

# Ultrasonic Studies of Intermolecular Interactions of Dextrose and Fructose in Alcoholic Medium at Three Different Temperatures

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**Abstract:** Ultrasonic velocity, density and viscosity have been measured experimentally of alcoholic solution of dextrose and fructose at three different temperatures (298.15, 303.15 and 308.15K) over the entire composition range. The thermodynamic and other parameters like adiabatic compressibility, free length, internal pressure, Gibb's free energy and enthalpy etc. have been worked out. These parameters are analyzed in the light of bonding and non-bonding intermolecular interactions, as well as the effect of temperature, ring size, equatorial and axial hydroxyl group, aliphatic cyclic and acyclic hydroxyl group, solvent medium on solute (dextrose and fructose) and stereo specificity.

**Keywords:** Ultrasonic velocity, alcoholic solution, compressibility, internal pressure, free volume, dextrose stereo specificity.

## 1. Introduction

The study of inter molecular interactions play an important role in the development of molecular sciences. A wide study has been made on the molecular interaction in liquid system by various spectroscopic methods [1]. Ultrasonic investigation provides wide application in characterizing thermodynamic and physicochemical behavior of liquid mixture [2]. These acoustical parameters grant qualitative information about physical nature and strength of molecular interaction in liquid mixtures. During the last two decades the ultrasonic study of the carbohydrates in aqueous electrolytic medium, has gained much importance in assessing the nature of molecular interaction present in the mixture. The study of the carbohydrates or saccharides has become a subjects of growing interest because of multidimensional, physical, biochemical and scientifically useful molecules [3-6]. Due to composite molecular structure of polysaccharides, straight study is difficult. Therefore, the useful approach is to study simpler form compounds, such as Dextrose and Fructose which are building blocks of polysaccharides. Most of the studies on carbohydrates have been carried out in pure and mixed solvent [7-9].

Most of the studies have been done concerning to the intermolecular interaction of carbohydrates in electrolytes and non electrolytes medium. But in our present work, not only considered the molecular interaction in ethanol-water medium but also the stereo specific relationships among them. These are very important biological molecules. The studies of these molecules in alcoholic aqueous medium are very important for biomolecular recognition and medicinal use.

## 2. Experimental

The solutions of Dextrose and Fructose were prepared by dilution method in 10% ethanol-water solution. All the

chemicals are of AR grades of 99.99 % purity. Composition range of each substance is from 0.1 M to 0.9M. The ultrasonic velocity in the liquid mixtures have been measured by means of ultrasonic interferometer (Mittal type: Model: M-83) functioning at frequency 2MHz with an overall accuracy of  $\pm 0.1$  m/s, an electronically digital operate constant temperature water bath has been used to flow water through the double walled measuring cell, made up of a steel containing the experimental solution at the preferred temperature. For weighing, an electronic digital balance having an accuracy of  $\pm 0.1$  mg was used. An Ostwald's viscometer was used for the measurement of viscosity of liquid mixtures with an accuracy of 0.0001Nsm<sup>2</sup>. The viscometer was calibrated before used. Time flow of water and liquid solutions were measured. Densities were determined using specific gravity bottle by relative measurement method with accuracy of  $\pm 0.1$  kg.m<sup>-3</sup>.

### Theory

**Adiabatic compressibility** can be determined from speed of sound (U) and density ( $\rho$ ) of the measurement.

$$\beta = 1/U^2\rho$$

**Intermolecular free length** can be determined as:

$$L_f = K \beta^{1/2}$$

Where, K values from different temperatures were taken from the work of Jacobson.

**Internal pressure** ( $\pi_i$ ) can be calculated by expression.

$$\pi_i = bRT (K\eta/u)^{1/2} (\rho^{2/3}/M)^{7/6} \text{ Nm}^{-2}$$

Where R is the gas constant, M is the effective molecular weight,  $\rho$  is the density, u is the velocity of sound, T is the temperature,  $\eta$  is the viscosity and K is the temperature independent constant.

Gibb's free energy ( $\Delta G$ ) can be calculated from the following relation:

$$\Delta G = KT \log (KT\tau/h)$$

Where,  $\tau$  is relaxation time,  $K$  is Boltzmann constant,  $T$  is absolute temperature and  $h$  is Plank's constant

### 3. Result and Discussion:

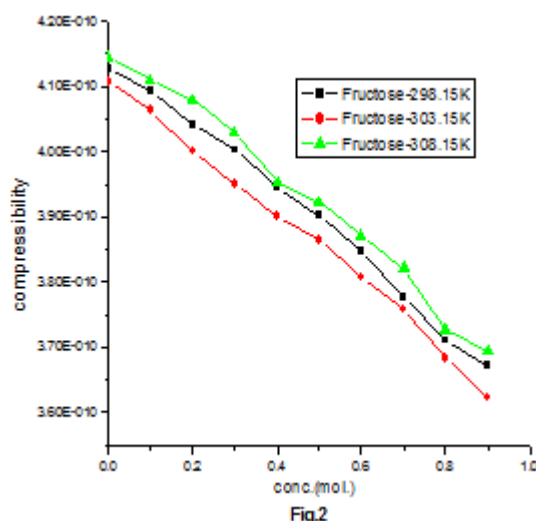
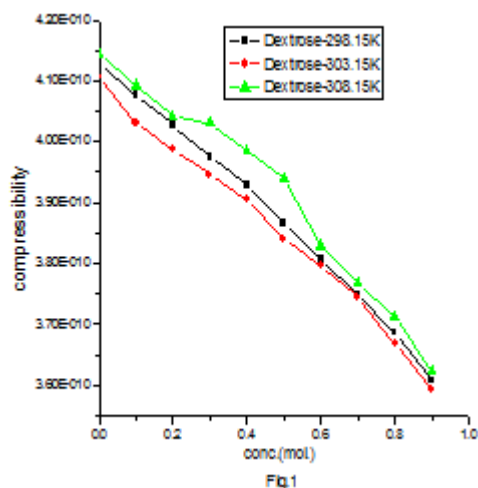
A measure of how strongly molecules are held in liquid mixtures is their Ultrasonic velocity, viscosity, density and their derived parameters such as adiabatic compressibility, free length internal pressure, Gibb's free energy and enthalpy. These are considered to be very important thermodynamic parameters. These parameters give information about how closed the liquid molecules are held, freedom of motion, the amount of empty space in liquid mixture, bulk properties of mixture (melting point, boiling point, solubility and fractional distillation), what types of forces (dipole-dipole, ion-dipole, ion-induced dipole and dipole-induced dipole) in liquid molecules exist. Of these some parameters are directly and some are inversely related to the strength of intermolecular forces that exist in liquid mixtures. Intermolecular forces may be long range or short range forces. Long range forces are dispersion forces and electrostatic induction. They occur when molecules come close together causing a significant overlap of electron density having a specific geometry [10].

**Graph 1-10** shows the plot of adiabatic compressibility, free length internal pressure, Gibb's free energy and enthalpy versus concentration at 2MHz and 298.15K, 303.15K and 308.15K temperature of dextrose and fructose. From **figures 1 & 2**, it is observed that adiabatic compressibility decreased with increased in concentrations for both systems of monosaccharide's indicating association in component molecules. Generally it is observed that compressibility is directly related to the temperature but in our systems, at 303.15 K compressibility decreased. This is very interesting result. It may be due to strong association of solute and solvent molecules. From **figure 3 & 4** it is observed that free length decreases with increase in concentration for both the systems indicating association in a component molecules. From **figure 5 & 6** it is observed that internal pressure decreases with increase in concentration represents the strong association of the mixture molecules. From **figure 7 & 8**, it is observed that Gibb's free energy ( $\Delta G$ ) increases with increase in concentration. This indicates that solution is highly ordered due to strong association among the solute and solvent molecules. From **figure 9 & 10**, it is observed that enthalpy decreased with increase in concentration suggest that solute and solvent molecules are strongly associated. Lower the values of enthalpy more would be the salvation and strong will be the molecular interaction among the constituent molecules.

This behavior suggests the formation of more compact structure, possible due to dipole-dipole interaction (hydrogen bonding) at the sites on the hydroxyl group (OH) of solute and water molecules. The association in constituent molecules may involve due to hydrogen bonding or dipole-dipole interaction among the constituent molecules. All these process may lead to strong solute-solvent interactions

It is known that the hydration of carbohydrates depends on the percentage of axial and equatorial hydroxyl groups. It is more favorable when the hydroxyl group is at the equatorial position [11]. It seems that hydration of equatorial -OH groups is more compact having lower entropy compared with water at normal temperature. The water around axial -OH groups seems to be less compact hence should have higher entropy. Glucose has more percentage of equatorial -OH group, would be strongly hydrated as compared to fructose. But result shows that the trend of hydration is dextrose < fructose. This can be explained that glucose is present as a pyranose ring and fructose as furanose ring which has also five -OH groups but out of these five, two are attached to -CH<sub>2</sub> groups and not to the ring. It is known that the interactions between open chain aliphatic -OH groups and water are more extensive than cyclic compounds with water [12]. Hence fructose is slightly more hydrated than dextrose.

### 4. Graphical Representation:



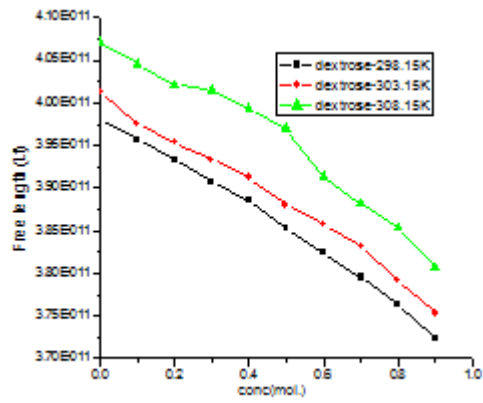


Fig.3

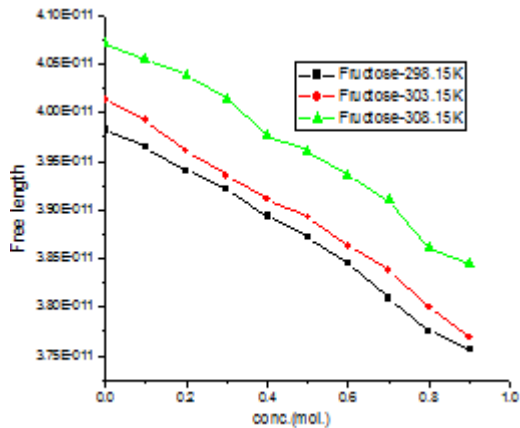


Fig.4

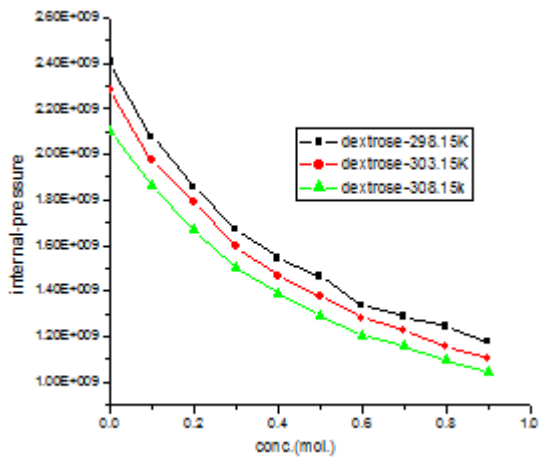


Fig.5

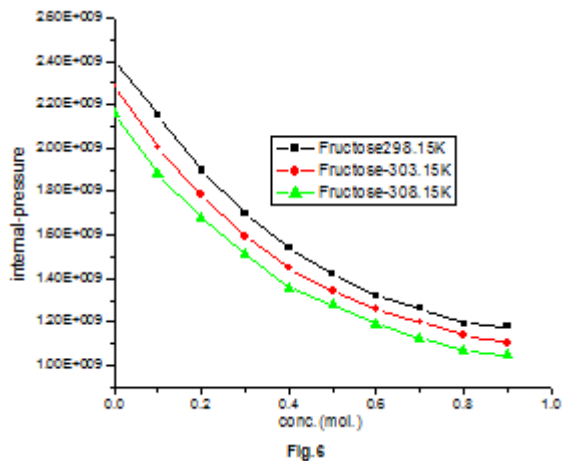


Fig.6

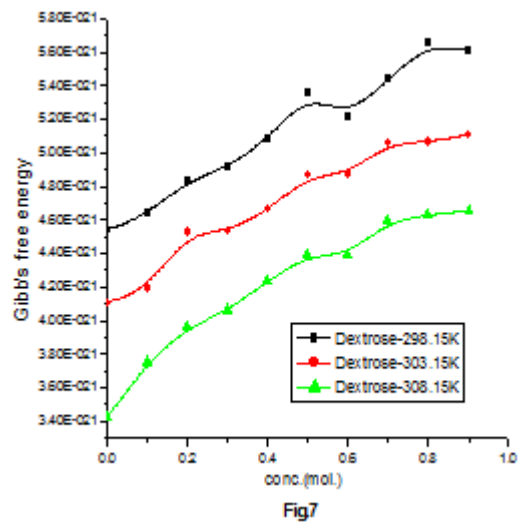


Fig.7

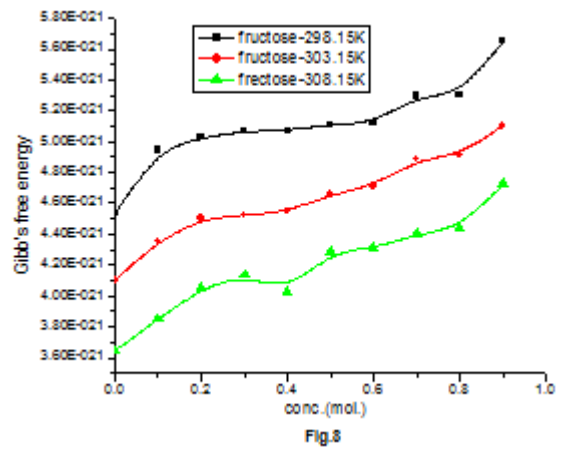


Fig.8

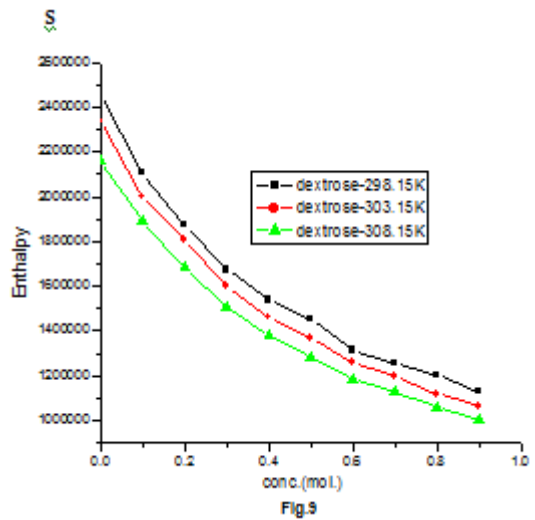


Fig.9

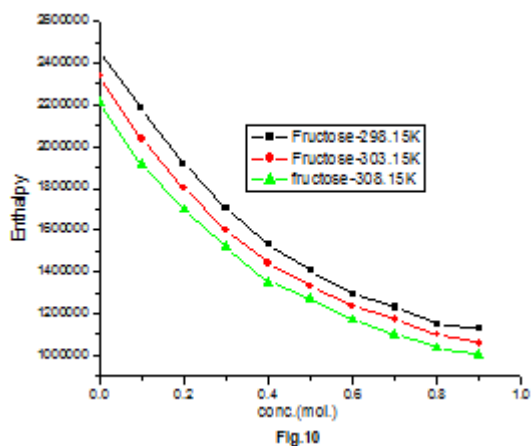


Fig.10

## 5. Conclusions

Intermolecular interactions of sugars with alcoholic-water mixture depend on the position (equatorial or axial) of –OH groups, cyclic and acyclic nature –OH groups and number of –OH groups in the molecules as well as temperature of medium. It is also conclude that specific configuration of sugar molecules play important role in hydration processes as presented in present work on basis of useful thermodynamic parameters.

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