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Investigation of Thermo-Acoustic Properties of Water-1-Propanolbinary Mixture at Different Temperatures

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ABSTRACT

Ultrasonic velocity, density and viscosity have been measured using Anton Paar DSA 5000 M in the binary mixtures of 1-Propanol with water at various mole fractions from 0.1 to 0.9 with temperature ranging from 288K to 318K. Various derived parameters like adiabatic compressibility, acoustic impedance, free length and relaxation time have been calculated using standard formulae. Non covalent interaction taking place in the liquid mixture has been discussed on the basis of the values obtained from experimental parameters and derived parameters.

Keywords : Binary Liquid Mixtures, Ultrasonic Velocity, Density, Viscosity, Adiabatic Compressibility, Acoustic Impedance, Relaxation Time, Free Length, Intermolecular Interactions.

I. INTRODUCTION

The knowledge of the structure and molecular interactions of liquid mixtures is very important from fundamental and engineering point of view. Fundamental thermodynamic and thermo-acoustic properties are essential sources of information necessary for a better understanding of the non-ideal behavior of complex systems because of physical and chemical effects, which are caused by molecular interactions, intermolecular forces, *etc.*, of unlike molecules. From a practical point of view, these properties are necessary for the development of thermodynamic models required in adequate and optimized processes of the chemical, petrochemical, pharmaceutical, food processing, drugs industries, paint industries, fluid mechanicsetc.[1,2]. In the recent years much important has been given to the behavior of mixed components rather than the single component because of their widespread range of applications. Thermodynamic properties derived from the measurement of ultrasonic velocities, densities and viscosities for binary mixtures are useful in understanding the nature and type of intermolecular interactions present between the constituent molecules. In chemical process industries, materials are normally handled in fluid form and as a consequence, the physical, chemical and transport properties of fluids, assume importance. Thus, data on some of the properties associated with the liquids and liquid mixtures like ultrasonic velocity, viscosity and density invention extensive application in solution theory models and molecular dynamics[3,4].

Properties of liquid–liquid mixtures are thermodynamically very important as part of studies

of the thermodynamic, acoustic and transport aspects. The compositional dependence of thermodynamic properties has proved to be very useful tool in understanding the nature and extent of pattern of molecular aggregation resulting from intermolecular interaction between components. Molecular interaction in liquid mixtures has been extensively studied using ultrasonic technique by many workers. The thermodynamic and acoustic properties are very essential for understanding the physicochemical behavior of the binary adult-component liquid mixtures[5].Ultrasonic velocity of sound waves in a medium is fundamentally related to the binding forces between the molecules. Ultrasonic velocities of the liquid mixtures consisting of polar and non-polar components are of considerable importance in understanding intermolecular interaction between components molecules and find application in several industrial and technological processes. Ultrasonic velocity measurements have been employed extensively to detect and assess weak and strong molecular interactions in binary mixtures[6,7]. Acoustical and thermo dynamical study of liquid mixtures provide enough knowledge about the association of molecular packing, molecular motion and strength of intermolecular interactions. Thermodynamic and acoustical properties such as adiabatic compressibility, intermolecular free length, internal pressure, acoustic impedance, relaxation time, molar volume, classical absorption and surface tension are calculated from measured ultrasonic velocity, density and viscosity for binary mixtures and they are very much helpful to interpret nature and type of intermolecular interactions between the component molecules[8,9,10].

Using the measured values of sound velocity (u) and density (r), the thermodynamic parameters such as isentropic compressibility (KS) and intermolecular free length (Fl) can be computed. The intermolecular free length (Lf) is an important physical property of liquid mixtures which mainly affects the sound velocity[11,12].

Binary liquid mixtures due to their unusual behavior have attracted considerable attention. In chemical process industries, the materials are normally handled in liquid form and as a consequence, the physical chemical, and transport properties of fluids assume importance. Thus, data on some of the properties associated with the liquids and liquid mixtures like density, viscosity and ultrasonic velocity, to find extensive application in solution theory and molecular dynamics. Such results are necessary for interpretation of data obtained from thermo chemical, electrochemical, biochemical and kinetic studies[13, 14,.

II. METHODS AND MATERIAL

The chemical1-propanol used in present work was procured from LobaChemie Pvt. Ltd., Palghar (INDIA) with assay of 99.5% and distilled water used was three times distilled (tripple distilled). 1-propanol was of AR (HPLC) grade and used without further purification. The instrument used for measurements of density, viscosity and ultrasonic velocity was Anton Paar DSA 5000 M having range, up to 3g/cc with 0.000007 g/cc accuracy for density, 1000 to 2000 m/s with 0.01 m/s accuracy for ultrasonic velocity, 0.2 to 30,000 mm^2/s range for viscosity with 0.1% accuracy and temperature range from 0^0C to 100^0C with repeatability of 0.001^0C.

Literature survey showed that measurements have been previously reported for the 1-propanol-Water binary mixture at limited range of temperature. The objective of the present investigation was to find out the density (ρ), viscosity (η) and ultrasonic velocity (U) for the binary system constituted by these components at 288K, 293K, 298K, 303K, 308K, 313K and 318K over the concentration range of 0.1 to 0.9 mole fraction. The experimental values were used to calculate adiabatic compressibility (βa), acoustic impedance (Z), relaxation time (τ) and free length (Lf)

over the entire mole fraction range for the binary mixtures. The results are discussed in terms of the molecular interactions.

III. THEORY AND CALCULATIONS

The various acoustical parameters computed from experimental parameters using the following relations,

Adiabatic compressibility(βa)	$\beta a=1/(U^2\rho)$
Acoustic Impedance (Z)	$Z=\rho U$
Relaxation Time (Sec) (τ)	$\tau=(4/3)\eta\beta a$
Free Length (Lf)	$Lf=K^*\sqrt{\beta a}$,

Where K is the temperature independent Jacobson's constant

The evaluation of theoretical values of ultrasonic velocity, viscosity and density in binary mixture those obtained experimentally in the binary mixture is expected to interpret the nature of interaction between components of the mixture. Such theoretical study is useful in the wide-ranging theoretical modeling for the liquid mixtures[3].

IV. RESULTS AND DISCUSSION

1. Density is defined as mass per unit volume. In our present system, density decreases with increase in concentration of 1-propanol. It indicates water has greater density than 1-propanol. Initially water has higher concentration and having compact structure than 1-propanol due to strong hydrogen bonding compared to 1-propanol. At higher concentration of 1-propanol, concentration of water diminishes and 1-propanol shows the predominance in the solution. It has smaller dipole moment compared to water and also has long carbon chain. Hence density decreases with increase in composition of 1-propanol.

As the temperature increases the translational, rotational and vibrational energy of components in the given mixture increases. Due to increase in energy the compactness of the solution decreases and more volume occupied by same number of molecules in the given mixture. Hence, density of the system decreases with increase in temperature. Above system shows same variation with temperature[15,16].

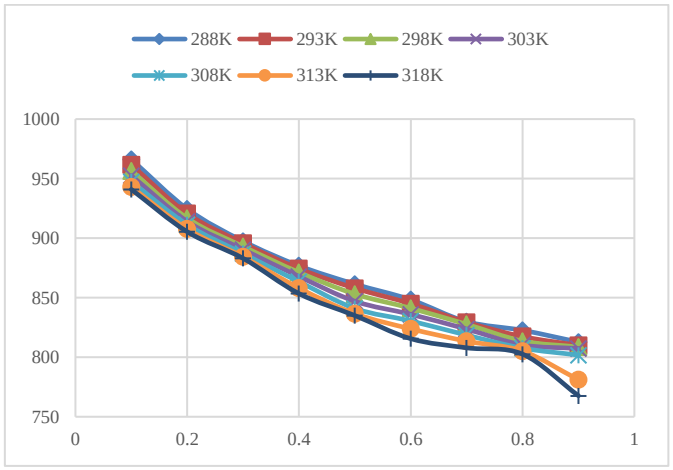

Fig. 1- Concentration Vs Density

2. Viscosity depends on compact structure of the medium. If there is a strong interaction of Van der Waal forcesand hydrogen bonding, system has greater viscosity and vice versa. In our present system, viscosity increases with increase in concentration of 1-propanol up to 0.4 mol fraction then viscosity slightly decreases up to end. Even though water forms strong hydrogen bonding but its viscosity is lesser than 1-propanol. It may be due to the size of 1-propanol. Greater the size of molecule, greater will be its polarizability. Higher the polarizability, higher will be the Van der Waal forces of attraction. It will contribute to increase in viscosity. 1-propanol also forms hydrogen bonding hence viscosity of 1-propanol is higher as compared to water. Higher viscosity up to concentration of 0.4 mol fraction may be due to hydrogen bond formation by 1-propanol with water is stronger than 1-propanol with itself.

As the temperature increases the translational, rotational and vibrational energy of components in the given mixture increases resulting in weakening of Van der Waal forces and hydrogen bonding. Hence, viscosity of the system decreases with increase in temperature. Above system shows same variation with temperature[17,18].

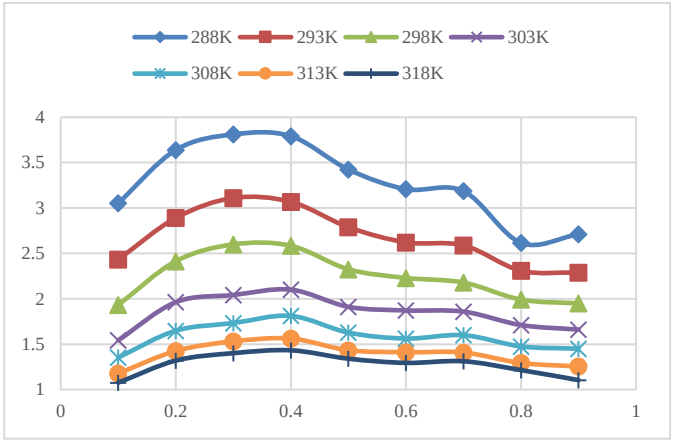

Fig. 2- Concentration Vs Viscosity

3. Ultrasonic velocity depends on stiffness of the medium. Stiffness of the medium not only depends on strong interaction of Van der Waal forces and hydrogen bonding but also on the compact structure of medium. As the stiffness of the system increases, ultrasonic velocity also increases. In our present system, ultrasonic velocity decreases with increase in concentration of 1-propanol.1-propanol has the capacity to form hydrogen bonding as well as Van der Waal forces but due to its bigger size, it will not form compact structure as like in water. Hence ultrasonic velocity decreases with increase in concentration of 1-propanol.

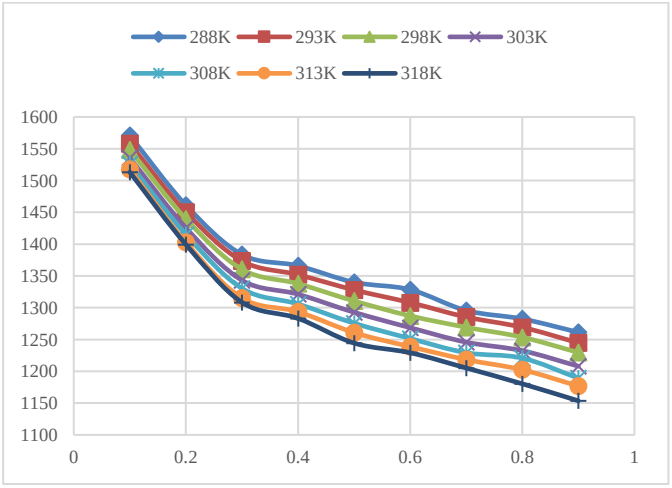

Fig. 3- Concentration Vs Ultrasonic Velocity

As the temperature increases the translational, rotational and vibrational energy of components in the given mixture increases resulting in weakening of Van der Waal forces and hydrogen bonding leading to reduce the stiffness of the medium. Hence, ultrasonic velocity of the system decreases with increase in temperature[19-21].

4. Adiabatic compressibility of gases is higher than liquids and liquids has greater compressibility than solids. Compressibility is directly proportional to the compactness of the medium.

In our present system, adiabatic compressibility increases with increase in concentration of 1-propanol. 1-propanol has the capacity to form hydrogen bonding as well as Van der Waal forces but due to its bigger size, it will not form compact structure as like in water. Hence Adiabatic compressibility increases with increase in concentration of 1-propanol.

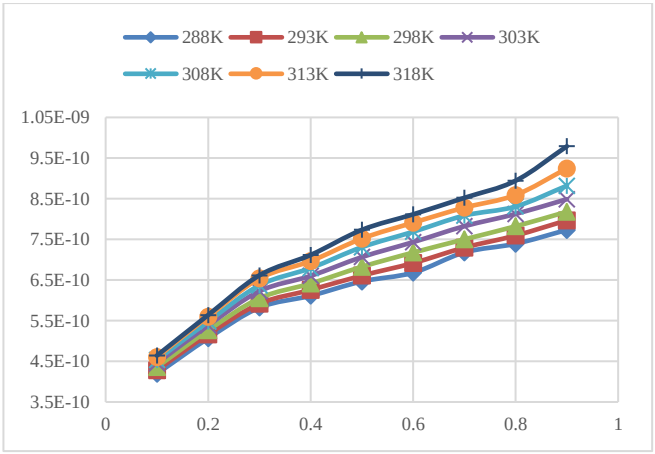

Fig. 4 - Concentration Vs Adiabatic Compressibility

As the temperature increases the kinetic energy of components in the given mixture increases which leads to weakening of Van der Waal forces and hydrogen bonding and reduces the compactness of the structure of the medium. Hence, adiabatic compressibility of the system increases with increase in temperature[22-24].

5. Acoustic impedance depends on density and ultrasonic velocity of the medium. Density depends on molecular arrangement per unit volume and sound velocity depends on stiffness of the medium. As the concentration of 1-propanol increases, acoustic impedance decreases indicating decrease in stiffness of the medium.

As the temperature increases the kinetic energy of components in the given mixture increases which

leads to decrease in Van der Waal forces and hydrogen bonding and reduces the compactness of the structure of the medium. Hence, acoustic impedance of the system decreases with increase in temperature[25,26].

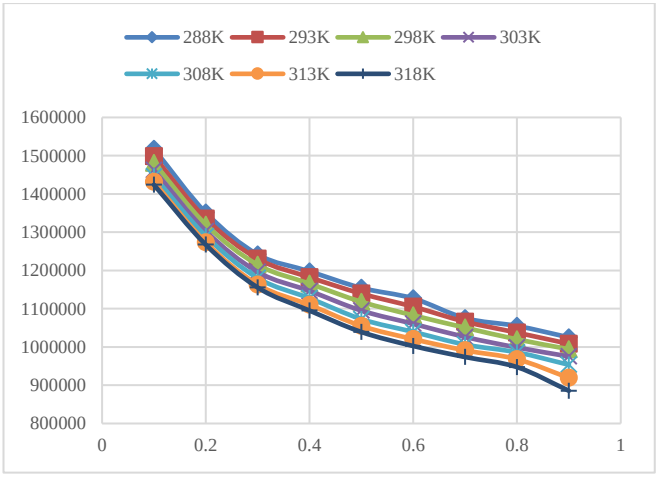

Fig. 5 - Concentration Vs Acoustic Impedance

6. Relaxation time depends mostly on viscosity of the medium. In our present system, viscosity increases with increase in concentration of 1-propanol. Hence relaxation time increases in accordance with concentration of 1-propanol.

The agitation in the system increases with increase in temperature resulting in the decrease in viscosity of the medium and hence the relaxation time[27,28].

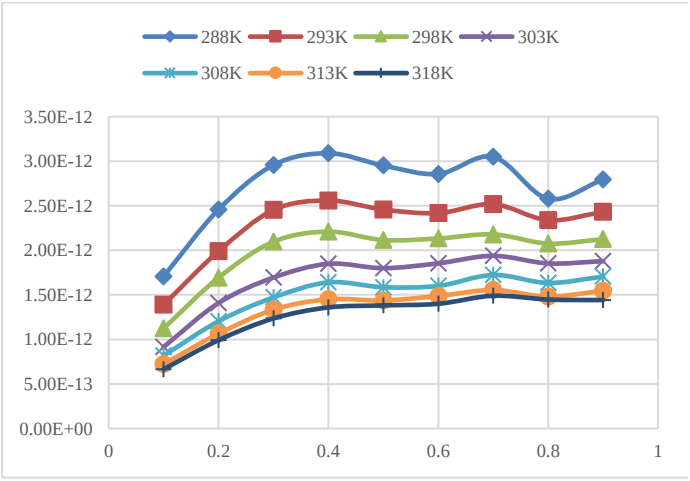

Fig. 6- Concentration Vs Relaxation Time

7. Free length depends on adiabatic compressibility and is directly proportional to its square root. So, in our present system free length is following the same order with increase in temperature and concentration of 1-propanol as the adiabatic compressibility does, indicating lack of compact structure in the system at higher concentrations and at high temperatures[29].

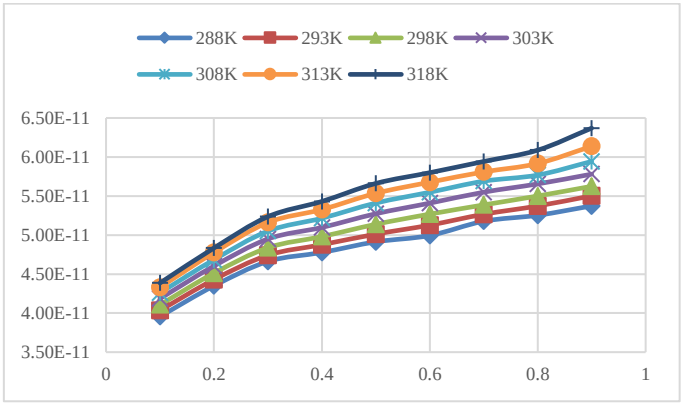

Fig. 7- Concentration Vs Free Length

V. CONCLUSION

It has been observed that the inter molecular interactions depends not only on Van-der-Waal forces and hydrogen bonding but also on the size of the molecules.

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