Ultrasonic Investigation of Thermoacoustical Properties of Glucan-Sodium Hydroxide Solutions at Various Temperatures and Concentrations

Smita S. Kharkale-Bhuyar[1]
[1]*Assistant Professor, Department of Chemistry, Shri Lemdeo Patil Mahavidyalaya, Mandhal, Kuhi, Nagpur, Maharashtra, India*

***Abstract*—This study employs ultrasonic methods to explore the molecular interactions between glucan and aqueous sodium hydroxide solutions. The investigation focuses on the effects of temperature and concentration on these interactions. Ultrasonic measurements were performed at a frequency of 5MHz, and temperatures ranging from 301K to 320K. The experimental parameters measured include: Density (ρ), Viscosity (η), Ultrasonic velocity (U). These parameters were used to calculate various acoustic properties, such as: Free volume (Vf), Internal pressure (Πi), Absorption coefficient (α), Rao's constant (R), Wada's constant (W). The calculated acoustic parameters provide valuable insights into the molecular interactions between glucan and sodium hydroxide. The results show that these interactions are influenced by factors such as: Concentration, Temperature, Ionic size, Ionic field strength, Nature of the ion. The study also examines the structural rearrangement of solute and solvent in aqueous solutions, shedding light on the underlying mechanisms governing these interactions. This investigation demonstrates the effectiveness of ultrasonic techniques in probing molecular interactions in glucan-sodium hydroxide solutions. The findings of this study contribute to a deeper understanding of the complex interactions governing these systems, with potential implications for various fields, including materials science and chemistry.**

***Index Terms*—Aqueous glucan, free volume, internal pressure, Rao's constant and Wada's constant.**

I. INTRODUCTION

Ultrasonic studies of liquid solutions have significant implications for understanding intermolecular interactions between solute-solvent molecules, with applications in various industrial and technological processes. [1,2] This research focuses on the ultrasonic characterization of glucan-sodium hydroxide solutions, exploring their thermodynamic and acoustic properties. Density (ρ), viscosity (η), and ultrasonic velocity (U) measurements were performed using a specific gravity bottle, capillary viscometer, and ultrasonic interferometer, respectively. The study examined five different concentrations (0.1%, 0.20%, 0.40%, 0.60%, and 0.80%) of glucan (molecular weight: 504.438 g/mol) in 1(N) sodium hydroxides at temperatures ranging from 301K to 320K, with a frequency of 5MHz. [3-4]
Glucan, a water-soluble polysaccharide, has widespread industrial applications, particularly in the pharmaceutical sector. Its derivatives have been used in clinical applications, such as synthetic blood-volume expanders and human red blood cell aggregation. The increasing demand for glucan and its derivatives in medical, industrial, and research applications motivated this investigation into the thermoacoustic properties of glucan using ultrasonic techniques. 1. Investigate the intermolecular interactions between glucan and sodium hydroxide molecules. [5-7] Explore the thermodynamic and acoustic properties of glucan-sodium hydroxide solutions. 3. Provide insights into the structural arrangement of glucan molecules in solution. [8-9]
By examining the ultrasonic velocity, density, and viscosity of glucan-sodium hydroxide solutions, this research contributes to a deeper understanding of the complex interactions governing these systems, with potential implications for various industrial and technological applications. [12-14].

II. EXPERIMENTAL MATERIALS & METHODS

In present study, the solute is glucan of molecular weight 504.438 g/mol and solvent is sodium hydroxide (Fisher scientific), both are of analytical reagent (AR) grade and are used as such throughout the experiments. The density of solvent and the solution are measured using a 25ml specific gravity bottle with an accuracy of ± 0.1 Kgm^{-3} and calculated using standard equation.

$$\rho 1 = \frac{W1}{W2}\rho 2$$

Where, w1 = weight of distilled water, w2 = Weight of experimental solution, ρ1 = Density of water, ρ2 = Density of experimental solution,

An Ostwald's viscometer was used for the viscosity measurement of polymer solution with accuracy 0.001 NSm^{-2} immersed in the temperature-controlled water bath.

The time of flow was measured using a digital racer stop watch with an accuracy of 0.01 seconds at above mentioned temperatures and calculated by using the relation,

$$\eta 2 = \eta 1\left(\frac{\mathrm{t2}}{\mathrm{t1}}\right)\left(\frac{\rho 2}{\rho 1}\right)$$

Where, η1 = Viscosity of water, η2 = Viscosity of the aqueous solution of dextran, ρ1 = Density of water, ρ2 = Density of aqueous solution of dextran, t1 = Time of flow of water, t2 = Time of flow of aqueous solution of dextran. The ultrasonic velocity in the polymer solution have been measured using an ultrasonic interferometer (Mittal -Model: M-84) working at frequency 5 MHz with an overall accuracy of ± 0.1 ms^{-1}. All the precautions were taken to minimize the possible experimental error. [15-16]

III. THEORY

The density, Viscosity and ultrasonic velocity of the solution is measured and is used to compute free volume (Vf), internal pressure (Πi), absorption coefficient or attenuation coefficient (α), Rao's constant (R) and Wada's constant (W) basing on the following standard formula.

1. Free volume (Vf)

The free volume is broadly defined as the average volume in which the molecules can move inside the hypothetical cell due to the repulsion of the surrounding molecules. The free volumes can be calculated using the relation as given below,

$$\mathrm{Vf} = \left(\frac{xMeffU}{K^{\eta}}\right)3/2$$

Where Meff is the effective molecular weight of the solution (Meff = ΣmiXi, where mi and Xi are the molecular weight and mole fraction of solute and solvent), K is the temperature independent constant which is equal to 4.281 × 109 for all liquids.

2. *Internal pressure* (πi)

It can be calculated using the relation as given below

$$\pi\mathrm{i} = \mathrm{bRT}\left(\frac{\mathrm{K}\eta}{\mathrm{U}}\right)\left(\frac{\rho 2/3}{\mathrm{Meff}\ 7/6}\right)$$

Where b stands for cubic packing, which is assumed to be 2 for all liquids, k is dimensionless constant independent of temperature and nature of liquids. Its value is 4.281 × 10^9. T is the absolute temperature in Kelvin, M eff is the effective molecular weight, R is the universal gas constant, η is the viscosity of solution in Ns·m^{-2}, U is the ultrasonic velocity in m·s^{-1}, and ρ is the density in kg·m^{-3} of solution.

3. *Absorption coefficient or attenuation coefficient*

It is a characteristic of the medium. It depends on the external condition like temperature, Pressure and frequency of measurement. It is given by the following relation,

$$\alpha = \left(\frac{8\pi 2\eta \mathrm{f}2}{3\rho \mathrm{U}3}\right)$$

Where f is the frequency of ultrasonic wave

4. Rao's constant

Rao has established the empirical relation between molecular weight, density and ultrasonic velocity of liquids as

$$\mathbf{R} = \frac{\mathrm{Meff}}{\rho}\mathrm{U}1/3$$

This equation is called Rao's rule and R is also called as the molar sound velocity. A number of authors have provided a theoretical explanation of Rao's formula on the basis of phase rule and kinetic theory of liquids.

5. Wada's constant

Wada had analyzed the variation of molar compressibility with concentration for many liquid systems. He derived the empirical relation,

$$\mathrm{W} = \frac{\mathrm{Meff}}{\rho}\beta - 1/3$$

not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to separate compound units, e.g., —A·m^2.‖

IV. RESULTS

Table 1: Values of density ( ) and viscosity (of dextran with 1(N) sodium hydroxides at different concentrations and temperatures. 0.1%, 0.20%, 0.40%, 0.60% and 0.80% Fig. 1 Variation of density with concentration.

T(K)	Concentration									
	0.1%		0.20%		0.40%		0.60%		0.80%	
	ρ kg m^{-3}	ɳ kg m^{-3}	ρ kg m^{-3}	ɳ kg m^{-3}	ρ kg m^{-3}	ɳ kg m^{-3}	ρ kg m^{-3}	ɳ kg m^{-3}	ρ kg m^{-3}	ɳ kg m^{-3}
301	1030.18	0.988	1032.08	0.982	1036.87	0.980	1035.26	0.997	1039.30	0.905
305	1028.67	0.902	1031.86	0.887	1035.65	0.914	1034.04	0.901	1038.41	0.865
310	1026.84	0.797	1030.03	0.800	1033.82	0.710	1033.82	0.835	1037.38	0.801
315	1022.29	0.710	1028.60	0.756	1031.01	0.665	1033.20	0.774	1035.66	0.780
320	1019.24	0.663	1027.21	0.682	1028.00	0.598	1030.98	0.703	1032.14	0.720

Fig. 1 Variation of density with concentration.

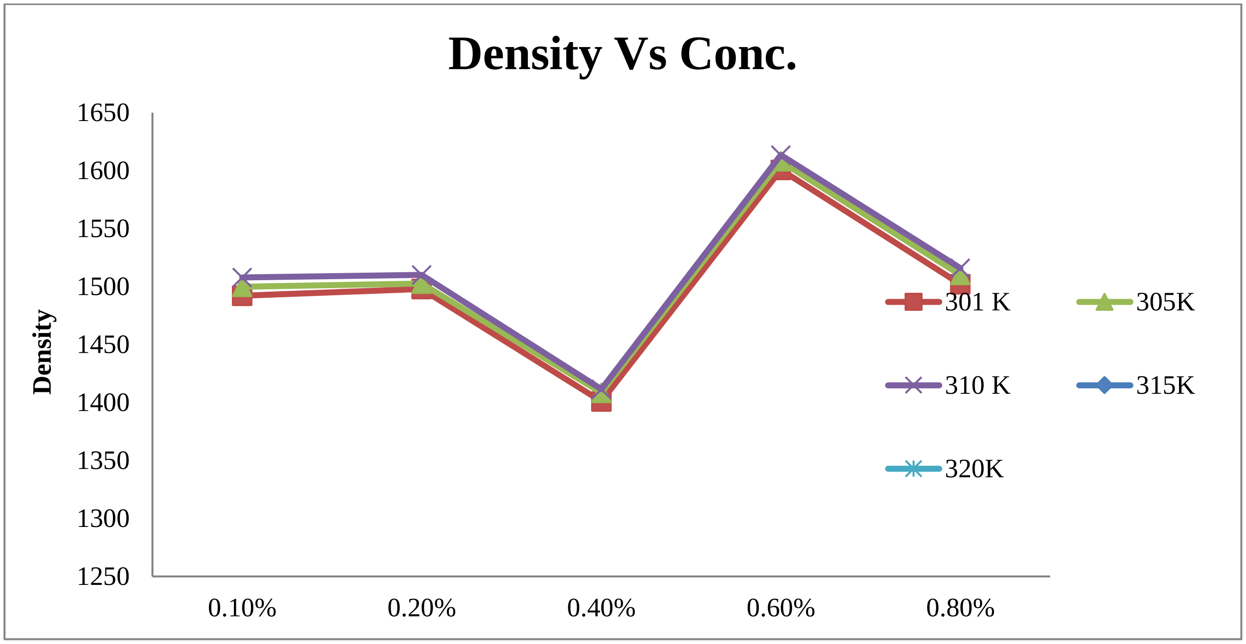


Fig. 2 Variation of density with Temperature.

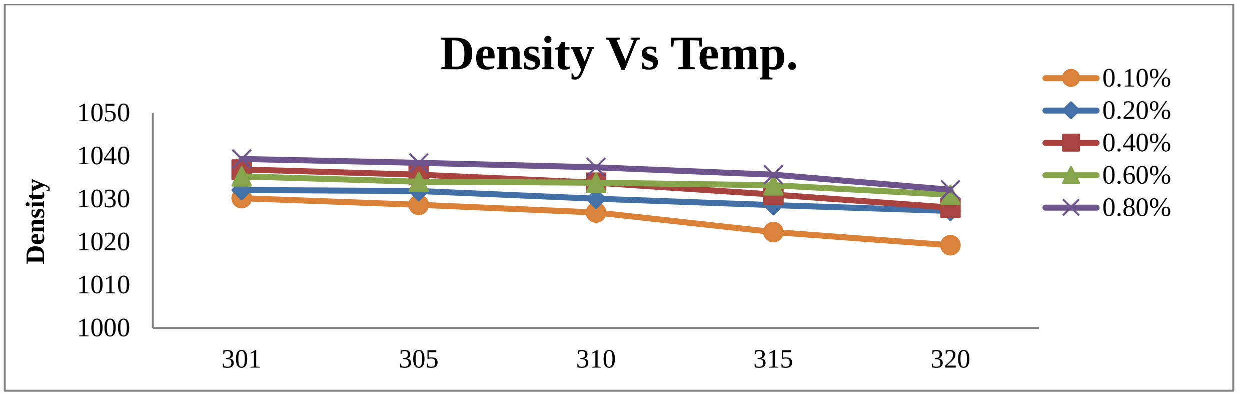


Fig. 3 Variation of Viscosity with Conc.

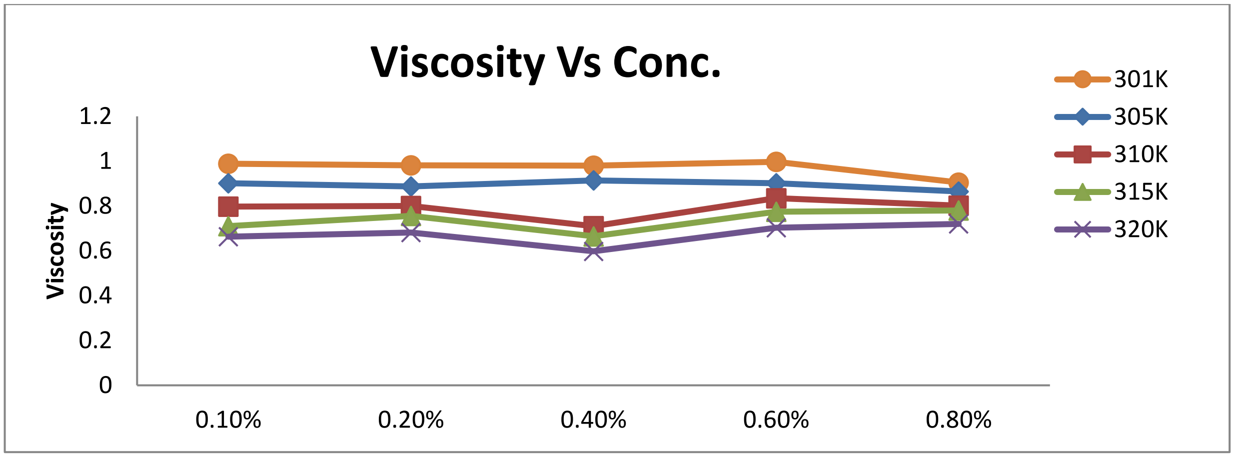


Fig. 4 Variation of Viscosity with Temperature

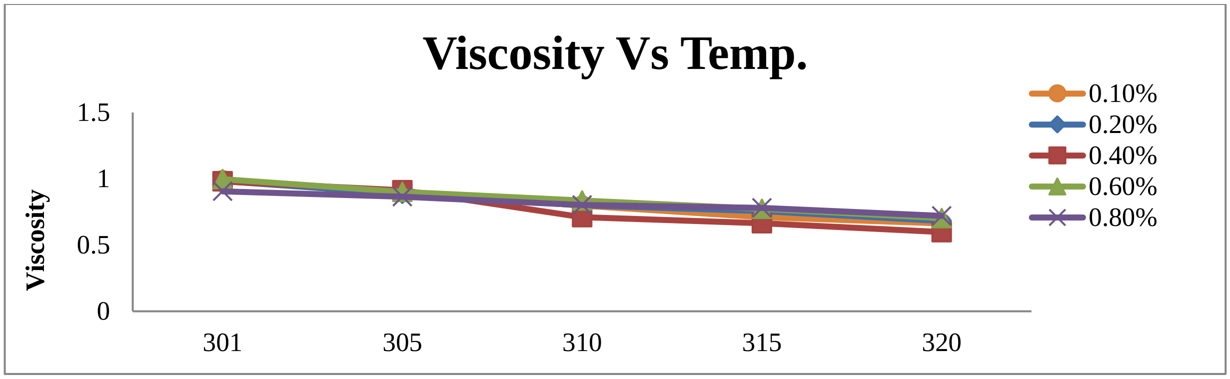


Table 2: Values of ultrasonic velocity (U) and free volume (Vf) of glucan with 1(N) sodium hydroxides at 5MHz frequency at different temperatures and concentrations. T(k) Ultrasonic velocity (U) m/s^2 Free volume (V_f) (x10^{-3}m^3·mol^{-1})

T(k)	Ultrasonic velocity (U) m/s2					Free volume(Vf) (x10-3m3·mol−1)				
	0.1%	0.20%	0.40%	0.60%	0.80%	0.1%	0.20%	0.40%	0.60%	0.80%
301	1480.0	1483.0	1385.0	1487.0	1489.0	7.888	7.807	7.122	5.861	6.646
305	1488.0	1492.0	1393.0	1496.0	1496.0	7.320	8.489	8.350	7.141	7.762
310	1492.0	1498.0	1401.0	1600.8	1502.0	09.678	10.070	10.918	9.480	8.998
315	1500.0	1502.5	1408.5	1608.0	1510.0	10.576	11.008	11.836	11.692	10.193
320	1508.0	1510.0	1411.5	1613.5	1516.0	11.195	12.952	13.516	12.897	11.292

Fig. 5 Variation of Velocity with Conc.

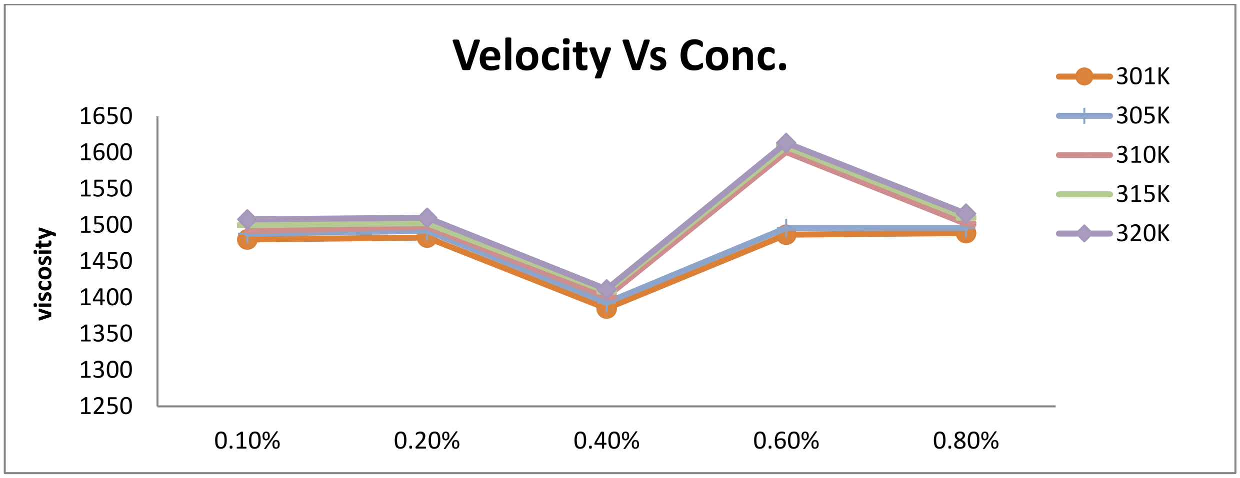


Fig. 6 Variation of Velocity with Temp.

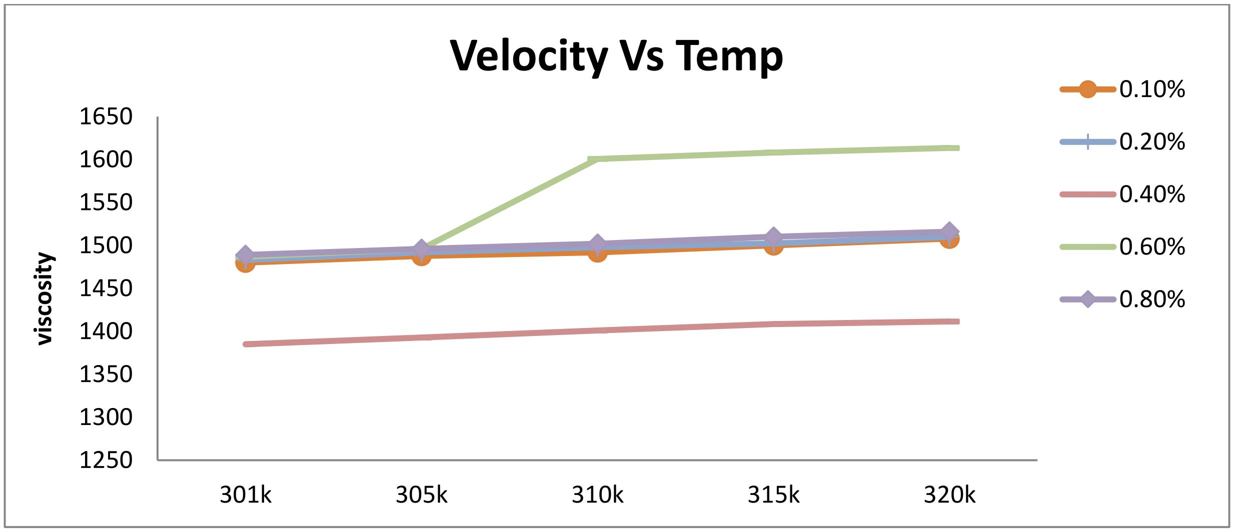


Fig. 7 Variation of Free Volume with Conc.

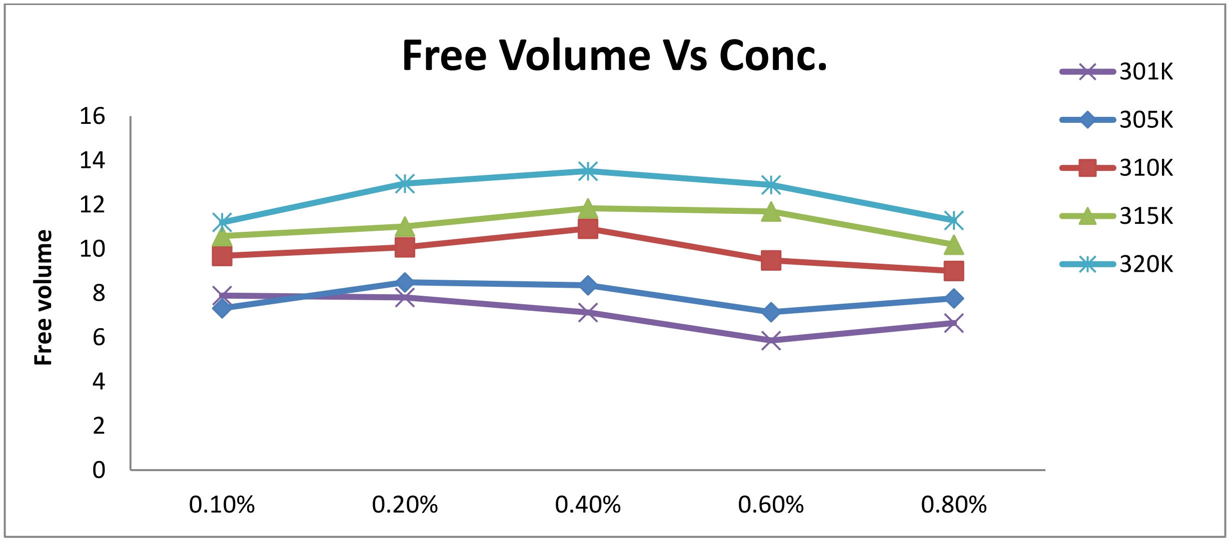


Fig. 8 Variation of Free Volume with Temp.

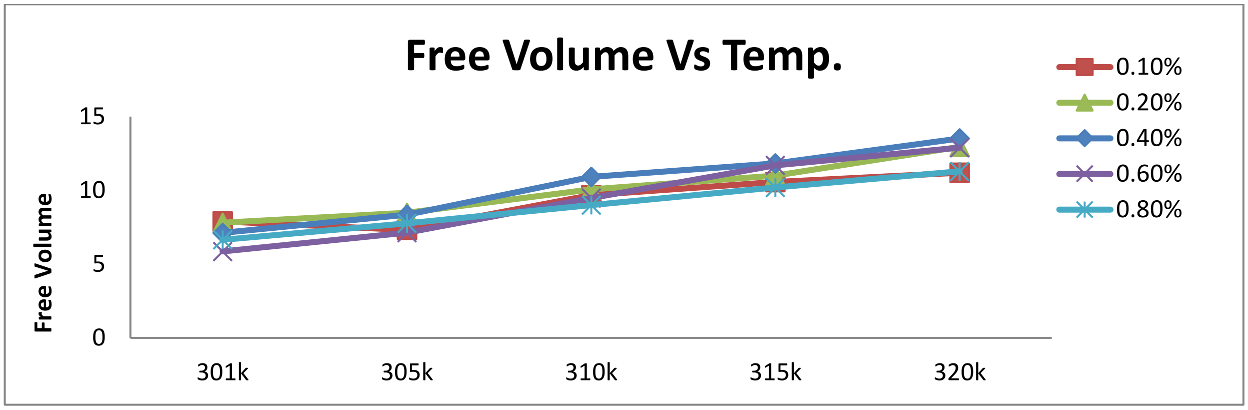


Table 3: Values of Rao's constant (R) and Wada's constant (W) of glucan with 1(N) sodium hydroxides at different temperatures and concentrations at 5MHz frequency.

T(k)	Rao's constant $(m^3/mole)(m/s)^{1/3}(10^{-3})$					Wada's constant (W) $(m^3/mole)(N/m^2)^{1/7}(10^{-3})$				
	0.1%	0.20%	0.40%	0.60%	0.80%	0.1%	0.20%	0.40%	0.60%	0.80%
301	10.25	10.25	10.24	10.25	10.23	78.59	78.59	78.59	78.59	78.50
305	10.29	10.28	10.28	10.28	10.26	78.84	78.82	78.78	78.79	78.65
310	10.32	10.32	10.31	10.31	10.29	80.02	80.05	80.00	78.98	78.83
315	10.36	10.35	10.35	10.35	10.33	80.02	80.02	80.02	80.22	80.08
320	10.42	10.41	10.40	10.39	10.37	80.02	80.02	80.02	80.42	80.36

Fig. 9 Variation of Rao's Const. with Conc.

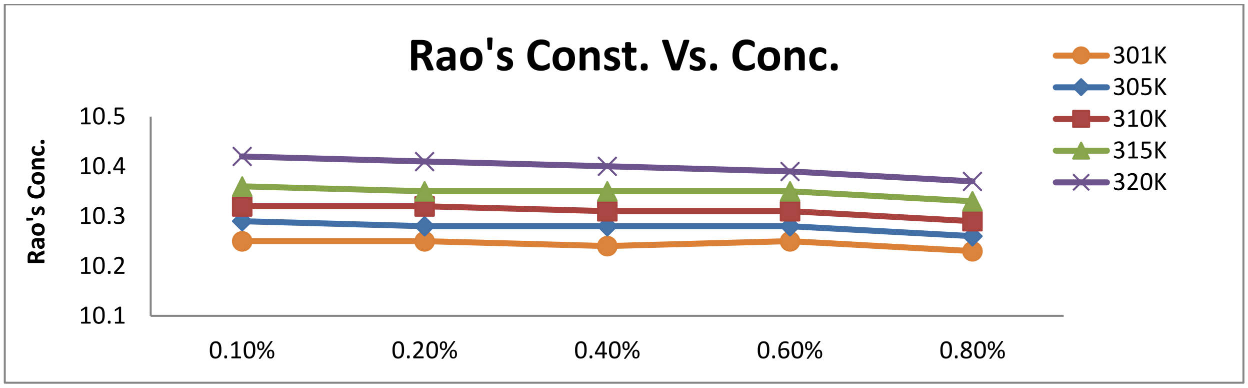


Fig. 10 Variation of Rao's Const. with Temp.

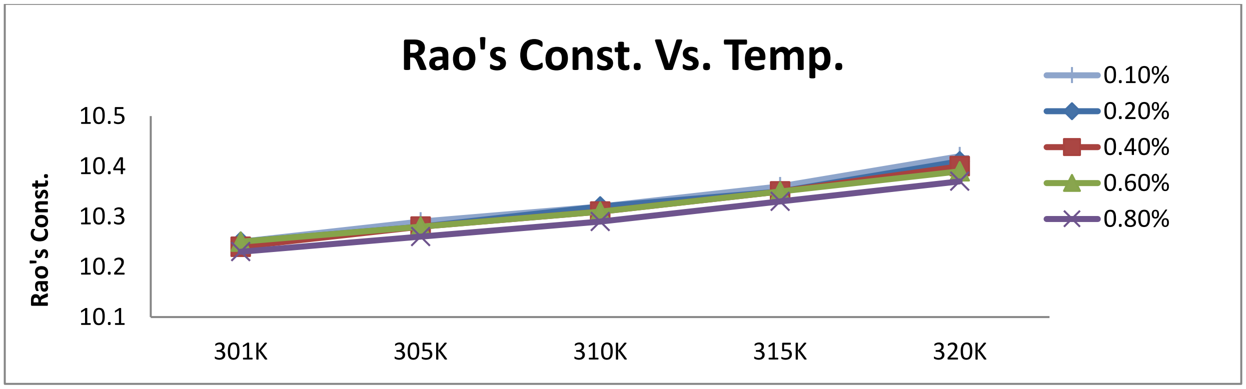


Fig. 11 Variation of Wada’s Const. with Conc.

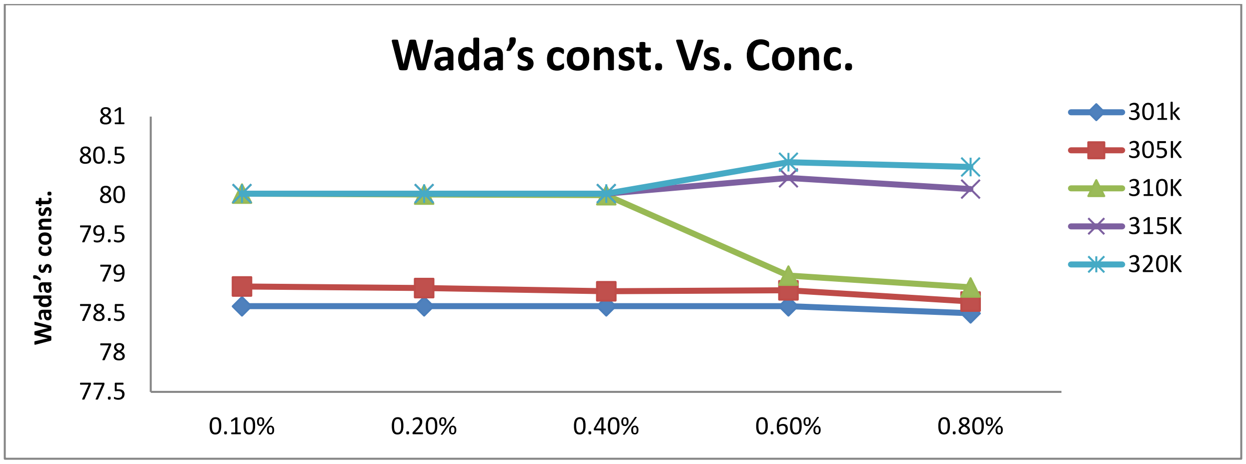
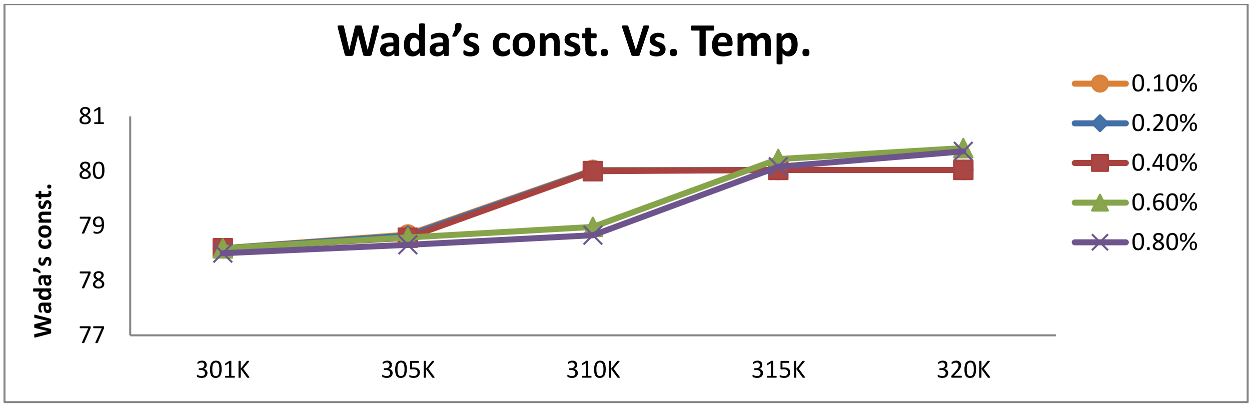


Fig. 12 Variation of Wada’s Const. with Temp.



V. DISCUSSION

Investigating the Thermodynamic and Acoustic Properties of Glucan-Sodium Hydroxide Solutions. The density and viscosity of a solution are critical parameters that influence its purity and packaging. As the temperature rises, the density and viscosity of the solution decrease, indicating a reduction in intermolecular forces. This phenomenon is attributed to the increased thermal energy of the system [Table-1]. The ultrasonic velocity of glucan-sodium hydroxide solutions exhibits a concentration-dependent behavior, increasing as the glucan concentration rises. This trend suggests that the stiffness of the mixture increases with concentration, leading to enhanced association between the solute and solvent molecules.

The free volume of the solution decreases as the glucan concentration increases, while the internal pressure rises. Conversely, the ultrasonic velocity and viscosity of the solution increase with concentration. These observations indicate that the interactions between the solute and solvent molecules are weak [Table-2].

The values of Rao's constant and Wada's constant decrease with increasing glucan concentration, indicating weak interactions between the solute and solvent molecules. These observations provide valuable insights into the molecular dynamics of the solution [Table-3].

VI. CONCLUSION

When a polymer meets a solvent, a fascinating interaction unfolds. The solvent molecules begin to interact with the polymer segments, forming connections that can be stronger than the segments own attraction to each other. As the solvent-polymer interaction gains strength, the bonds between polymer segments start to break. Solvent molecules slip into the gaps, surrounding and embracing individual segments. This process of solvation causes the tightly coiled polymer segments to relax and unfold. As the segments interact with the solvent molecules, they begin to loosen their grip on each other, adopting a more open and relaxed configuration.

VII. ACKNOWLEDGMENTS

I sincerely thanks to the Shri Lemdeo Patil Mahavidyalaya, Mandhal, Department of Chemistry Cuttack for their logistical support and encouragement.

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