Comparison of Ultrasonic Absorption and Relaxation Behavior of some Binary-liquids

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Abstract: ***The ultrasonic absorption has been measured at different frequencies 1 MHz to 10 MHz in the binary liquid mixtures of methanol with cinnamaldehyde and acrylonitrile over the entire range of composition and at five different temperatures 293 K, 298 K, 303 K, 308 K and 313 K. The result has been used to discuss the nature and strength of intermolecular interactions in the system. In these systems structural relaxation plays a predominant role over thermal relaxation process. The increase or decrease in ultrasonic absorption with increase in molar concentration is due to the possible structural relaxation process in these binary liquid mixtures. These studies may be important because of their extensive use in the engineering, process industries, textile industries, pharmaceutical industries and nuclear energy industries.***

Keywords: Ultrasonic absorption; classical absorption; relaxation time; viscosity; binary liquids

1. Introduction

Study of propagation of ultrasonic waves and their absorption forms one of the most important methods of investigation of properties of matter in all the three states. It is well known that study of absorption of ultrasonic waves in a medium provides important information about various inter and intra-molecular processes such as relaxation of the medium or the existence of isomeric states or the exchange of energy between various molecular degrees of freedom [1-3].

Ultrasonic absorption and their deviation from the additive rule provide a better insight into molecular processes [4-6]. Ultrasonic absorption α can be evaluated from the slope of the linear plot of Ln ΔI versus γ_{mean}, since the maximum and minimum current are close to each other γ may be taken as the mean of the γ_{max} and γ_{min}. Where γ_{max} and γ_{min} are the respective micrometer reading corresponding to I_{max} and I_{min}.

$$\text{slope} = \tan\theta = 2\alpha .$$
$$\text{Hence, } \alpha = \text{slope}/2. \text{ Thus, ultrasonic absorption} = \text{slope}/2$$
$$\text{Hence, Ultrasonic absorption coefficient} = \alpha / f^2 \ldots\ldots\ldots\ldots (1)$$

2. Materials and Methods

The liquids used were of AR grade and were redistilled in the laboratory. In this study the measurements have been made at a temperature 303K. The temperature of the liquid mixture was kept constant by the use of thermostat U-10 with ± 0.10C accuracy. Density measurement was carried out using specific gravity bottles ±1x10-5 gm/cm3 and digital mono pan-balance with an accuracy of 0.001mg. Ultrasonic velocity measurements were made with an ultrasonic multi frequency interferometer (Mittal enterprises, New Delhi) at a frequency range 1MHz to 10MHz with an accuracy of ±0.01m/s. The time of descent of the liquid between the viscometer marks was measured using electronic timer with accuracy of ± 0.01sec for digital clock.

3. Results and Discussion

Fig.1 contains the plot of experimental ultrasonic absorption (α/f^2) versus molar concentration at different frequencies. It is observed that ultrasonic absorption (α/f^2) slightly increases with increase in the molar concentration of cinnamaldehyde in methanol indicating more stability of cinnamaldehyde molecules. Cinnamaldehyde molecule has three resonating structure which increases the relaxation time. Increase in relaxation time increases the ultrasonic absorption in this binary liquid system. The non-linear variation of ultrasonic absorption in each curve with molar concentration strongly supports the presence of strong intermolecular interaction through hydrogen bonding [7-9] in the component molecules of this binary liquid system.

Fig.2 contains the plot of observed experimental ultrasonic absorption (α/f^2_{obs}) versus molar concentration at different temperatures for 7MHz. It is observed that ultrasonic absorption (α/f^2) slightly increases with increase in the molar concentration of cinnamaldehyde in methanol and decreases with increase in the temperature. The non-linear variation of ultrasonic absorption in each curve with molar concentration strongly supports the presence of strong intermolecular interaction through hydrogen bonding in the interacting molecules of this binary liquid system.

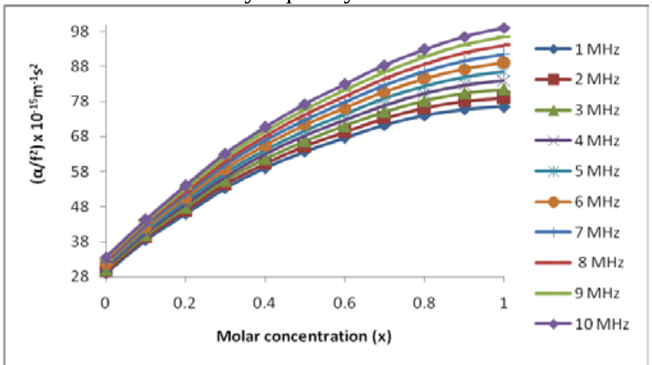

Figure 1: Variation of (α/f^2) versus x at different frequencies

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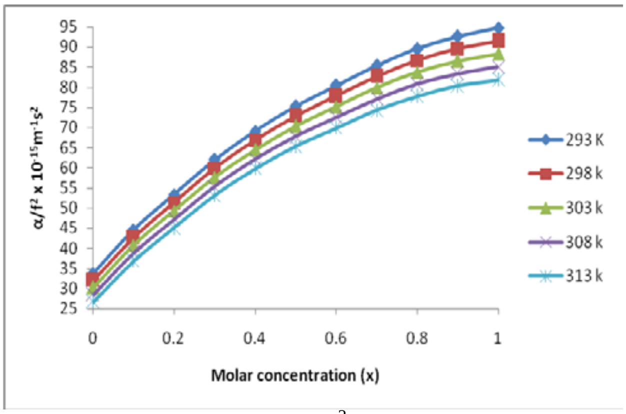

Figure 2: Variation of (α/f^2) versus x at different temperatures

The general increase in absorption may be explained on the basis of energy transfer between different energy modes. The propagation of ultrasonic wave through a binary liquid mixture disrupts thermal and structural equilibrium of the solution and produces energy transfer between different modes of the molecules. The increase in ultrasonic absorption with increase in molar concentration is due to the possible structural relaxation process in this binary liquid mixture. These structural relaxation processes play very important role in the study of molecular and structural properties of the component molecules in binary liquid mixture. The high value of viscosity and the relaxation time of component molecule cinnamaldehyde are responsible for increase in ultrasonic absorption with increase in molar concentration [10 & 11].

The maximum absorption occurs at 10MHz and for 293 K this shows that binary liquid mixture is more structured at higher frequencies and at lower temperature. This higher structured solution generally absorbs more ultrasonic energy.

Dipole-Dipole interaction between constituents molecules and strong hydrogen bond between oxygen atom (O) of cinnamaldehyde and hydrogen (H) from hydroxyl (-OH) group in methanol are also responsible for increase in absorption. High value of viscosity of component molecule cinnamaldehyde is also responsible for increase in ultrasonic absorption.

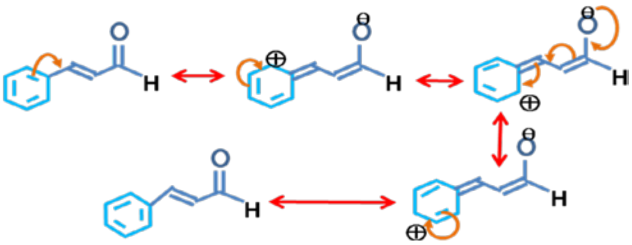

Figure 3: Resonating structure of Cinnamaldehyde

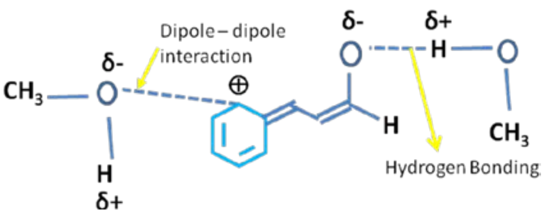

Figure 4: Intermolecular Interactions in Methanol and Cinnamaldehyde

Fig. 5 contains the plot of experimental ultrasonic absorption (α/f^2) versus molar concentration at different frequencies. It is observed that ultrasonic absorption (α/f^2) slightly decreases with increase in the molar concentration of acrylonitrile in methanol indicating less stability of acrylonitrile molecules. Acrylonitrile molecule has single resonating structure which decreases the relaxation time. Decrease in relaxation time decreases the ultrasonic absorption in this binary liquid system. The non-linear variation of ultrasonic absorption in each curve with molar concentration strongly supports the presence of strong intermolecular interaction through hydrogen bonding in the component molecules of this binary liquid system. Peak at molar concentration 0.9 shows the association in the constituent molecules.

Fig. 6 contains the plot of observed experimental ultrasonic absorption (α/f^2_{obs}) versus molar concentration at different temperature for 7 MHz. It is observed that ultrasonic absorption (α/f^2) slightly decreases with increase in the molar concentration of acrylonitrile in methanol and decreases with increase in the temperature. The non-linear variation of ultrasonic absorption in each curve with molar concentration strongly supports the presence of strong intermolecular interaction through hydrogen bonding in the interacting molecules of this binary liquid system. Peak at molar concentration 0.9 shows the association in the constituent molecules.

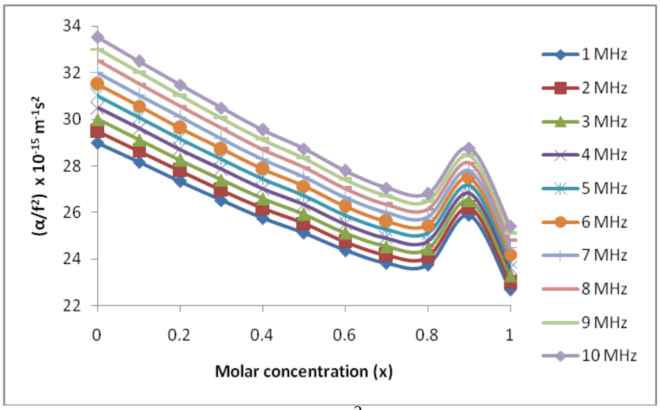

Figure 5: Variation of (α/f^2) versus x at different frequencies

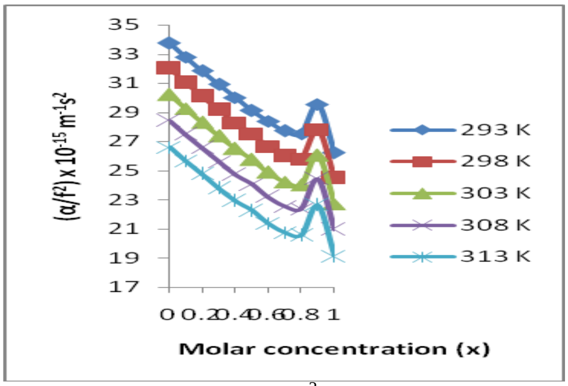

Figure 6: Variation of (α/f^2) versus x at different temperatures

The maximum absorption occurs at 10MHz and for 293 K this shows that binary liquid mixture is more structured at higher frequencies and at lower temperature. This higher structured solution generally absorbs more ultrasonic energy. Dipole-Dipole interaction between constituents molecules and strong hydrogen bond between constituent molecules responsible for increase in absorption.

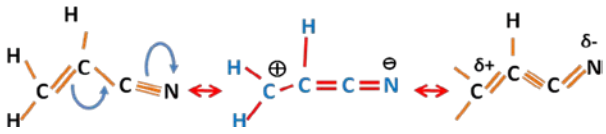

Figure 7: Resonating structure of Acrylonitrile

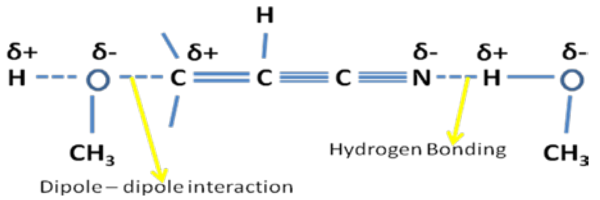

Figure 8: Intermolecular Interaction in methanol and acrylonitrile

4. Conclusions

1) In this binary liquid mixture absorption process is due to structural relaxation. These structural relaxation processes play very important role in the study of molecular and structural properties of the component molecules in binary liquid mixture.
2) Decrease in ultrasonic absorption with increase in the molar concentration in binary liquid systems methanol and methyl methacrylate are due to less stability of constituent molecules methyl methacrylate. Because methylmethacrylate molecules have single resonating structure which decreases the relaxation time. Decrease in relaxation time decreases the ultrasonic absorption.
3) Increase in ultrasonic absorption with increase in molar concentration in binary liquid systems methanol and cinnamaldehyde are due to more stability of cinnamaldehyde molecules. Molecules of the cinnamaldehyde has three resonating structure which increases the relaxation time. Increase in relaxation time increases the ultrasonic absorption.

5. Applications

1) Capsules of cinnamaldehyde are used as food supplements or as dietetic foods to reduce blood sugar levels in diabetes. Cinnamaldehyde change the structure in drug after some periods. Hence their drug activity lost and drug is expired. Intermolecular association of cinnamaldehyde with methanol increases the drug durability.
2) Associative property of binary liquid mixture of methanol and methyl methacrylate enhanced the strength and rate of production during the manufacture of polymethyl methacrylate acrylic plastics (PMMA) and Methyl methacrylate-butadiene-styrene (MBS).
3) This study play very important role in chromatography technique. It is the criteria for the separation of pure component from their mixture.

6. Future Scope

1) Ultrasonic study of bio-liquid has the potential to change the face of modern medicine and Biology.
2) In future Bio-fuel like methanol overcomes the energy crises in the world without depleting the ozone layer.
3) For physiological behavior of body particular potential energy is required, we can guess that particular amount of potential energy by this study
4) For replacement of damage or diseased body parts by appropriate solid materials, selected materials should be match with the tissue. This study helps for the selection of such materials.

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References

[1] Burton C J, J Acoust Am, 20, (1948) 186.
[2] Rao M R, "Current Sci", 8, (1939) 510.
[3] Wada Y, J Phys Soc Jpn, 4, (1949) 280.
[4] Ravichandran S & Ramanajchan K, J Pure & Appl Ultrason, 28, (2006) 40.
[5] Rath D C & Samal K, J pure Appl Ultrason 16, (1994) 6.
[6] Chimankar O P, Tabhane V A & Baghel G K, J Acoust Soc of India, 34, 4, (2007) 126
[7] Tabhane V A, Chimankar O P, Manja S & Nambinarayanan T K, J Pure & Appl Ultrason, 21 , 3, (1999) 57.
[8] Chimankar O P, Rewatkar K G & Tabhane V A, Indian J of Phys, 75 B, 2, (2001) 141.
[9] Manikiam B & Narasimham A V, Indian J Pure & Appl Phys, 22, (1984) 29.
[10] N R Pawar, O P Chimankar, V D Bhandakkar & N N Padole J Pure & Appl Ultrasonic, 34, 2-3, (2012), 49-52.
[11] **N R Pawar**, O P Chimankar, V D Bhandakkar & N N Padole, International Symposium on Ultrasound in the Control of Industrial Processes (UCIP 2012) IOP Publishing IOP Conf. Series: Materials Science and Engineering **42** (2012) 012030 doi:10.1088/1757-899X/42/1/012030