t / t□

ηsp = ηr – 1

$$\eta = \eta_{\square} \times \eta r \text{ --3}$$

where η□ is the viscosity of the solvent. Measurements were conducted at the same temperatures as ultrasonic and density experiments, with three replicates for each solution.

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Acoustic Parameters

Using the measured ultrasonic velocity and density, the following acoustic parameters were calculated.
Relative association is a function of ultrasonic velocity and is calculated by the equation,

$$RA = \frac{ds}{do}\left[\frac{v_0}{vs}\right]^{1/3}$$

d0 vs Where, v0 and vs are ultrasonic velocities in solvent and solution respectively Where, v0 and vs are ultrasonic velocities in solvent and solution respectively.

$$\tau = 4/3\beta.\eta$$

III. RESULT AND DISCUSSION

Artesunate

Temperature (k)	Concentration (M)	Ultrasonic velocity (m/s)	Density (Kg/m^3)	Viscosity (ηx10^{-3})	Relative Association	Relaxation Time
298.15	0.001	1350.6	1050	0.9579	1.089915	6.67
	0.01	1360.8	1052	0.9906	1.089255	6.78
	0.1	1376.8	1053.6	1.0025	1.08667	6.69
303.15	0.001	1362.2	1045.6	0.8832	1.088043	6.07
	0.01	1372.5	1049.6	0.9049	1.089451	6.1
	0.1	1382.2	1052.4	0.9256	1.089812	6.14
308.15	0.001	1373.5	1042.4	0.7289	1.085433	4.94
	0.01	1380.7	1047.6	0.7662	1.088948	5.12
	0.1	1401.5	1049.2	0.7927	1.08522	5.13

Table No 1 Ultrasonic Velocity, Density, Viscosity, Relative Association and Specific relaxation time of Artesunate at different Concentration (0.001, 0.01, 0.1 M) and Differernt Temperature (298.15, 303.15, 308.15 K) 2 Mz frequency.

Clindamycin

Temperatures	Concentration (M)	Ultrasonic velocity (m/s)	Density (Kg/m^3)	Viscosity (ηx10^{-3})	Relative Association	Relaxation Time
298.15	0.001	1368.8	1010.2	0.9315	1.04393	6.56
	0.01	1378.1	1012.3	0.9632	1.04372	6.68
	0.1	1408.8	1033.6	1.1964	1.05788	7.78
303.15	0.001	1376.9	1005.6	0.8355	1.04266	5.84
	0.01	1384.9	1009.6	0.8588	1.04479	5.91
	0.1	1417.2	1032.1	1.1229	1.0599	7.22
308.15	0.001	1380.7	1002.4	0.7437	1.04196	5.19
	0.01	1389.2	1007.6	0.7756	1.04523	5.32
	0.1	1424.6	1030.4	0.9843	1.05994	6.28

Table No 2 Ultrasonic Velocity, Density, Viscosity, Relative Association and Specific relaxation time of Clindamycin at different Concentration (0.001, 0.01, 0.1 M) and Different Temperature (298.15, 303.15, 308.15 K) 2 Mz frequency.

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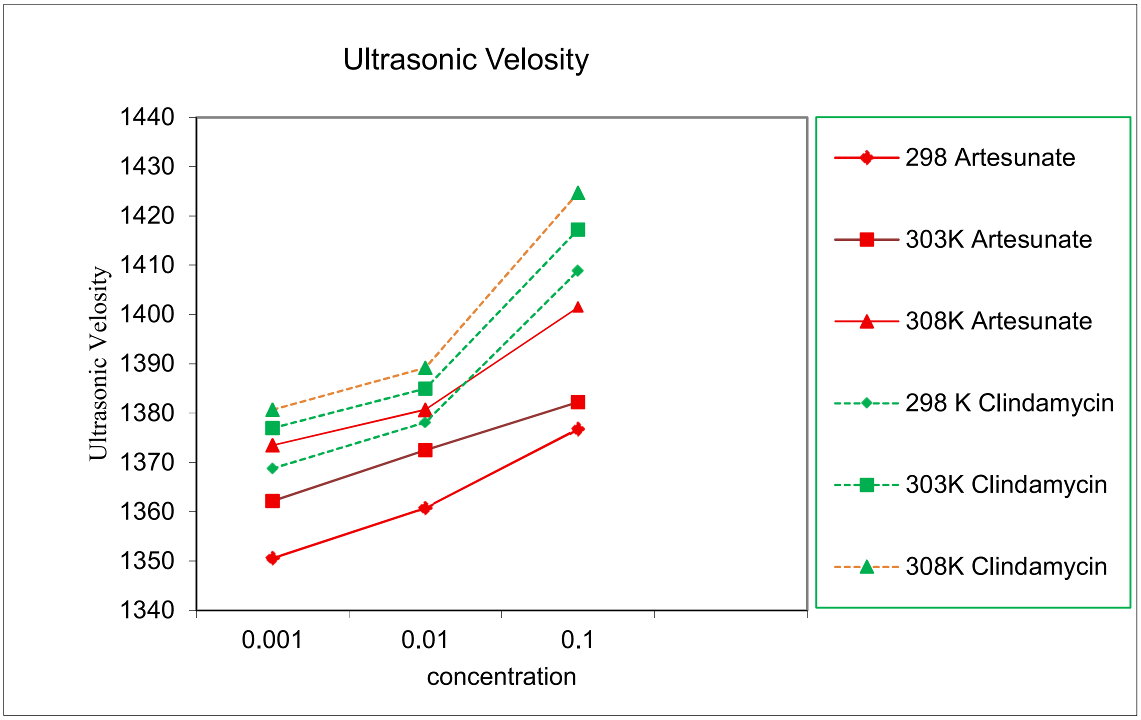

Fig.1 Ultrasonic Velocity of Artesunate and Clindamycin at different Concentration and Temperature at 2 Mz frequency.

Fig 2 Relative association of Artesunate and Clindamycin at different Concentration and Temperature at 2 Mz frequency.

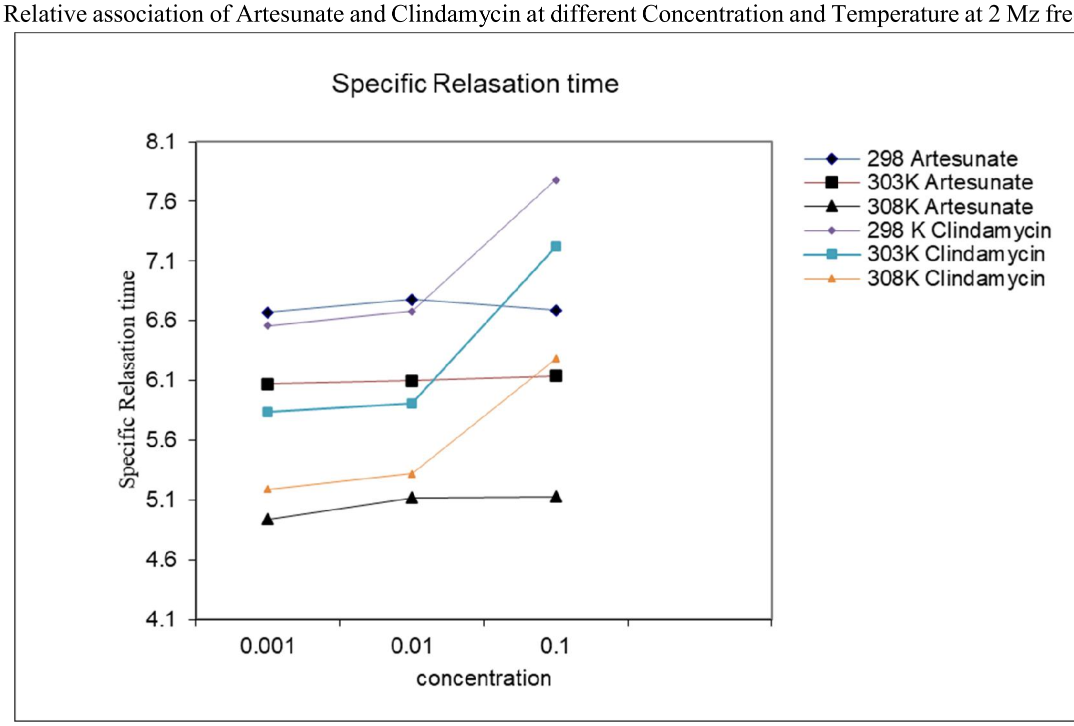

Fig 3 Specific relaxation time of Artesunate and Clindamycin at different Concentration and Temperature at 2 Mz frequency.

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IV. DISCUSSION

The relative association values for Artesunate, Clindamycin, show slight variations with increasing temperature and concentration, indicating differences in molecular interactions. Hydroxychloroquine consistently Artesunate exhibits the higher relative association values, suggesting stronger solute-solvent interactions and greater structural stability. Clindamycin has the lowest values, implying weaker molecular interactions and less association between molecules

The specific relaxation time values for Artesunate, Clindamycin decreasing trend with increasing temperature, indicating faster molecular dynamics and reduced intermolecular forces at higher temperatures. Clindamycin and Artesunate show moderate relaxation time values, with Clindamycin displaying a more pronounced decrease at higher temperatures.

V. CONCLUSION

The comparative ultrasonic study indicates that both Artesunate and Clindamycin exhibit temperature- and concentration-dependent changes in ultrasonic velocity, density, viscosity, and acoustic parameters. Artesunate consistently shows stronger solute–solvent interactions, higher ultrasonic velocity, higher viscosity, and higher relative association. to.

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