UNDERSTANDING STRUCTURE OF WATER BY ULTRASONIC MEASUREMENTS IN AQUEOUS AND 10% ETHANOL-WATER SOLUTIONS OF FRUCTOSE AT THREE DIFFERENT TEMPERATURES

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A B S T R A C T

Ultrasonic velocity (U) and density have been measured experimentally for aqueous solution of fructose and 10% ethanol-water solutions at concentration range(0.1M-0.9M) and at temperatures (298, 303 and 308K).The acoustic parameter such as adiabatic compressibility(β)has been worked out. The results are correlated in terms of structure of water described to the cage like structures of water and secondary molecular interaction between the solute and solvent molecules of the medium

Keywords: Ultrasonic velocity, Adiabatic compressibility, fructose, Ethanol-water

1. Introduction

Ultrasonic velocity of pure liquids and liquid mixtures are basically correlated to the secondary forces (hydrogen bonding, Vander Waal's forces and dispersion forces) between molecules and atoms [1]. Ultrasound analysis provides extensive applications in characterizing thermodynamic and physiochemical behavior of liquid mixture[2]. The study of the carbohydrates or saccharides has become a subject of growing curiosity because of multidimensional, physical, biochemical and scientifically used molecule[3-6]. The ultrasonic velocity in a liquid is basically related to the binding forces between the atoms or molecules and has been effectively employed in understanding the nature of molecular interactions in pure liquids and binary and ternary mixtures[7-9]. Carbohydrates displayed on the surface of cells play critical roles in cell-cell recognition, adhesion, signaling between cells, and as markers for disease progression. Neural cells use carbohydrates to facilitate development and regeneration[10]. Viruses identify carbohydrates to get entry into host cells[11]; and bacteria attach to carbohydrates for host cell adhesion[12]. Recognition of the specific saccharides involved in these processes is important to better understand cell-cell recognition at the molecular level and to assist the design of therapeutic and diagnostic tools.

2. Experimental

The solutions of fructose were prepared by dilution method. All the chemicals are of AR grades of 99.99 % purity. Composition range of Fructose is from 0.1 M to 0.9M in aqueous and in 10% ethanol-water solvent systems. The ultrasonic velocity in the liquid mixtures have been measured by means of ultrasonic interferometer (Mittal type: Model: M-83) functioning at frequency 3MHz with an overall accuracy of ±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 with an accuracy of ±0.1 mg was used. Densities were measured

using specific gravity bottle method with an accuracy of ±0.1 $kg.m^{-3.}$

3. Result and Discussion

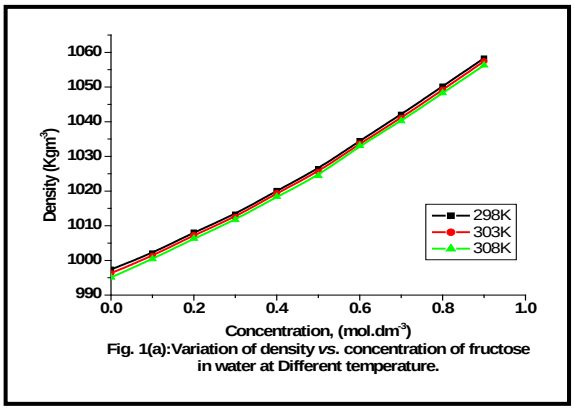

Fig. 1(a):Variation of density *vs.* concentration of fructose in water at Different temperature.

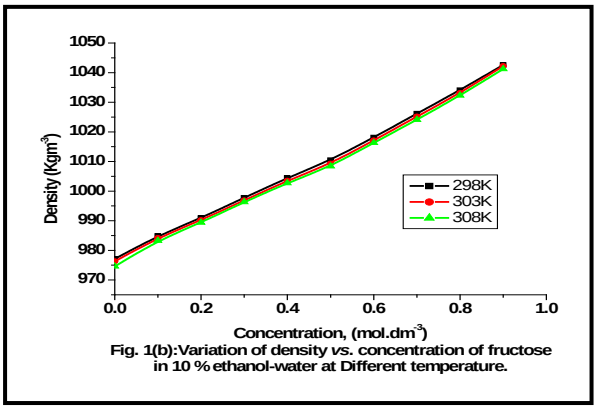

Fig. 1(b):Variation of density *vs.* concentration of fructose in 10 % ethanol-water at Different temperature.

Density:

From Figs.1(a) and 1(b), it is observed that the density of aqueous and 10% ethanol-water solution of fructose is found to enhance with increase in concentration of solute. Density of aqueous and 10% ethanol-water solution of fructose is found to decrease with increase in temperature. As the temperature increased, kinetic energy of the molecules increased[13]. And gap among the components of the system increases and this leads to decrease the number of molecules per unit volume and hence density of the solution.

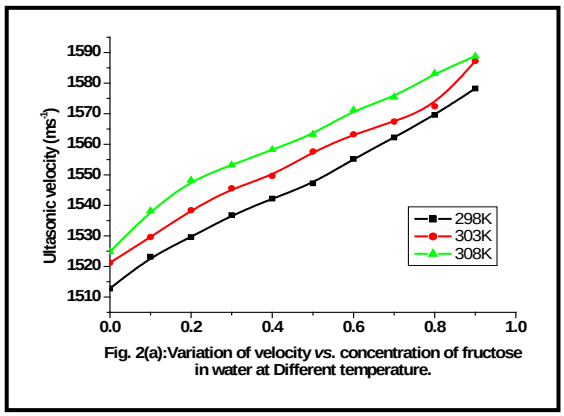

Fig. 2(a):Variation of velocity *vs.* concentration of fructose in water at Different temperature.

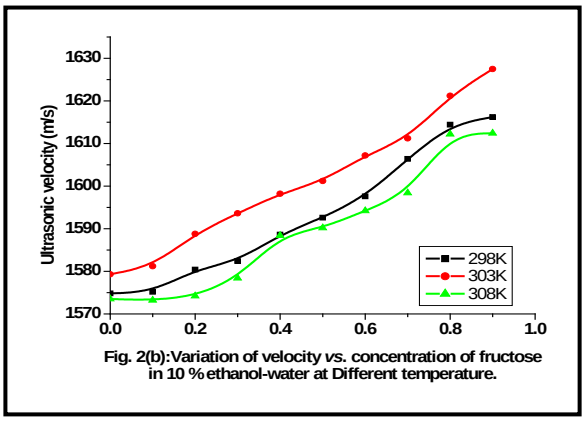

Fig. 2(b):Variation of velocity *vs.* concentration of fructose in 10 % ethanol-water at Different temperature.

Ultrasonic velocity:

From Figs. 2(a) and 2(b), it is found that the value of ultrasonic velocity for aqueous and10% ethanol-water solution of fructose is found to increase with increase in concentration of fructose. It can be observed that the velocity of ultrasound is found to increase with increase in solute concentration. As concentration of solute increases, the number of the molecules in the solution increases. This makes the medium denser and leads to the lesser compressibility and hence the ultrasonic velocity increases[14]. The increase in ultrasonic velocity in any solution implies the better association among the components of the solution. The better association may be due to the intermolecular hydrogen bonding and dispersion forces between solute and solvent molecules.

It is observed from Figs. 1.1(b), velocity of ultrasound is found to increase with increase in temperature for both the solvent systems. This might be due to formation of cage like structures of water. As temperature increases, the hydrogen bonds among water molecules detach and more monomers of water molecules are formed. These free water molecules go into the vacant space present in the cage like water structures and thus get 'trapped'. As a consequence, the number of close-packed water structures increases with the increased in temperature. This increase in close-packed water structures forms the rigid material medium for the propagation of ultrasonic waves[15]. Thus, the ultrasonic velocity increases

with the increase in temperature for pure water as well as for aqueous solutions of fructose.

It is observed from Figs. 1.2(b), for 10% ethanol-water solution of fructose, ultrasound velocity is found to reduce with raise in temperature. In this solvent system, water and ethanol molecules freed from complex clusters at 308K. The dissociation speed of ethanol and water molecules in this temperature range (298-303K) may be lesser and it may be better at 308K. Percentage of dissociation of ethanol molecules may be greater than water molecules due to higher dipole moment and dielectric constant of water. Its association with solute and with themselves is stronger than ethanol molecules. Hence, number of ethanol molecules freed may be larger. The freed ethanol molecules can't go into the empty space of cage like water structures due to bigger molecular size as compare to water molecule. Thus, medium become loosely packed. Hence, the speed of ultrasound dropped in 10% ethanol-water solvent system at higher temperature (308K).

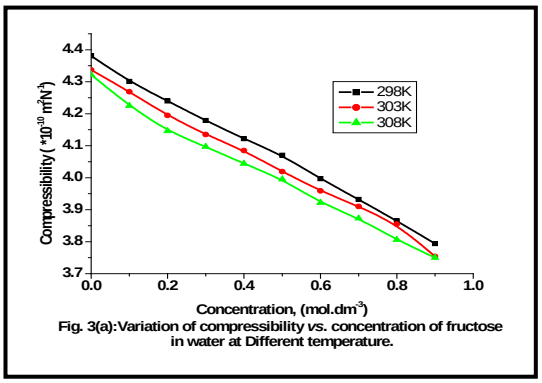

Fig. 3(a):Variation of compressibility *vs.* concentration of fructose in water at Different temperature.

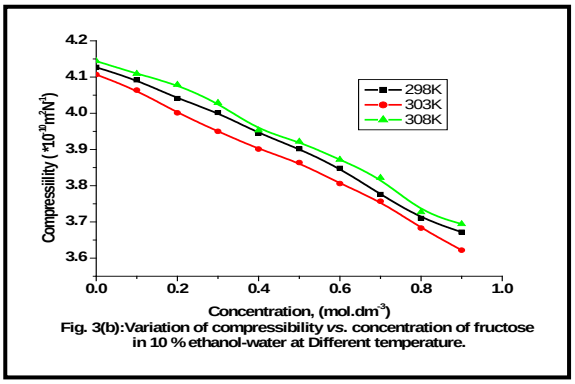

Fig. 3(b):Variation of compressibility *vs.* concentration of fructose in 10 % ethanol-water at Different temperature.

Adiabatic compressibility:

From Figs. 1.1 and 1.2(c) it is observed that decrease in compressibility implies that there is enhanced molecular association in this system upon addition of fructose and less available free space between the components of the solution[16]. The new complexes formed due to molecular organization turn out to be more compact and less compressible. These also recommend that the compressibility of the solution is less than that of solvent. The degree of compressibility depends on the electrostriction

As temperature increases of fructose solution, compressibility is found to decrease. Compressibility decreases with increase with temperature from 298K to 303K. At 308K, compressibility increases. As described earlier concerning the speed of sound, as the temperature increases, speed of ultrasound increases and compressibility is inversely related to the speed of sound[17-18]. Hence, compressibility of solution at high temperature decreased. In 10% ethanol-water system, compressibility increases at 308K.

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