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Ultrasonic Study of Molecular Interactions in Aqueous Solution of Enclex (Enoxaparin Sodium) Blood Thinner at 298.15 K Temperature by using Different Concentration Solutions

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Abstract: *The present study investigates the acoustical and thermodynamic properties of aqueous solutions of blood thinner drugs at different concentrations using ultrasonic techniques. Parameters such as density, viscosity, ultrasonic velocity, adiabatic compressibility, intermolecular free length, acoustic impedance, relative association, relaxation time, Rao constant, Wada constant, internal pressure and cohesive energy were evaluated. Measurements were carried out at 298.15 K using an ultrasonic interferometer. The results indicate strong solute–solvent interaction and molecular association between drug molecules and water molecules. The study helps in understanding the molecular behaviour of anticoagulant drugs in aqueous media.*

Keywords*:* Adiabatic compressibility, Internal Pressure, Relaxation Time, Free Length, Acoustic Impedance, Apparent Molar Volume

I. INTRODUCTION

Ultrasonic techniques are widely used to investigate the physicochemical properties of liquid mixtures and solutions. 1-4Ultrasonic velocity measurements provide valuable information about molecular interaction, structure of liquid systems and solute–solvent interactions. Mechanical longitudinal waves can propagate through all three states of matter—solids, liquids, and gases. The study of ultrasonic waves falls under the branch of acoustics known as ultrasonics, which deals with the generation, propagation, and application of high-frequency sound waves. Ultrasonic techniques have become powerful tools in investigating the physicochemical, acoustical, and thermodynamic properties of liquids and liquid mixtures. Measurement of ultrasonic velocity, along with density and viscosity, provides valuable information about molecular interactions, structural behaviour, and solute–solvent interactions in solutions5-10. Blood thinner drugs play a significant role in preventing the formation of blood clots and are widely used in the treatment of cardiovascular diseases. One such anticoagulant drug is Enoxaparin Sodium, which belongs to the class of low molecular weight heparins.

In the present study, the acoustical and thermodynamic properties of aqueous solutions of this drug at different concentrations and temperatures were investigated11-15 using an Ultrasonic Interferometer. 16-18The analysis of parameters such as ultrasonic velocity, adiabatic compressibility, intermolecular free length, acoustic impedance, and other related properties provides insights into the nature of intermolecular forces and molecular association present in the solution.

Blood thinning drugs are widely used in the treatment of cardiovascular disorders. One such important anticoagulant drug is Enoxaparin Sodium, a low molecular weight heparin used to prevent blood clot formation. Studying the acoustical properties of its aqueous solutions provides information regarding intermolecular interactions and structural

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behaviour in biological systems. In the present investigation, ultrasonic velocity along with density and viscosity measurements were used to evaluate various acoustical and thermodynamic parameters of aqueous solutions of Enoxaparin sodium at different concentration.

II. METHODS AND MATERIALS

Materials:

The blood thinner drug Enoxaparin Sodium was used as solute and distilled water was used as solvent for preparing aqueous solutions of different concentrations. Solutions of concentrations:

- 0.1 M
- 0.01 M
- 0.001 M

were prepared using analytical grade chemicals.

Instruments:

The following instruments were used:

- Ultrasonic Interferometer (2 MHz frequency) for ultrasonic velocity measurement
- Density bottle for density measurement
- Ostwald viscometer for viscosity measurement
- Thermostatic water bath for maintaining constant temperature

All measurements were carried out at 298.15 K.

III. EXPERIMENTAL METHOD

The ultrasonic velocity of the solution was measured using an ultrasonic interferometer operating at a frequency of 2 MHz.

Density of the solution was measured using a calibrated pycnometer, while viscosity was measured using an Ostwald viscometer.

Using experimental values of ultrasonic velocity, density and viscosity, several acoustical and thermodynamic parameters were calculated using standard relations.

Computation : By using ultrasonic velocity following ultrasonic parameters are calculated-

Adiabatic compressibility - β =1/vs 2d where, v - velocity of solution, d - density of liquid , Intermolecular free length - Lf = K √ β s where, K - temperature dependent known as Jacobson' s constant , Specific acoustic impedance - Z = v × ds , Relative association -RA = ds / d0 [v0 /vs] 1/3 where, v0 - ultrasonic velocity of solvent vs - ultrasonic velocity of solution , Relaxation time - τ = 4/3 βs × η

IV. RESULTS AND DISCUSSION

The experimentally determined values are listed in the following tables :-

Following values are calculated at 298.15 K temperature and at 2 MHz :-

Table 1: Density, Viscosity and Ultrasonic Velocity at 298.15 K -

Concentration (M)	Density (kg/m3)	Viscosity (centipoise)	Ultrasonic velocity (m/s)
0.1	1.246	1.5702	1523.65
0.01	1.166	1.1122	1521.29
0.001	1.150	0.9863	1495.33

Table 2 :- Acoustical Parameters -

Conc. (M)	Adiabatic compressibility (m²/N)Bx10-10	Free Length (m)(x10-11)	Acoustic Impedance (Zx10-6) (Kgm-2 sec-1)	Relative Association
0.1	3.46	3.96	1.898	1.241
0.01	3.70	4.10	1.774	1.163
0.001	3.89	4.20	1.720	1.155

Table 3: Thermodynamic Parameters -

Relaxation Time (Tx10-10)	Free Volume (Vf x 10-8) (m3/mole)	Rao Constant (R) (m3 /mole)(m/s)1/3	Wada Constant (W) (m3 /mole)(N/m2) 1/7	Apparent molar volume
7.24	0.164	0.1220	0.2370	-943.6
5.50	0.308	0.1310	0.2520	-12329
5.12	0.386	0.1300	0.2480	-156289

Table 4: Additional Thermodynamic Parameters -

Molar Sound Velocity	Internal Pressure (MPa)	Cohesive Energy (kJ/mol)
1.22×10^4	518	549
1.31×10^4	474	537
1.32×10^4	421	484

The experimental data shows that (Table-1) density, viscosity and ultrasonic velocity increase with increase in concentration of the solution. (Table-2) Adiabatic compressibility decreases with increasing concentration, which indicates strong intermolecular interactions between solute and solvent molecules. Intermolecular free length decreases with increasing concentration, suggesting closer packing of molecules in solution. The increase in acoustic impedance also confirms strong molecular interaction between drug molecules and water molecules. Relative association values greater than unity indicate molecular association in the system. (Table-3) Rao constant and Wada constant increases which indicates non-ideal behaviour of acoustical and thermodynamics parameters. (Table-4) Internal pressure and cohesive energy values are also higher at higher concentration, which further supports the presence of strong intermolecular forces. Negative values of apparent molar volume indicate strong solvation of solute molecules by water molecules. Overall, the results confirm strong solute–solvent interaction and molecular association in aqueous solutions of the anticoagulant drug.

V. CONCLUSION

The acoustical and thermodynamic properties of aqueous solutions of Enoxaparin Sodium were studied using an Ultrasonic Interferometer at 298.15 K.

The study reveals that:

- Ultrasonic velocity increases with concentration
- Adiabatic compressibility decreases with concentration
- Intermolecular free length decreases with concentration
- Strong solute–solvent interaction exists in the system
- Internal pressure and cohesive energy values are also higher at higher concentration, which further supports the presence of strong intermolecular forces
- Molecular association occurs between drug molecules and water
- The results confirm strong solute–solvent interaction and molecular association in aqueous solutions of the anticoagulant drug.

Thus ultrasonic techniques are effective tools for studying molecular interactions and structural properties of pharmaceutical solutions.

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