Variation of Acoustical Parameters of Dextran in 2(M) Glycine with Temperature and Concentrations

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Abstract

This article reports variousacoustical parameters such as adiabatic compressibility, intermolecular free length, relaxation time, acoustic impedance, and Gibb's free energy of dextran solution with 2(M) glycine at 303K, 308K, 313K, 318K & 323K at 5MHz frequency in different concentration. By using experimental values of density (ρ), viscosity (η) and ultrasonic velocity (U) the above mentioned parameters have been evaluated.. The measures of different physio-chemical and derivative properties of solutions have been shown to be useful in understanding the solute-solvent interaction and packing effects of solutes with solvent molecules. The purpose of this study is to analysethe factors that influence solute-solvent interaction hence effect on these parameters.

Key Words: Dextran solution, ultrasonic velocity, acoustic impedance (Z), adiabatic compressibility (β), intermolecular free length (L_f), relaxation time (τ) , Gibb's free energy(ΔG).

Introduction

A lot of pharmaceutical and chemical industries usedifferent kinds of polymer solution and liquid mixtures in their processes, and for this reason it is necessary to pay attention to the thermodynamic studies and modelling test and development to optimal industrial designs and simulations. The interactions between different molecules are responsible for non-ideal mixing properties of solvents, and these interactions influence the physio-chemical properties. The practical importance of solution rather than single component liquid systems has gained much importance during the last two decades in assessing the nature of molecular interactions and investigating the physio-chemical behaviour of such systems [1].

Ultrasonic investigation of polymer solution consisting of polar and non-polar components is of considerable importance in understanding the physical nature and strength of molecular interaction between solute and solvent. [2]

For a better understanding of the physio-chemical properties and the molecular interaction between glycine-dextran, ultrasonic velocity together with density and viscosity are measured at different temperatures for different concentrations of the solution. These data furnish wealth of information about the interaction between dipoles; hydrogen bonding, multi-polar and dispersive forces[3-4].

In our present study we have evaluated thermo acoustic parameters like adiabatic compressibility, intermolecular free length, relaxation time, acoustic impedance, and Gibb's free energy of a novel polymer dextran of molecular weight 70,000 at five different concentration i.e. 0.1%, 0.25%, 0.50%, 0.75% and 1% in solvent 2(M) glycine at five different temperature ranging from 303K to 323K at constant frequency of 5MHz. Pasteur isolated dextran [5] for the first time in 1861 but he certainly did not expect that this simple structure, synthesized by bacteria polysaccharide, could find such wide applications in medicine. Although dextran is simply a combination of glucose molecules, it is extensively used in the medical field, primarily as supplementary material that reduces blood viscosity

and prevents the formation of blood clots [6]. Wide applications of dextran and their derivatives for medical, industrial and research purpose motivated to carry out investigation of thermo acoustic parameter of dextran by ultrasonic technique [7, 8 & 9].

Experimental Section

Materials[10] and methods[11] adopted are same as reported in our earlier paper.

Theoretical aspect

The density, viscosity and ultrasonic velocity have been measured and using these experimental data the thermo acoustic parameters like acoustic impedance, adiabatic compressibility, intermolecularfree length and Gibb's free energy were calculated using standard formula [12].

Results and Discussion

The density, viscosity, ultrasonic velocity of dextran in 2(M) glycine of different concentration are reported in our earlier paper[10].Using those data the acoustic impedance were calculated at different concentration and temperature which is represented in table1.

Table 1:Values of Acoustic impedance (Z) of dextran in 2(M) glycine at different concentrations and temperatures at 5MHz frequency.

T (kelvin)	Acoustic impedance (Z) 106 kg·m2·s−1)				
	0.10%	0.25%	0.50%	0.75%	1%
303	1.6885	1.6923	1.6948	1.6969	1.7000
308	1.6967	1.7011	1.7032	1.7068	1.7099
313	1.6999	1.7035	1.7063	1.7077	1.7104
318	1.7025	1.7065	1.7086	1.7106	1.7128
323	1.6992	1.7018	1.7041	1.7088	1.7110

The ultrasonic velocity 'U' depends on the wavelength 'λ'of the sound wave. Since the frequency (5 MHz) is constant, λ increases with the increase in the concentration. It is observed that ultrasonic velocity increases with increase in concentration (vol. %) of dextran in glycine, indicating the increase in stiffness of the mixture and hence association. This suggests presence of solute solvent interactions. The increase suggests a structure-making capacity of polymers in solution. Moreover, the increase in ultrasonic velocity indicates the possibility of H-bond formation between solute and solvent. There is also an indication of greater association among the molecules..The solute occupy the interstitial space of solvent and tend to break the ordered state of solvent due to its self association But With increase in Temperature there occurs a structural rearrangement as a result of solvation leading to a comparatively more ordered state.

Acoustic impedance is the product of ultrasonic velocity and density. As density and velocity both increase with the increase in concentration the acoustic impedance value also increases as shown in table−1 which indicates the interaction between the solute and solvent molecules. This is due to increase in pressure and cohesive energy of the system because of strong interaction. Acoustic impedance increases with increase in temperature up to 318 K then decreases for 323 K this is because the decrease

in density is more appreciable then increases in velocity for higher temperature 323K.The variation of acoustic impedance with temperature and concentration is plotted in figure1 and 2 respectively.

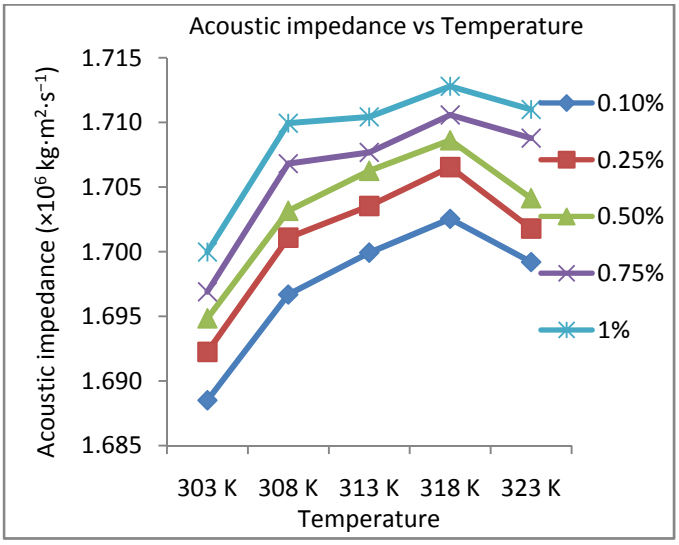

Fig.-1 Variation of Acoustic impedance with Temperature

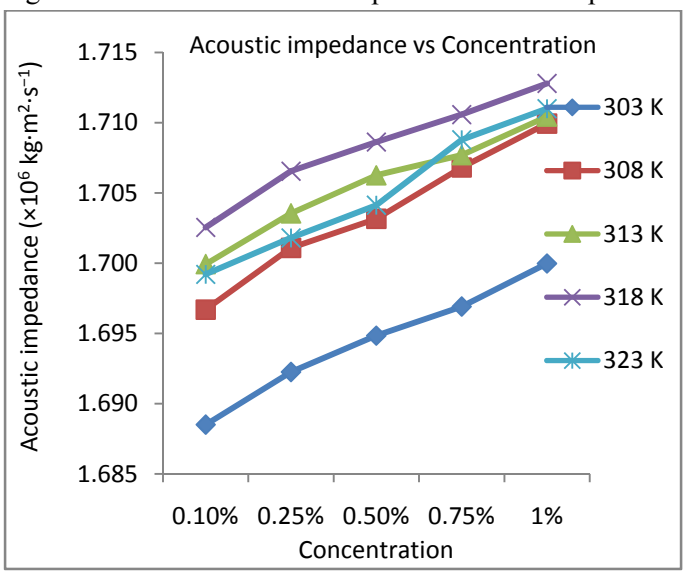

Fig.-2 Variation of acoustic impedance with concentration.

Fig. 4 plots adiabatic compressibility versus concentration. It is observed that adiabatic compressibility (β) decreases with increase in concentration (vol. %) of dextran in glycine indicating strong intermolecular interaction between dextran in glycine. This also shows associating tendency of solute and solvent molecules. This is because of the fact that dipole-dipole interaction of pure dextran in glycine. Adiabatic compressibility (β) decreases with increase in temperature.This decrease may be due to (i) an increase in the number of incompressible molecule. (ii) Structural changes occurring in the solution.

This may be due to the association taking place between the molecules. When the temperatureincreases, the associated groups of molecules breakdown increasingly [13] and the force of attraction between the molecules decrease. This leads to an increase in the adiabatic compressibility of the system at higher temperature 323 K.

Table 2 Values of adiabatic compressibility and acoustic impedanceat different temperatures and different concentrations of dextran in 2(M) glycineat 5MHz frequency.

T (kelvin)	Adiabatic Compressibility (β)(10-10N-1.m2)					Intermolecular free length (Lf) 10-10 m				
	0.10%	0.25%	0.50%	0.75%	1%	0.10%	0.25%	0.50%	0.75%	1%
303	3.6952	3.6829	3.6745	3.6683	3.6605	3.8140	3.8077	3.8033	3.8001	3.7961
308	3.6540	3.6406	3.6344	3.6216	3.6089	3.8256	3.8186	3.8154	3.8087	3.8020
313	3.6324	3.6224	3.6150	3.6103	3.6023	3.8472	3.8419	3.8380	3.8355	3.8312
318	3.6128	3.6027	3.5967	3.5898	3.5818	3.8696	3.8642	3.8610	3.8573	3.8530
323	3.6138	3.6055	3.5984	3.5870	3.5790	3.9030	3.8985	3.8946	3.8884	3.8841

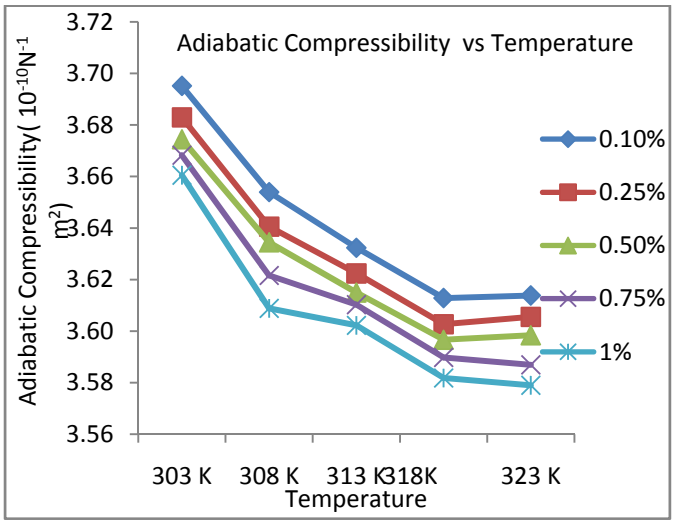

Fig.-3 Variation of Adiabatic Compressibility with Temperature

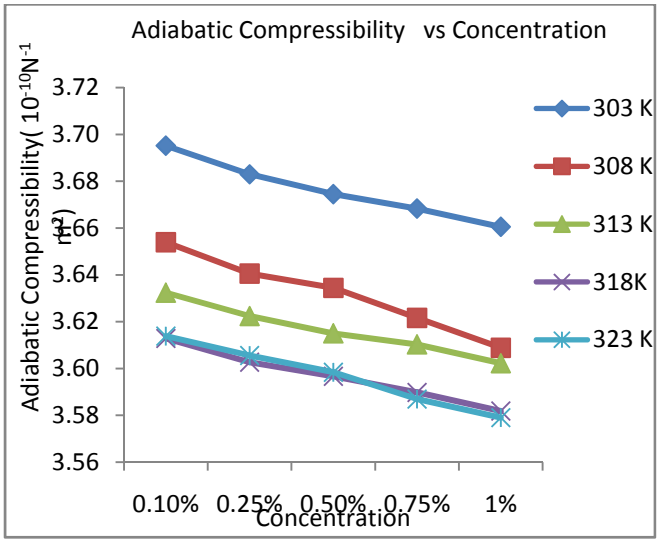

Fig.-4 Variation of Adiabatic Compressibility with Concentration

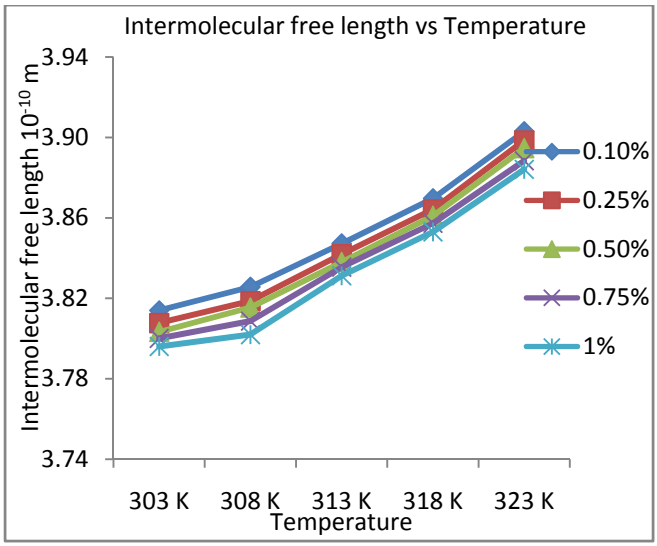

Fig.-5 Variation of Intermolecular free length with Temperature

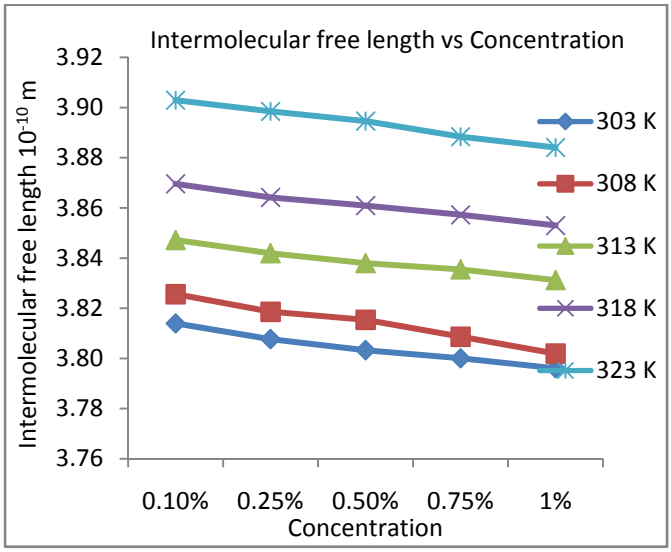

Fig.-6 Variation of Intermolecular free length with Concentration

Intermolecular free length (Lf) depends on the intermolecular attractive and repulsive forces. The attractive force depends on the distance between the centres of attraction of the molecules whereas the repulsive force depends on the distance between the surfaces of the molecule. Out of these two, distance between the surfaces of the molecule has a clear physical significance. As concentration increases, number of ions or particles increase in a given volume leading to decrease in the gap (intermolecular free length) between two species.

Also, the decreased compressibility brings the molecules to a closer packing resulting in decrease in intermolecular free length [14]. The variation of intermolecular free length with concentration is shown in Fig-6. Inter molecular free length increases(Fig.5) with increase in temperature as the temperature increases it leads to the less order structured and more spacing between the molecules due to increase in thermal energy of the system which increases in volume expansion and hence increase in inter molecular free length.

Table 3 Values of relaxation time and Gibb's free energy (ΔG) at different temperatures and concentrations of aqueous solution of dextran at 1MHz frequency.

T	Relaxation time (τ)(10-13Sec.)					Gibb's free energy(ΔG)10-20kJ·mol−1				
(kelvin)	0.10%	0.25%	0.50%	0.75%	1%	0.10%	0.25%	0.50%	0.75%	1%
303	5.3159	5.3651	5.5303	6.0321	6.1063	219.9825	221.6573	227.1655	242.9466	245.1677
308	4.6603	4.7825	4.9556	5.2507	5.3798	202.3266	207.1058	213.6735	224.3555	228.8435
313	4.2454	4.3477	4.6011	4.8601	5.0129	191.1365	195.6047	206.2362	216.5141	222.3211
318	3.8938	4.0573	4.3238	4.5632	4.5944	180.7276	188.5692	200.6993	210.9739	212.2737
323	3.5898	3.7296	3.9862	4.0986	4.1296	170.8440	178.2435	191.1330	196.5153	197.9779

With increase in temperature excitation energy increases and hence relaxation time decreases. Increase in relaxation time with increase in concentration indicates that the solution is highly ordered due to excellent hydration. The variation of relaxation time with temperature and concentration is plotted in figure 7 & 8 respectively.

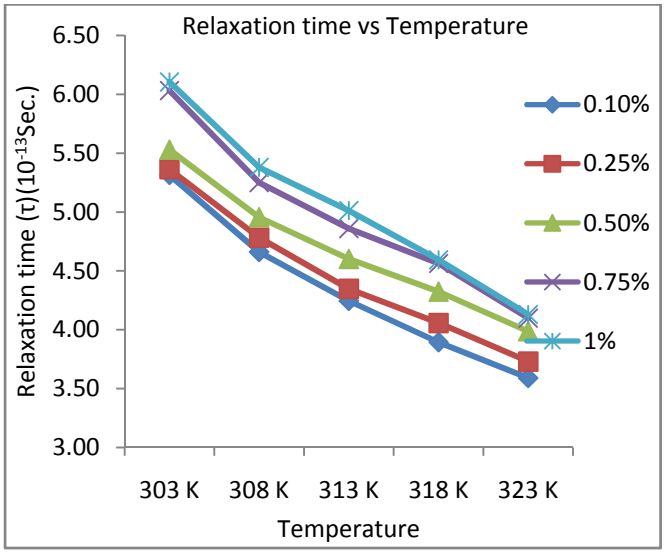

Fig.-7 Variation of Relaxation time with Temperature

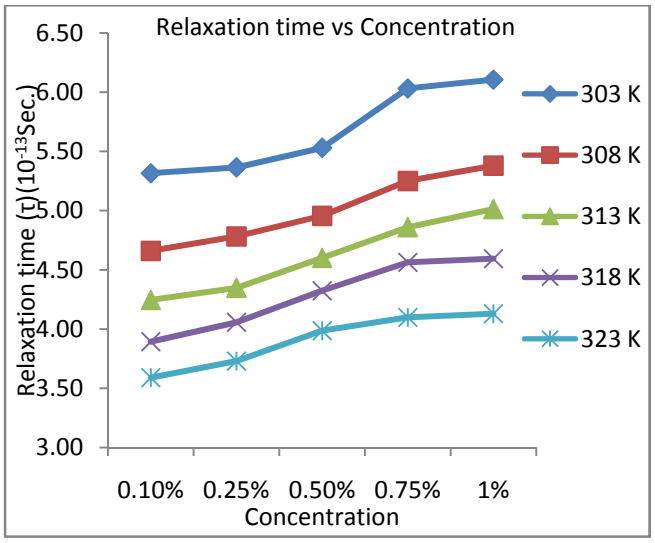

Fig.-8 Variation of Relaxation time with Concentration

Gibbs free energy increases with increase in concentration of dextran (Fig.10). Increasing value of Gibbs free energy suggests that the closer approach of unlike molecules due to hydrogen bonding [15].The increase in Gibb's free energy with concentration suggests shorter time for rearrangement of the solute molecules in the solution.

Viscous relaxation time and Gibbs free energy both decrease as temperature increases as shown Fig.7 & fig.9 respectively. Further as the temperature increases, kinetic energy of the molecule increases, so it takes long time for rearrangement of molecule and this suggests a decrease in Gibb's free energy.

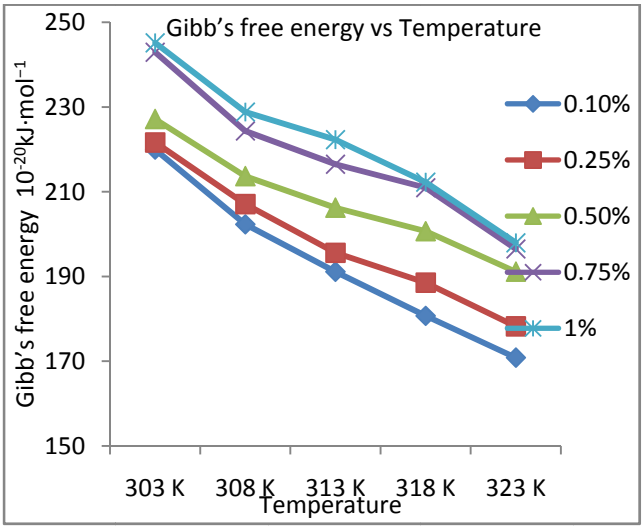

Fig.-9 Variation of Gibb's free energy with Temperature

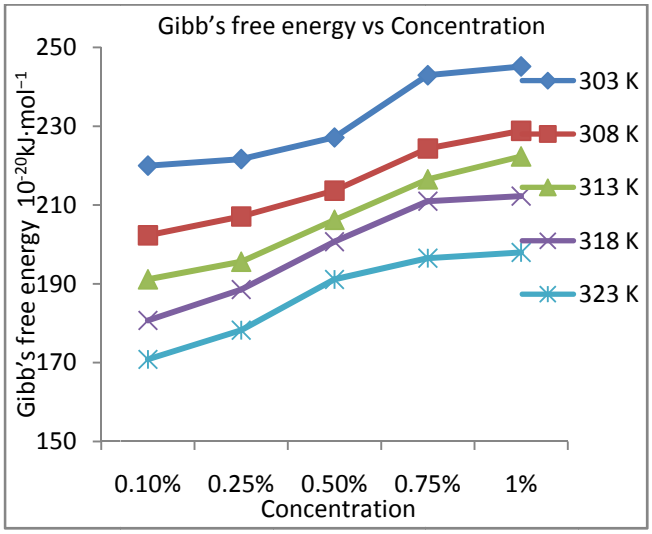

Fig.-10 Variation of Gibb's free energy with Concentration

Conclusion

From the experimental measured parameters(i.e. density, viscosity and ultrasonic velocity) of dextran solution in 2(M) glycine at different concentrations and temperatures, thermo-acoustic parameters like acoustic impedance (Z), adiabatic compressibility (β), intermolecular free length(Lf) ,relaxation time (τ), Gibb's free energy (ΔG), have been calculated at 5MHz frequency .The results show that the specific solute-solvent interactions play an important role for explaining acoustic parameters. However any deviation from the usual behaviour is due to characteristic structural changes in the respective system.

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