Estimation of Hydration Number and Apparent Molar Volume of Ternary Liquid Mixtures by Ultrasonic Studies at Different Temperatures

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ABSTRACT

In the development of molecular sciences, the studies of intermolecular interaction in binary and ternary mixtures of polar and non polar liquids play a key role. It also helps to understand the nature and behavior of solute in particular solvent. The ultrasonic velocity measurement is one of the most important and accurate technique to observe inside of the liquid mixtures. The ultrasonic velocity of liquid and liquid mixtures is fundamentally related to the attractive or repulsive forces between atoms or molecules in the system. Present study discusses about the experimental results of ultrasonic velocity (v), density (ρ) and viscosity (η) along with estimated parameters like hydration number, apparent molar volume (φ_v) for the ternary liquid mixture of sodium-2-hydroxy benzoate in 50% ethanol at 0.1M, 0.01M and 0.001M concentration range. The temperature range selected for all investigations is 298.15K, 303.15K and 308.15K. The thermo-acoustic studies are made on these liquid mixtures to access the intermolecular interactions in the liquid mixtures.

Keywords – Ultrasonic velocity, Molecular interactions, Molar cohesive energy, Apparent molar volume and molar hydration number.

I. INTRODUCTION

The ultrasonic technique is one of the simple and accurate method of analysis which is widely used in the study of liquid state[1]. Since last few decades, the ultrasonic technique is used to investigate hydration of various liquid mixtures because these properties are useful in the detection of the degree and nature of hydration[2]. In the dissolution of solute in the solvent, there are some factors studied like hydrogen bonding. One of the acoustic parameter which is important in detection of molecular interactions is the apparent molar volume. It is a simple and convenient tool for studying solute-solvent interactions in solutions[3]. The measurement of Ultrasonic velocity in liquid mixtures gives an idea about the compressibility of a fluid related to inter- and intra-molecular interactions. These parameters can be characterized with the variation of thermodynamic parameters such as temperature, pressure and volume[4]. When ultrasonic waves are passed through the solutions, these are affected by intra-molecular and inter-molecular association which is related to structural changes[5]. In the present study we passed the ultrasonic waves through the liquid mixture at different temperatures

and by using measured velocity, the values of molar hydration number (h), apparent molar volume (ϕv) and surface tensions are calculated. The results are interpreted at various concentrations and temperature ranging from 0.1M, 0.01M, 0.001M and 298.15K, 303.15K and 308.15K respectively. The results analyzed are presented in terms of solute-solvent, solvent – solvent interactions.

II. METHODS AND MATERIAL

Materials :

A.R. grade Sodium-2-hydroxy benzoate was used for study. Solutions were prepared by using distilled water. Weights have been taken on digital electronic balance. (Model-CB/CA/AT-Series).

Methods :

The measurements of ultrasonic velocity were carried out by using ultrasonic interferometer (Model-M-83). Mittal Enterprises, New Delhi) operating at 4MHz frequency with an accuracy of ±2m/s. The densities (ρ) were measured accurately using digital densitometer (Model - DMA-35, Anton Paar). Thermostat with continuous circulation of water was used to maintain constant temperature.

III. RESULTS AND DISCUSSION

The values of molar hydration number, apparent molar volume , surface tension are calculated from the measured values of ultrasonic velocity(v), density (ρ) by using standard formulae [6] and are given in **Table No. 1**

Apparent Molar Volume

$$\phi_v = [1000(d_o-d_s)/C.d_o]+(M/d_o) \quad ---------- 1$$

Where d_o – Density of solvent

D_o – Density of solution, C- Molar concentration

Molar Hydration Number

$$h = n_w/n_s[1-(\beta_s/\beta_o)] \quad -------------- 2$$

n_w – Number of moles of water, n_s – Number of moles of solute.

β_s – Adiabatic compressibility of solution.

β_o - Adiabatic compressibility of solvent.

Surface Tension

$$\sigma = 6.3 \times 10^{-4} \times V_s^{3/2} \times d_s \quad -----------------3$$

Molar Cohesive Energy

$$= \pi_i \times V_m \quad -----------------4$$

Table .1 : Molar hydration number, apparent molar volume (ϕv), Surface Tension (σ) and Molar Cohesive Energy of sodium-2-hydroxy benzoate in water.

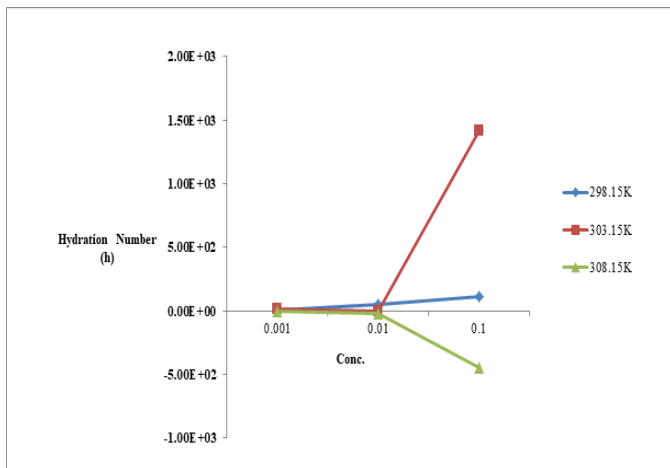| Sr.No.	Temperature (⁰K)	Concentration (M)	Apparent molar volume (ϕv) (m³/mole)	Molar hydration number (h)	Surface Tension (σ) Dynes/cm	Molar Cohesive Energy (πi×Vm) Lit.atm/mole
01		0.1	2.03E+02	5.32E+00	2.22E+02	5.59E+07
02	298.15K	0.01	2.05E+02	5.05E+01	2.18E+02	5.64E+07
03		0.001	1.39E+04	1.17E+02	1.68E+02	5.97E+07
04		0.1	1.83E+02	-1.28E+01	9.16E+01	7.15E+07
05	303.15K	0.01	1.17E+02	1.42E+00	1.49E+02	6.14E+07
06		0.001	1.08E+04	1.42E+03	1.00E+02	6.95E+07
07		0.1	1.52E+02	-1.53E+00	1.27E+02	6.15E+07
08	308.15K	0.01	-1.14E+02	-1.72E+01	1.26E+02	6.16E+07
09		0.001	6.94E+03	-4.49E+02	1.12E+02	6.42E+07

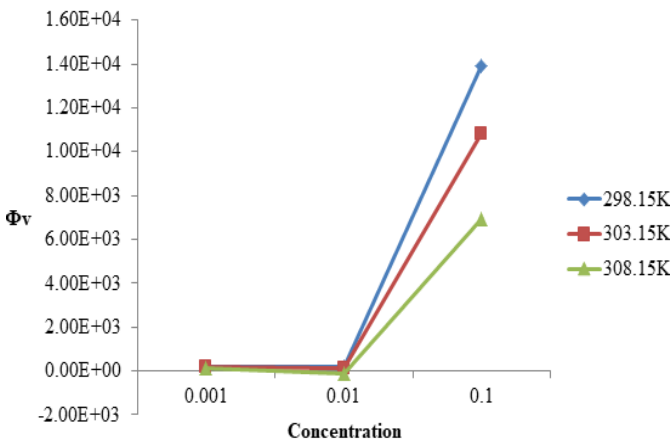Fig.-1: Molar hydration number (h) Vs Concentration (Sodium-2-hydroxy benzoate)

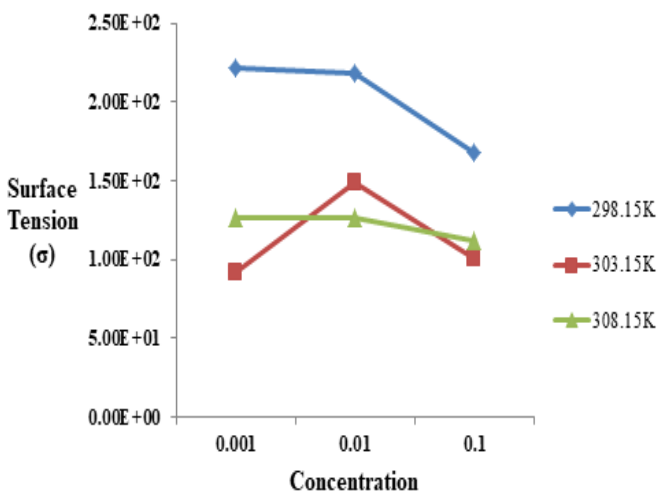Fig.-2: Apparent molar volume (φv)Vs Concentration (Sodium-2-hydroxy benzoate)

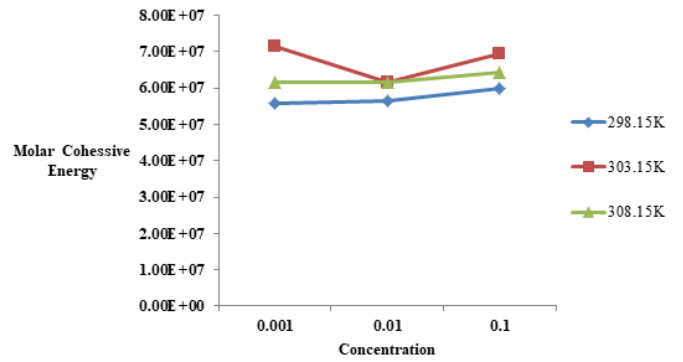Fig.-3: Surface Tension (σ) Vs Concentration (Sodium-2-hydroxy benzoate)

Fig.-4 : Molar Cohesive Energy Vs Concentration (Sodium-2-hydroxy benzoate)

The experimentally determined and calculated values of molar hydration number, apparent molar volumes, surface tension and molar cohesive energy are shown in **Table – 1 and fig. 1, 2, 3 and 4.** The value of molar hydration number shows nonlinear variation with concentration. Molar hydration number shows positive values at 298.15 K and 303.15K and negative values at 308.15K (Fig. 2). These value increases with concentration at 298.15 K and 303.15K. The hydration number is calculated by various researchers earlier by considering adiabatic compressibility is due to the free solvent molecules [7]. The variation in the values of hydration number may be due the hydration effect of solute over the solvent molecules also the may be effect of ethanol molecules on the solvation process. The molar hydration number decrease with rise in the temperature is due to interaction of ethanol molecules with solute effectively than the water molecules[8]. The values of surface tension and molar cohesive energy are plotted against concentration (**Fig. 3 and 4**). The linear relationship in the values of surface tension is found at 298.15L and 308.15K. Same relationship is observed in the variation of molar cohesive energy values. It may be said that molar cohesive energy of a liquid system conditions the surface tension[9]. It is noted that the solutions exhibit negative values of solvation number at 308.15K and positive values at 298.15K ,303.15K. The sign of the solvation number indicates the relative value of compressibility of solution and the solvent[10]. The negative value of solvation number shows that solutions are more

compressible than the solvent and positive solvation number suggests that compressibility of the solution is less than that of solvent supporting the fact that the ions gain high mobility.

IV. CONCLUSION

A gradual increase in solvation number from lower to higher concentration is observed at two temperatures indicates that as concentration increases solvation increases is due the effect of two different solvent molecules H_2O and C_2H_5OH. There may be interference of ethanol molecules in the solvation process between water - solute and decrease in the interaction between water molecules and Sodium-2-hydroxy benzoate molecules.

V. REFERENCES

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