Ultrasonic And Viscometric Investigation of Solute–Solvent Interactions in Aqueous Primaquine Solutions at Variable Temperatures

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***Abstract*—Ultrasonic velocity (υ), density (ρ), and viscosity (η) were measured at 1 MHz for binary mixtures of primaquine with water in the concentration range 0.1–0.0125% at 303 K and 313 K using a multifrequency ultrasonic interferometer. From these experimental values, acoustical parameters such as adiabatic compressibility (κ), relaxation time (τ), acoustic impedance (z), free length (Lf), free volume (Vf), internal pressure (IIi), and Wada's constant (W) were derived. The variation of these parameters with concentration and temperature reveals significant solute–solvent interactions. Results indicate complex formation and molecular association in the mixtures, primarily governed by intermolecular hydrogen bonding between primaquine and water molecules. This study demonstrates the effectiveness of ultrasonic and viscometric techniques in probing drug–solvent interactions and provides new insights into the physicochemical behavior of primaquine in aqueous environments.**

***Index Terms*—Primaquine, ultrasonic velocity, acoustical parameters, solute–solvent interactions.**

I. INTRODUCTION

The study of solute–solvent interactions in aqueous drug solutions is fundamental to understanding physicochemical behavior, stability, and therapeutic efficacy. Ultrasonic velocity, density, and viscosity measurements provide valuable insights into molecular association, complex formation, and hydrogen bonding in liquid mixtures. These experimental techniques, when combined with derived acoustical parameters such as adiabatic compressibility, free volume, and internal pressure, offer a powerful approach to probe intermolecular forces and structural modifications in solution systems [1–3]. Ultrasonic interferometry has been extensively applied to investigate drug–solvent interactions, revealing the role of temperature and concentration in modulating molecular dynamics [4]. Viscosity and density data complement ultrasonic studies by elucidating solvation effects and relaxation processes [5,6]. Such approaches have been successfully employed in analyzing non-steroidal anti-inflammatory drugs, muscle relaxants, and antipsychotic agents in aqueous and mixed solvent systems [7–9]. Recent investigations highlight the importance of acoustical studies in pharmaceutical research. For example, metformin–dulcitol interactions demonstrated strong hydrogen bonding and solvation effects [10], while isradipine in binary solvent mixtures revealed temperature-dependent structural tendencies [11]. Similar studies on diclofenac potassium, chlorpromazine, and muscle relaxant drugs further confirm the utility of ultrasonic and viscometric techniques in drug–solvent characterization [12,13]. Comprehensive reviews emphasize the methodological advances and relevance of ultrasonic wave propagation in molecular interaction studies [14]. Despite these advances, primaquine—a widely used antimalarial drug—has not been systematically studied using ultrasonic and viscometric methods. Given its clinical importance and aqueous solubility, investigating primaquine–water systems across different temperatures can provide novel insights into its solvation behavior and intermolecular interactions. The present work aims to fill this gap by measuring ultrasonic velocity, density, and viscosity of primaquine aqueous solutions at 303 K and 313 K, and deriving acoustical parameters to interpret solute–solvent interactions. This study

contributes to the broader understanding of drug–solvent dynamics and highlights the role of hydrogen bonding in primaquine aqueous systems.

II. MATERIAL AND METHOD

Primaquine of AR grade (≥ 99.9 chastity) was attained from original suppliers. Distilled water was used to prepare results of Primaquine in different attention (0.1 – 0.0125 w/ v). Ultrasonic haste(υ) was measured at 1 MHz using a Mittal Model F- 05 interferometer (delicacy ± 0.1). viscosity(ρ) was determined with a pycnometer (± 0.001 g cm $^{-3}$), and density(η) with an Ostwald viscometer under thermostatic control (± 0.1 K). measures were carried out at 303 K and 313 K.
From υ, ρ, and η values, auricular parameters were calculated using standard relations adiabatic compressibility(κ), intermolecular free length (Lf), relaxation time(τ), free volume (Vf), internal pressure(Πi), aural impedance(Z), Wada's constant(W), ultrasonic attenuation (α/ f ^{2}), Rao's constant(R), molar volume (Vm), and cohesive energy (CE).

III. RESULT AND DISCUSSION

The measured values of ultrasonic velocity, density, and the derived thermo-acoustical parameters of Primaquine in aqueous solutions at 303 K and 313 K across varying concentrations are presented in Figures 1–14. The parameters include adiabatic compressibility (κ), intermolecular free length (Lf), relaxation time (τ), free volume (Vf), internal pressure (Πi), acoustic impedance (Z), Wada's constant (W), ultrasonic attenuation (α/f²), Rao's constant (R), molar volume (Vm), and cohesive energy (CE).

Figure: The following figures shows the variation of various acoustical parameters with concentration and temperature

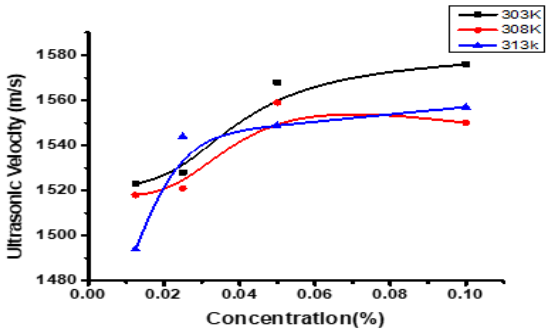

Fig.1: -Variation of Ultrasonic velocity with concentration and temperature

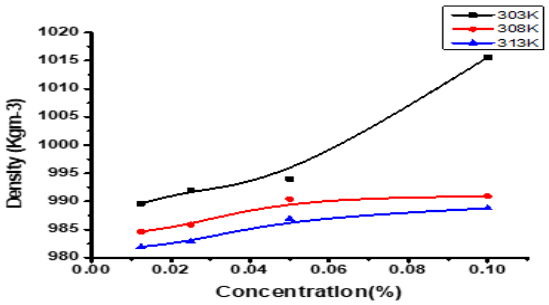

Fig.2: -Variation of Density with concentration and temperature

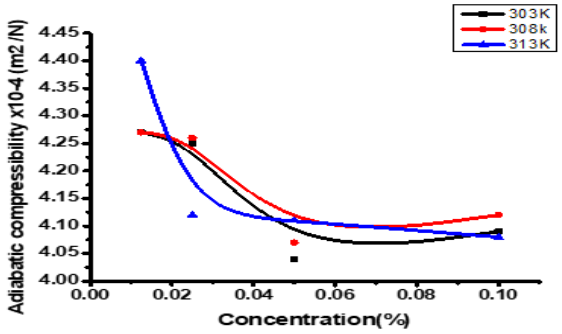

Fig.3: -Variation of Adiabatic compressibility with concentration and temperature

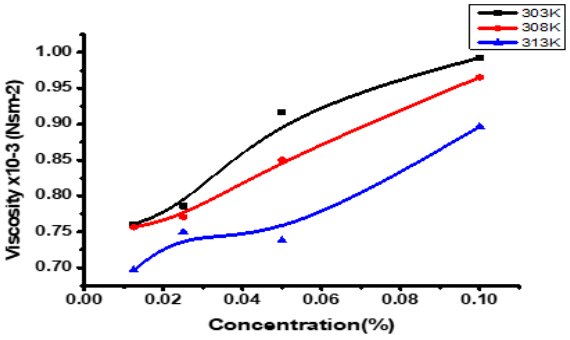

Fig.4: -Variation of Viscosity with concentration and temperature

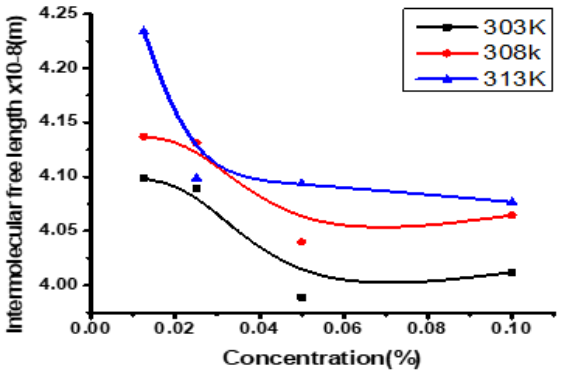

Fig.5: -Variation of Intermolecular free length with concentration and temperature

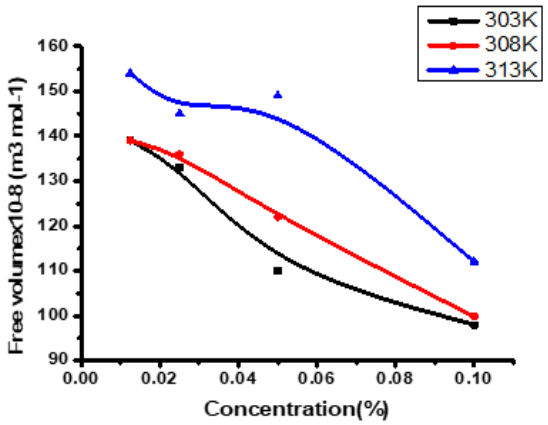

Fig.6: -Variation of free volume with concentration and temperature

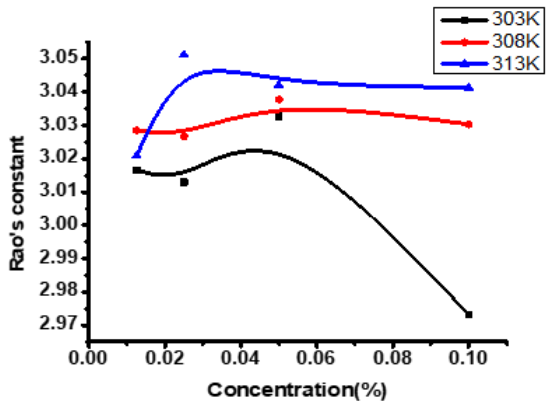

Fig.7: -Variation of Rao's constant with concentration and temperature

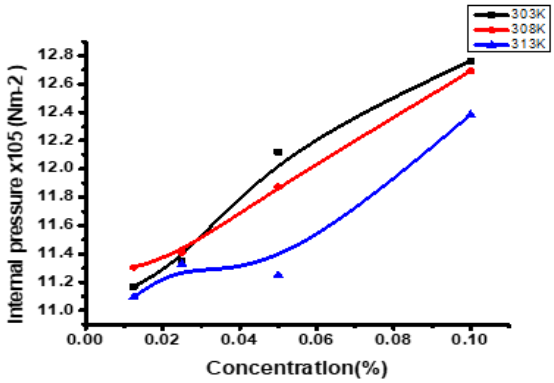

Fig.8: -Variation of Internal Pressure with concentration and temperature

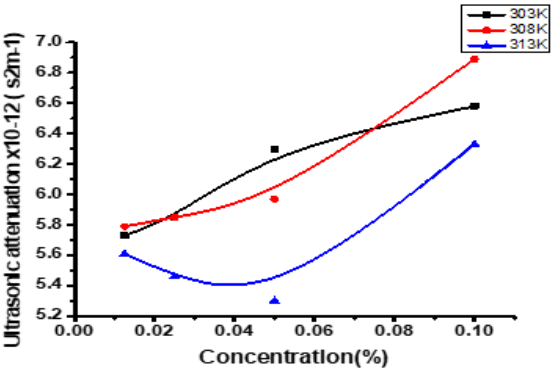

Fig.9: -Variation of Ultrasonic attenuation with concentration and temperature

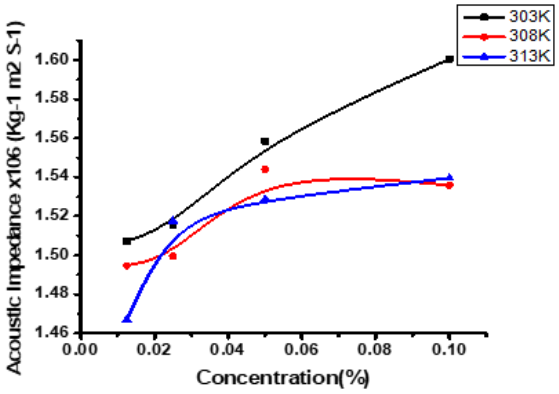

Fig.10: -Variation of Acoustic Impedance with concentration and temperature

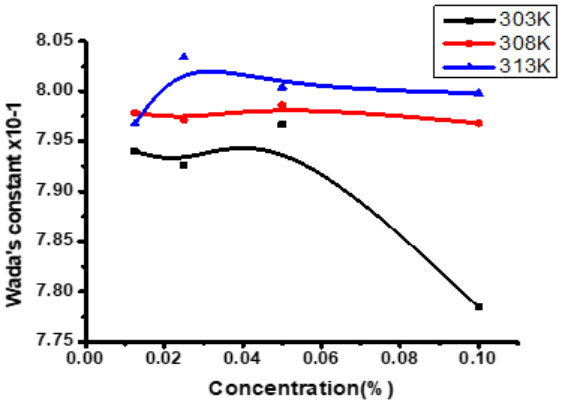

Fig.11: -Variation of Wada's constant with concentration and temperature

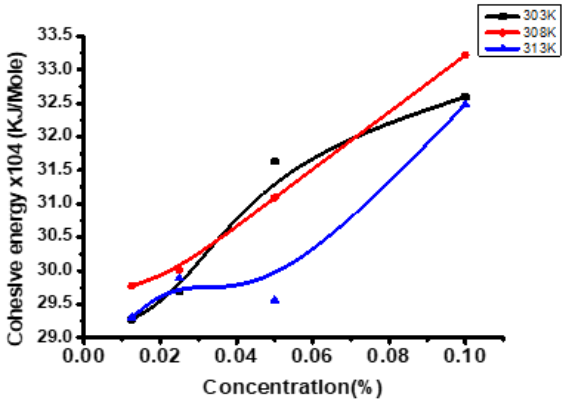

Fig.12: -Variation of Cohesive energy with concentration and temperature

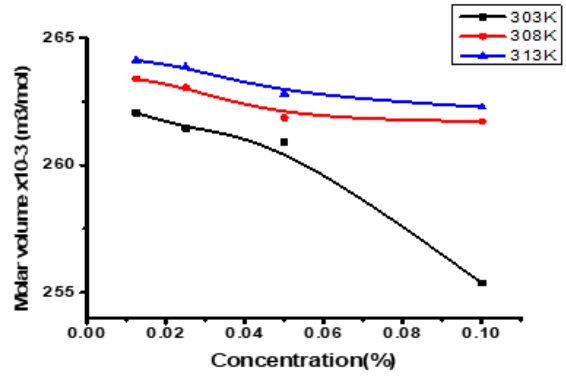

Fig.13: -Variation of Molar volume with concentration and temperature

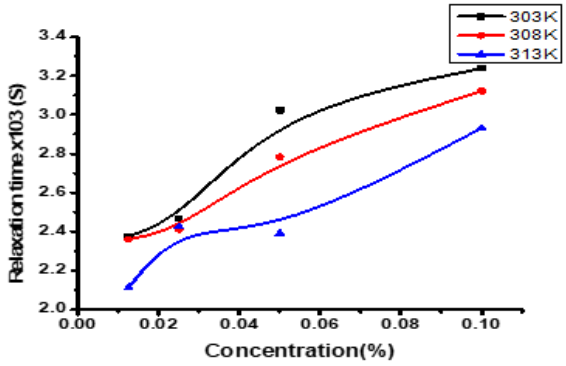

Fig.14: -Variation of Relaxation time with concentration and temperature

IV. CONCLUSION

The ultrasonic velocity, density, viscosity, and derived acoustical parameters of primaquine aqueous solutions confirm strong solute–solvent interactions at higher concentrations, primarily due to hydrogen bonding and molecular association. These interactions weaken with increasing temperature, indicating reduced structural stability. The study demonstrates the effectiveness of ultrasonic and viscometric techniques in probing drug–solvent dynamics and highlights the physicochemical behavior of primaquine in aqueous environments.

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