

ULTRASONIC INVESTIGATION OF BIO-LIQUID MIXTURES OF METHANOL WITH CINNAMALDEHYDE BY INTERFEROMETRIC METHOD OPERATED IN THE FREQUENCY RANGE 1 MHz-10 MHz

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Abstract

Ultrasonic absorption study of binary liquid mixtures of cinnamaldehyde with polar solvent methanol and their binary liquid mixture were carried out at 298 K in the frequency range 1MHz-10MHz and at five different temperatures 293 K, 298 K, 303 K, 308 K and 313 K for 7 MHz over the entire range of composition. The observed ultrasonic absorption (αf_{obs}^2), classical absorption (αf_{class}^2), excess absorption (αf_{excess}^2) and the ratio of the observed ultrasonic absorption (αf_{obs}^2) and classical absorption (αf_{class}^2) in the temperature range 293 K, 298 K, 303 K, 308 K and 313 K and at 7 MHz over the entire range of composition and their variation with compositions were studied. In this binary system it is observed that ultrasonic absorption is higher than the classical absorption. It is a characteristic feature of this binary liquid mixture.

The thermo acoustical parameters acoustic impedance (Z), molecular weight (M), molar volume (V), molar sound velocity (R), molar compressibility (W), Vander Waal's constant (b), internal pressure (π_i), viscosity (η), intermolecular radius (r_o), relaxation time (τ), adiabatic compressibility (β_a), free volume (V_f), isothermal compressibility (β_i), intermolecular free length (L_f), etc were computed for the all the binary systems from ultrasonic velocities, densities and viscosities at 303 K and at frequency 7 MHz. Comparison of experimental ultrasonic velocity and its theoretically calculated values by Junjie's relation, Impedance dependence relation and Nomoto's relation were studied. The increase in ultrasonic absorption with increase in molar concentration is due to the possible structural relaxation process in this binary system. These structural relaxation processes play very important role in the study of molecular and structural properties of the component molecules in binary liquid mixture.

Keywords: Ultrasonic velocity, absorption, compressibility, relaxation time, acoustic impedance, Vander wall's constant, adiabatic compressibility (β_a), internal pressure (π_i), relaxation time (τ), free length (L_f), methanol and cinnamaldehyde.

1. INTRODUCTION

The ultrasonic studies in bio-liquid are essential for utilizing them in bio-medical technology. Bio-liquids are made up of long chain molecules consisting of aromatic compounds. Bio-molecules are bigger in size and complicated in structure. The exhaustive literature survey shows scanty work on pure bio-liquids and liquid mixtures¹⁻³. Therefore it was though worthwhile to understand ultrasonic study on some bio-liquids and their mixtures. Methanol and cinnamaldehyde has large number of applications in bio-medical technology and industries⁴⁻⁵.

Ultrasonic parameters are extensively being used to study molecular interactions in pure liquids binary liquid mixtures⁶⁻⁷ and ionic interactions in single and mixed salt solutions of bio-liquids. The experimental investigations have shown that derived parameters such as the adiabatic compressibility (β_a), ultrasonic absorption and their deviation from the additive rule provide a better insight into molecular processes.

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. This study 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. Ultrasonic absorption and their deviation from the additive rule provide a better insight into molecular processes.

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. This study becomes important because of their extensive use in the engineering, process industries, textile industries, pharmaceutical industries and in nuclear energy industries.

2. MATERIALS AND METHODS

The liquids used were of BDH analar grade and were redistilled in the laboratory. In this study the measurements have been made in the temperature range 293 K-313 K. The temperature of the liquid mixture was kept constant by the use of thermostat U-10 with ± 0.01 K accuracy. Density measurement was carried out by using hydrostatic sinker method with an accuracy ±0.01%. A monopan electrical balance of least count as 0.0001 gm was used to record change in plunger weight dipped in the solutions correct to fourth place of decimal. Ultrasonic velocity and absorption measurements were made with an ultrasonic multifrequency interferometer (Mittal enterprises, New Delhi) in the frequency range 1 MHz to 10 MHz with an accuracy of ±0.1%. The time of descent of the liquid between the viscometer marks was measured using electronic timer. The time of descent of the liquids between the viscometer marks was measured using an electronic digital timer with least count 0.01 sec. The viscosity was measured in Ostwald's viscometer with an accuracy 0.001 cP.

3. THEORITICAL APPROACH

For the measurement of ultrasonic absorption⁸ by interferometer technique, liquid is placed in the cell of the ultrasonic interferometer. Let the distance (γ) between the crystal and the reflector be slowly varied by the micrometer screw. The current in the anode circuit of the oscillator undergoes cyclic variation giving rise to alternate maxima and minima. The distance between alternate maxima and minima corresponds to half wavelength in the liquid medium. When (γ) is increased, the successive maximum current goes on decreasing whereas the successive minimum current goes on increasing. The curves approach each other as γ is increased. The magnitudes of maxima and minima currents are related to absorption co-efficient 2α . Let I_{max} be the maximum current corresponding to the separation of γ_{max} between the crystal and reflector and I_{min} be the minimum current corresponding to the separation of γ_{min} between the crystal and reflector. Let ΔI be $I_{max} - I_{min}$. According to Mason, applying certain approximation

$$I = k \exp (-2\alpha\gamma) \dots\dots\dots(1)$$

Where, k is a constant involving parameters related to the oscillation and the interferometer.

Therefore,

$$\ln \Delta I = \ln k (-2\alpha\gamma) \dots\dots\dots (2)$$

From the equation (2), it is clear that α can be evaluated from the slope of the linear plot of $\ln \Delta I$ 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} .

$$\text{Slope} = 2\alpha$$

Hence,

$$\alpha = \text{slope} / 2$$

Thus, ultrasonic absorption = slope / 2

Hence,

$$\text{Ultrasonic absorption coefficient} = \alpha / f^2 \dots\dots\dots(3)$$

3.1 Classical Absorption

The propagation of ultrasonic wave through a thin layer of medium suffers a fractional loss of energy. If I and I₀ are the intensities of the sound before and after passing through a layer of thickness x, then

$$I = I_0 e^{-2\alpha_A X} \dots\dots\dots (4)$$

Where α_A is defined as the absorption coefficient of the medium and is generally expressed in Nepers/cm. The classical absorption arises because the propagating wave losses energy in overcoming the shear viscosity (η_s) and thermal conductivity of liquids. It may be represented as

$$(\alpha_A)_{class} = (\alpha_A)_{shear} + (\alpha_A)_{thermal} \dots\dots\dots(5)$$

As the thermal conductivity of most of the liquids is generally small its contribution to the attenuation of ultrasonic waves is negligible except for liquid metals. However, the attenuation due to shear viscosity will have a significant contribution.

The classical absorption coefficient $(\alpha/f^2)_{class}$ can be expressed by neglecting the loss of sound energy due to thermal conductivity as,

$$(\alpha/f^2)_{class} = \frac{8\pi^2\eta_s}{3\rho u^3} \dots\dots\dots (6)$$

Where, f is the frequency of the ultrasonic wave.

The classical absorption is always several times less than the actual measured absorption, since it is only due to the viscosity of the medium.

3.2 Excess Absorption

The classical absorption is a sum of shear viscosity and thermal conductivity contributions. But in many liquids, the experimentally measured ultrasonic absorption is found to be higher than the classical absorption. The difference between these two absorptions is termed as excess absorption.

Therefore,

$$(\alpha/f^2)_{excess} = (\alpha/f^2)_{obs} - (\alpha/f^2)_{class} \dots\dots\dots (7)$$

3.3 Nomoto's Relation

Assuming the linear dependence of molar sound velocity (R) on concentration in mole fraction and the additivity of molar volume V_m , Nomoto⁹ establish an empirical formula for ultrasonic velocity in binary liquid mixture as,

$$u_{NR} = \left(\frac{x_1 R_1 + x_2 R_2}{x_1 V_{m1} + x_2 V_{m2}} \right)^3 \dots \dots \dots (8)$$

For multicomponent mixture above equation can be written as,

$$u_{NR} = \frac{\sum_{i=1}^n x_i R_i}{\sum_{i=1}^n x_i V_{mi}} \dots \dots \dots (9)$$

Molar volume and sound velocity obeys the additivity,

$$R = x_1 R_1 + x_2 R_2$$

$$R = \sum_{i=1}^n x_i R_i \dots \dots \dots (10)$$

Similarly,

$$V_m = x_1 V_{m1} + x_2 V_{m2}$$

$$V_m = \sum_{i=1}^n x_i V_{mi} \dots \dots \dots (11)$$

3.4 Junjie's Relation

The Junjie's relation for the determination of ultrasonic velocity in ternary mixtures was extended by Dewan et al¹⁰. The extended Junjie's relation for the multicomponent mixtures can be written as,

$$u_{JR} = \left(\sum_{i=1}^n x_i V_{mi} \right) \left(\sum_{i=1}^n x_i M_i \right) \left[\frac{\sum_{i=1}^n x_i V_{mi}}{\sum_{i=1}^n \rho_i u_i^2} \right]^{\frac{1}{2}} \dots (12)$$

The symbols have their usual significance.

Impedance Dependence Relation: The ultrasonic velocity in binary liquid mixture is given by impedance-dependence¹¹ relation

$$u_{IDR} = \frac{x_1 Z_1 + x_2 Z_2}{x_1 \rho_1 + x_2 \rho_2} \dots \dots \dots (13)$$

The symbols have their usual significance.

4. 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 (fig.2) 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 in the component molecules of this binary liquid system.

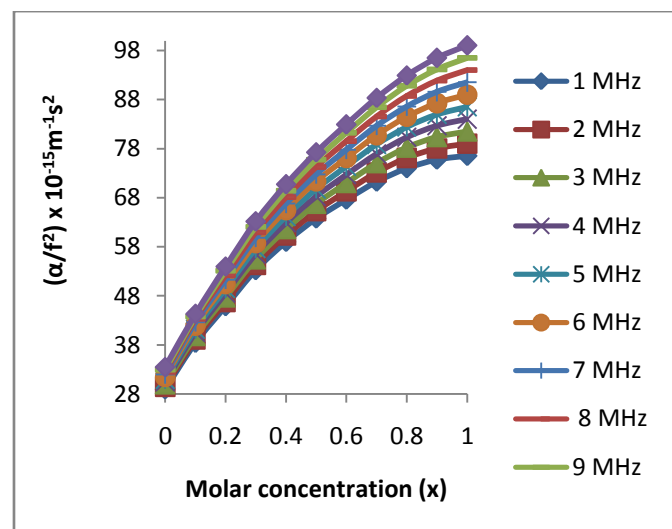


Fig.1 Variation of (α/f^2) versus x

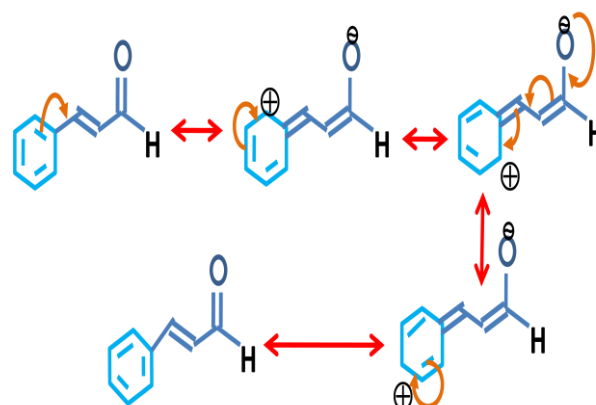


Fig. 2 Resonating Structure of Cinnamaldehyde

The general increase in absorption can 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 equilibria 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.

The curve obtained for 10 MHz is steeper than the other which indicates that slightly stronger dipole-dipole interaction exists in the former while weak dipole-dipole interactions exist in the latter. This indicated that weak and strong hydrogen bonds exist between oxygen atom (O) of cinnamaldehyde and hydrogen (H) from hydroxyl (-OH) group of methanol in latter and former curve respectively.

As the concentration of cinnamaldehyde increases more and more absorption coefficient increases. It is due to change in intermolecular arrangement in the molecules of the components. The maximum absorption occurs at 10MHz, this shows that binary liquid mixture is more structured at higher frequencies. This higher structured solution generally absorbs more ultrasonic energy.

As the component molecules are structurally different, structural relaxation occurs in this binary system. Strong intermolecular forces between the component molecules are responsible for the structural relaxation.

Fig.3 contains the plot of observed experimental ultrasonic absorption (α/Γ_{obs}^2) versus molar concentration at different temperature for 7 MHz. It is observed that ultrasonic absorption (α/Γ^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.

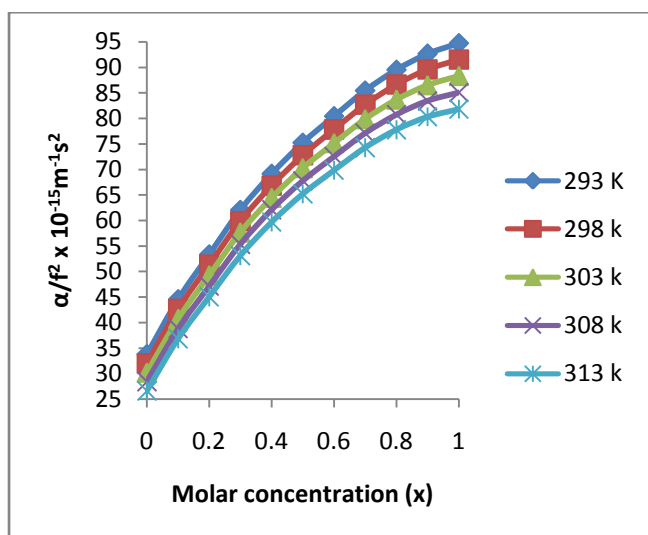


Fig.3 Variation of (α/Γ^2) versus x

The curve obtained for 293 K is steeper than the other which indicates that slightly stronger dipole-dipole interactions exist in the former while weak dipole-dipole interactions exist in the latter. This indicated that weak and strong hydrogen bond exist between oxygen atom (O) of cinnamaldehyde and hydrogen (H) from hydroxyl (-OH) group in methanol in latter and former curve respectively. As the concentration of cinnamaldehyde increases more and more absorption coefficient increases. It is due to high value of viscosity of component molecule cinnamaldehyde. The maximum absorption occurs at 293 K, this shows that binary liquid mixture is more structured at lower temperature. This higher structured solution generally absorbs more ultrasonic energy.

In present paper the nature and strength of heteromolecular methanol-cinnamaldehyde or cinnamaldehyde-methanol

interaction is determined by the interacting molecules. Molecule of methanol and cinnamaldehyde are polar. The dipole moment of methanol is 1.70 D and that of cinnamaldehyde is 0.58 D. Hence the nature of the forces responsible for the observed heteromolecular interactions in this binary liquid mixture are dipole-dipole type. In methanol and cinnamaldehyde active sub group are (-OH) and (-CHO) which plays important role in the association.

Fig.4 contains the plot of ultrasonic velocity versus molar concentration. It is observed that ultrasonic velocity increases with increase in concentration of cinnamaldehyde in methanol indicating association in the molecules of the component liquids. In methanol oxygen atom contain lone pair of electron act as nucleophile and provides a lone pair to the electron deficient β -carbocation of the cinnamaldehyde and the constituents molecules gets associated. The association in the constituent molecules may involve due to hydrogen bonding or due to dipole-dipole interaction between the constituent molecules¹²⁻¹³.

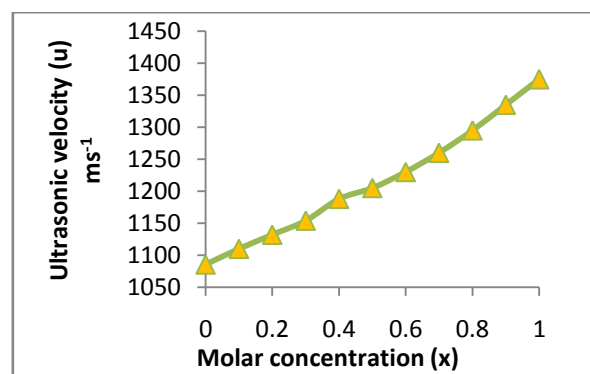


Fig. 4 Variation of u versus x

As the hydroxyl group (-OH) of methanol and (-CHO) group of cinnamaldehyde are bonded to adjacent carbon atoms, there is a possibility of intermolecular bond formation between the H of hydroxyl group (-OH) and oxygen atom (O) of (-CHO) which may exhibit association in the foreign molecules. Oxygen atom (O) of -CHO in cinnamaldehyde can be form hydrogen bond with hydrogen atom (H) of hydroxyl group (-OH) in methanol. Thus association is possible between methanol and cinnamaldehyde molecules through hydrogen bonding see fig.5

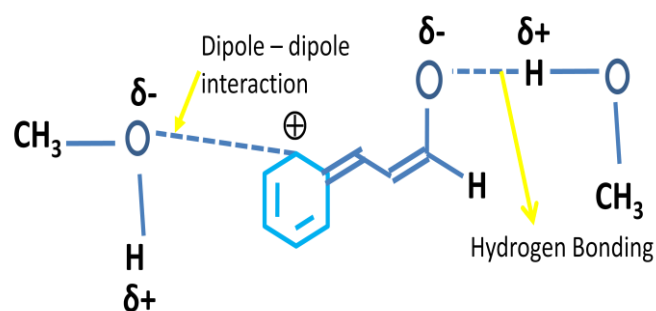


Fig.5 Intermolecular interactions in methanol and cinnamaldehyde

Fig.6 contains the plot of density versus molar concentration. It is observed that density increases with increase in concentration of cinnamaldehyde in methanol. Increase in density decreases the volume indicating association in component molecules. The density of the binary liquid mixture may be increase due to structural reorganization indicating the closed packed structure of component molecules increases. This makes the liquid medium less compressive.

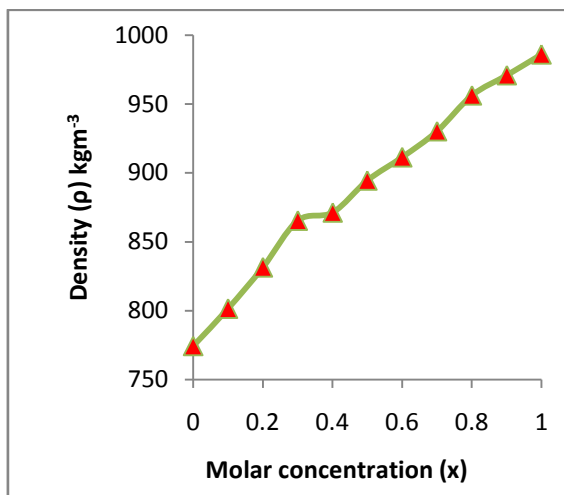


Fig. 6 Variation of ρ versus x

Fig.7 contains the plots of adiabatic compressibility (β_a) versus molar concentration. It is observed that adiabatic compressibility decreases with increase in molar concentration of cinnamaldehyde in methanol indicating strong intermolecular interaction in the molecules of component in binary liquid mixture shows associating tendency of the component molecules.

Kiyohara and Benson¹⁴ suggest that adiabatic compressibility is the result of several opposing effects. A strong dipole-dipole interaction or hydrogen bonding or interstitial accommodation between the constituent molecules leads to a more compact structure which decreases adiabatic compressibility. The magnitudes of the various contributions depend mainly on the relative molecular size of the components.

The observed decrease in adiabatic compressibility with molar concentration indicates the enhancement of degree of association in the component of liquid molecules. Hence the intermolecular distance decreases with increase in molar concentration. It is primarily the compressibility that changes with structure which leads to change in ultrasonic velocity. Decrease in adiabatic compressibility indicates that there is definite contraction in the component molecules. The decrease in adiabatic compressibility brings the molecules to a closer packing resulting into a decrease of intermolecular free length. The decrease in the values of adiabatic compressibility strengthens the strong molecular association between the unlike molecules through hydrogen bonding.

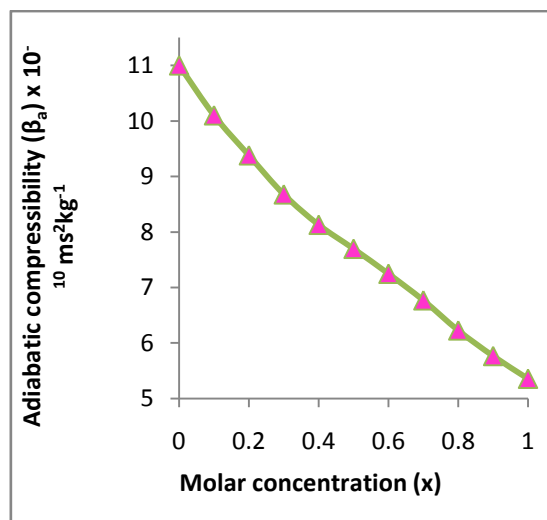


Fig.7 Variation of β_a versus x

Fig.8 contains the plot of viscosity (η) versus molar concentration. It is observed that viscosity increases with increase in molar concentration of cinnamaldehyde in methanol indicating strong dipole-dipole heteromolecular interactions in the molecules of the component.

According to Kauzman and Eyring¹⁵, the viscosity of a mixture strongly depends on the entropy of mixture, which is related with the liquid's structure and consequently with molecular interactions between the component of the mixtures. Thus the viscosity depends on molecular interaction as well as on the size and shape of the molecules. Measurements of viscosity in binary mixture yield some reliable information in the study of molecular interaction. The dipole-dipole interactions of permanent dipoles in constituent molecules of methanol and cinnamaldehyde increases viscosity in this binary liquid mixture.

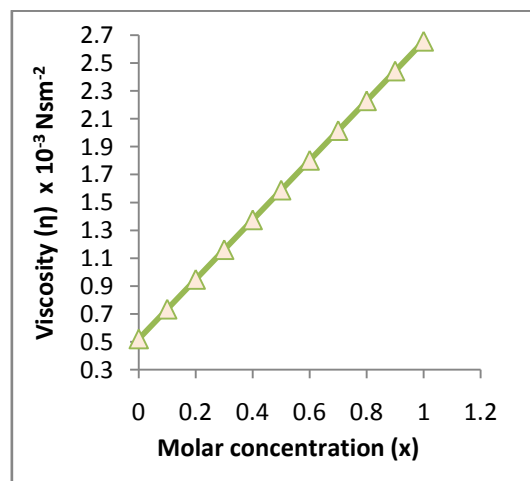


Fig.8 Variation of η versus x

Fig.9 contains the plot of relaxation time (τ) versus molar concentration. It is observed that relaxation time increases with increase in molar concentration of cinnamaldehyde in methanol indicating more stability of cinnamaldehyde molecules. Cinnamaldehyde molecule has three resonating

structure which increases the relaxation time. More the resonating structure more stable will be the molecules.

The relaxation is caused by the energy transfer between translational and vibrational degrees of freedom and all these degrees take part in the process observed¹⁶. Its behavior depends on viscosity and adiabatic compressibility of the binary liquid mixture. In this binary liquid mixture viscosity of mixture play very important role for increasing relaxation time with increase in molar concentration.

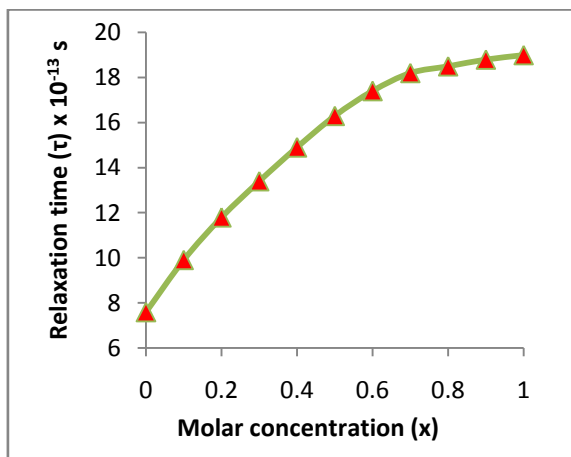


Fig.9 Variation of τ versus x

Fig.10 contains the plot of free length versus molar concentration. It is observed that free length decreases with increase in molar concentration of cinnamaldehyde in methanol. Free length decreases with molar concentration due to lack of perfect symmetry and decrease in available space between the component molecules. Free length decreases ultrasonic velocity increases showing an inverse behavior, it is in good agreement with theoretical requirements.

The decrease in free length with increase in molar concentration in mixture indicates increase in closed packed structure of components molecules i.e. enhancement of the closed structure. The decrease in the free length may due to gain of dipolar association, making strong hydrogen bond in the molecules of the liquid mixture.

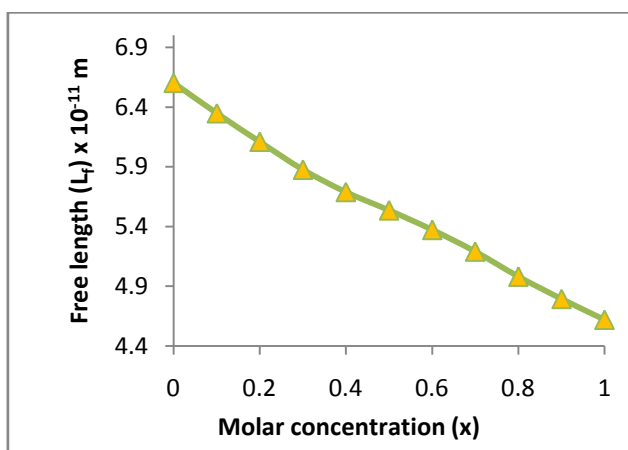


Fig.10 Variation of L_f versus x

Fig.11 and 12 respectively contain the plots of internal pressure (π_i) and free volume (V_f) versus molar concentration. It is to be noticed that the variation in the internal pressure values shows exactly in a reverse trend as that of free volume¹⁷. In this paper it is observed that internal pressure decreases and free volume (V_f) increases with increase in molar concentration of cinnamaldehyde in methanol indicating increase in dipolar association in the molecules of the component.

In this binary liquid mixture, increase in free volume and decrease in internal pressure with rise in concentration clearly show the increasing magnitude of interactions. Such behavior of internal pressure and free volume generally indicates the association through hydrogen bonding. This suggests close packing of the molecules inside the shield, it should be kept in mind that the main contribution to internal pressure comes from those interactions varying most rapidly near the equilibrium separation in the liquid i.e. dipole-dipole interaction or hydrogen bonding or interstitial accommodation between the constituent molecules.

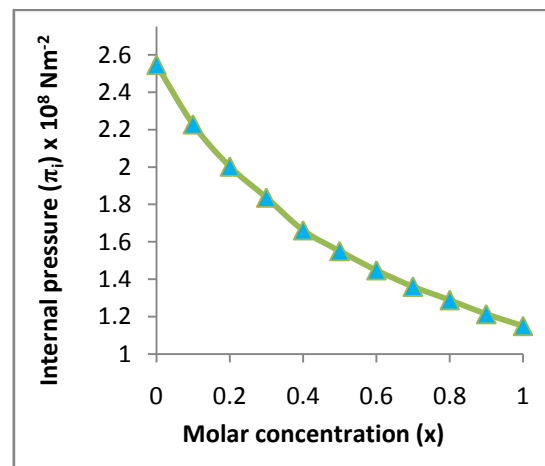


Fig.11 Variation of π_i versus x

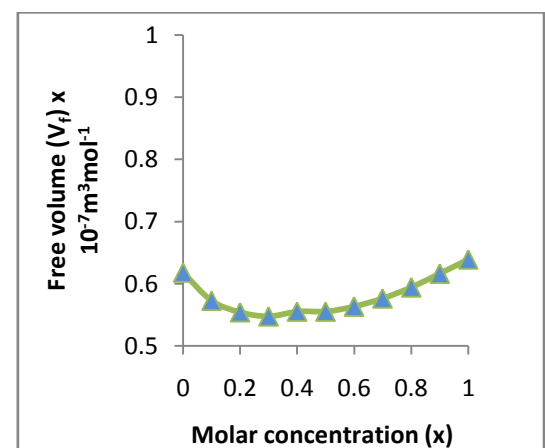


Fig.12 Variation of V_f versus x

Fig.13 contains the plot of acoustic impedance (Z) versus molar concentration. It is observed that, the values of acoustic impedance increases with increase in the molar concentration of cinnamaldehyde in methanol. It is in good agreement with the theoretical requirements because

ultrasonic velocity increases with increase in molar concentration. The increase in acoustic impedance (Z) with molar concentration can be explained on basis of the intermolecular interaction between component molecules, which decreases the intermolecular distance, making relative fewer gap between the molecules. This also indicates significant interactions in the binary liquid system.

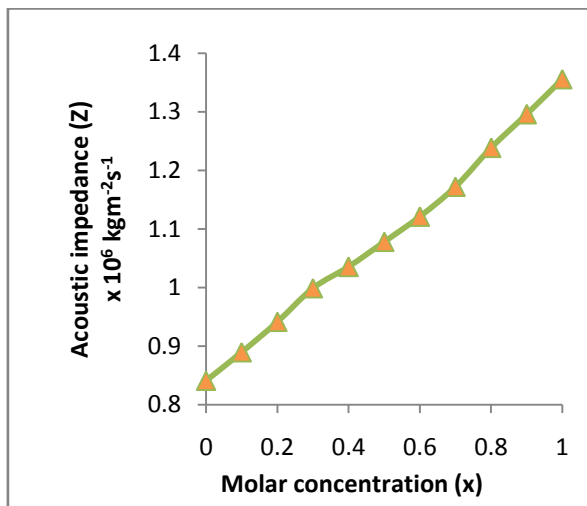


Fig.13 Variation of Z versus x

Fig.14 contains the plot of Vander Waal’s constant (b) versus molar concentration. It is observed that Vander Waal’s constant increases with increase in concentration of cinnamaldehyde in methanol. This is because of the association of a closed packing of the interacting molecules inside the shell. The change in Vander Waal’s constant (b) would be due to a change in intermolecular geometry (micro- geometry).

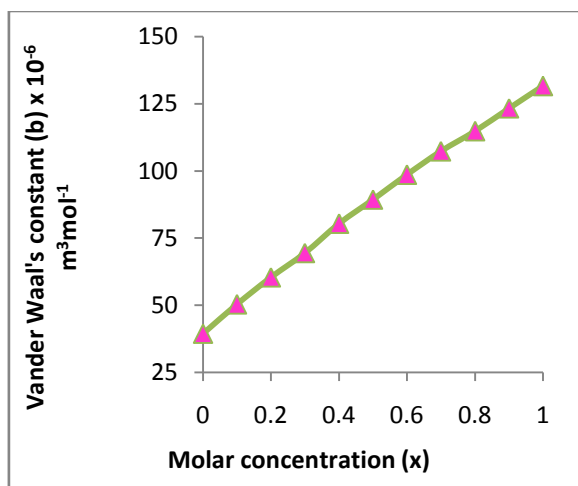


Fig.14 Variation of b versus x

The ultrasonic velocity produced by IDR empirical relation are in good agreement with the experimental data as compare to Nomoto’s relation and Junjie’s relation fig.15

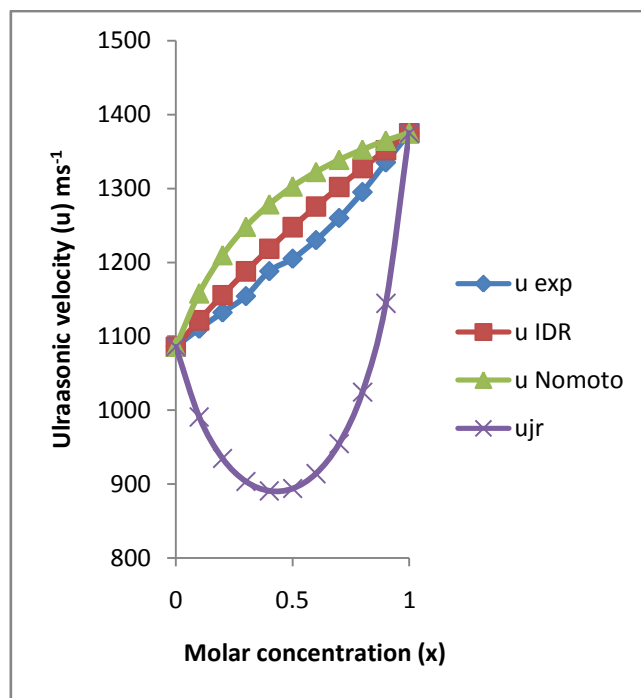


Fig.15 Comparison of u versus theoretical values at different x

The excess absorption is arises due to molecular relaxation¹⁸⁻¹⁹. It is due to either thermal relaxation or structural relaxation or both. The observed ultrasonic absorption (α/f_{obs}^2), classical absorption (α/f_{class}^2), excess absorption (α/f_{excess}^2) and the ratio of observed ultrasonic absorption and classical absorption at 293 K, 298 K, 303 K, 308 K and 313 K are represented in tables 1-5. Increase in observed ultrasonic absorption, classical absorption, excess absorption and the ratio of observed ultrasonic absorption and classical absorption with molar concentration may be attributed to the formation of strong hydrogen bonds between the component molecules. It is observed that the observed absorption is higher than the classical absorption. It is a characteristic feature of the solutions. As the component molecules are structurally different, structural relaxation occurs in this binary system. Strong intermolecular forces between the component molecules are responsible for the structural relaxation.

The experimentally measured values of ultrasonic velocity and density for pure liquids used for this study are in close agreement with the literature values at given temperature.

Table shows the comparision of literature and experimental values of ultrasonic velocity and density of pure liquids used for this study at 303 K.

Liquids	$u_{experimental}$	$u_{literature}$	$\rho_{experimental}$	$\rho_{literature}$
Methanol	1085.8	1085.95 ₂₀	774.5	774.53 ₂₀
Cinnamaldehyde	1374.9	1374.85 ₂₀	986.15	986.15 ₂₀

Table: 1 Ultrasonic velocity (u), density (ρ), viscosity (η) and absorption coefficient (α/f^2) classical, observed, excess, and ratio of observed and classical absorption coefficient at 293 K for METHANOL + CINNAMALDEHYDE

X	u(m/s)	P(kg/m ³)	η (cP)	$(\alpha/f^2)_{\text{Observed}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Classical}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Excess}}$ x10 ¹⁷ sec ² /cm	$\frac{(\alpha/f^2)_{\text{Observed}}}{(\alpha/f^2)_{\text{Classical}}}$
0	1117.2	784	0.5901	33.7586	14.192	19.5666	2.3787
0.1	1137.5	813.1	0.8684	44.5736	19.079	32.5226	3.6987
0.2	1170.64	842.5	1.1468	53.3432	22.309	42.6372	4.9826
0.3	1189.44	882.1	1.4251	62.0402	25.242	52.4556	6.4729
0.4	1217.05	888.1	1.7034	69.1341	27.974	60.7519	8.2477
0.5	1235.84	912.4	1.982	75.2489	30.259	67.9741	10.3438
0.6	1263.4	930.6	2.2599	80.4433	31.662	74.3211	13.1396
0.7	1298.36	946.6	2.5382	85.4352	32.22108	80.3120	16.6761
0.8	1325.9	975.6	2.8165	89.5302	32.5637	85.5461	22.4719
0.9	1368.34	990.7	3.0948	92.6240	32.058	88.3475	21.6588
1.0	1409.95	1002.45	3.3733	94.7478	31.5652	91.2274	26.9139

Table: 2 Ultrasonic velocity (u), density (ρ), viscosity (η) and absorption coefficient (α/f^2) classical, observed, excess, and ratio of observed and classical absorption coefficient at 298 K for METHANOL + CINNAMALDEHYDE

X	u(m/s)	P(kg/m ³)	η (cP)	$(\alpha/f^2)_{\text{Observed}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Classical}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Excess}}$ x10 ¹⁷ sec ² /cm	$\frac{(\alpha/f^2)_{\text{Observed}}}{(\alpha/f^2)_{\text{Classical}}}$
0	1101.5	779.25	0.5471	31.9987	13.8122	18.1865	2.3166
0.1	1123.75	807.25	0.7938	42.6525	18.219	24.4335	2.3411
0.2	1151.425	837	1.0405	51.3032	21.411	29.8922	2.3961
0.3	1171.785	873.75	1.2872	59.8601	24.074	35.7861	2.4865
0.4	1202.535	879.75	1.5339	66.8139	26.362	40.4519	2.5344
0.5	1220.425	903.5	1.7807	72.7678	28.507	44.2608	2.5526
0.6	1246.75	921	2.0274	77.8222	29.865	47.9572	2.6057
0.7	1279.195	938.5	2.2742	82.6753	30.438	52.2373	2.7162
0.8	1310.5	966	2.5209	86.6292	30.486	56.1432	2.8416
0.9	1351.675	980	2.7676	89.5829	30.067	59.5159	2.9794
1.0	1392.4	994.3	3.0145	91.5368	29.528	62.0088	3.1

Table: 3 Ultrasonic velocity (u), density (ρ), viscosity (η) and absorption coefficient (α/f^2) classical, observed, excess, and ratio of observed and classical absorption coefficient at 303K for METHANOL + CINNAMALDEHYDE

X	u(m/s)	P(kg/m ³)	η (cP)	$(\alpha/f^2)_{\text{Observed}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Classical}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Excess}}$ x10 ¹⁷ sec ² /cm	$\frac{(\alpha/f^2)_{\text{Observed}}}{(\alpha/f^2)_{\text{Classical}}}$
0	1085.8	774.5	0.5199	30.2185	13.7347	16.4838	2.2002
0.1	1110	801.5	0.7338	40.7284	17.6008	23.1276	2.3140
0.2	1132.2	831.5	0.9473	49.2351	20.6388	28.5963	2.3855
0.3	1154.1	865.4	1.1608	57.6182	22.9424	34.7058	2.5127
0.4	1188	871.4	1.3743	64.4577	24.7311	39.7266	2.6063
0.5	1205	894.6	1.5878	70.2678	26.6707	43.5971	2.6346
0.6	1230.1	911.4	1.8013	75.1781	27.918	47.2601	2.6928
0.7	1260	930.4	2.0148	79.8872	28.4629	51.4243	2.8067
0.8	1295.1	956.4	2.2283	83.6969	28.2002	55.4967	2.9679
0.9	1335	971	2.4418	86.5068	27.7891	58.7177	3.1129
1.0	1374.9	986.15	2.6553	88.3146	27.2386	61.0760	3.2423

Table: 4 Ultrasonic velocity (u), density (ρ), viscosity (η) and absorption coefficient (α/f^2) classical, observed, excess, and ratio of observed and classical absorption coefficient at 308 K for METHANOL + CINNAMALDEHYDE

X	u(m/s)	P(kg/m ³)	η (cP)	$(\alpha/f^2)_{\text{Observed}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Classical}}$ x10 ¹⁷ sec ² /cm	$(\alpha/f^2)_{\text{Excess}}$ x10 ¹⁷ sec ² /cm	$\frac{(\alpha/f^2)_{\text{Observed}}}{(\alpha/f^2)_{\text{Classical}}}$
0	1070.1	769.5	0.4849	28.4187	13.5207	14.8980	2.1019
0.1	1096.25	795.55	0.6659	38.7843	16.7048	22.0795	2.3217
0.2	1112.995	826	0.8471	47.1471	19.557	27.5901	2.4108
0.3	1136.475	857.05	1.0281	55.3272	21.4871	33.8401	2.5749

0.4	1173.505	863.05	1.2092	62.0817	22.7948	39.2869	2.7235
0.5	1189.545	885.7	1.3903	67.7164	24.5162	43.2305	2.7633
0.6	1221.345	901.8	1.5714	72.5141	25.6412	46.8729	2.8280
0.7	1240.865	922.3	1.7525	77.0793	26.1481	50.9312	2.9478
0.8	1279.7	946.8	1.9335	80.7448	25.6206	55.1242	3.1516
0.9	1318.345	958.6	2.115	83.4107	25.3171	58.0936	3.2946
1.0	1357.3	978	2.2957	85.0702	24.6818	60.3884	3.4467

Table: 5 Ultrasonic velocity (u), density (ρ), viscosity (η) and absorption coefficient (α/f^2) classical, observed, excess, and ratio of observed and classical absorption coefficient at 313 K for METHANOL + CINNAMALDEHYDE

X	u(m/s)	P(kg/m ³)	η (cP)	$(\alpha/f^2)_{\text{Observed}}$ $\times 10^{17}$ sec ² /cm	$(\alpha/f^2)_{\text{Classical}}$ $\times 10^{17}$ sec ² /cm	$(\alpha/f^2)_{\text{Excess}}$ $\times 10^{17}$ sec ² /cm	$\frac{(\alpha/f^2)_{\text{Observed}}}{(\alpha/f^2)_{\text{Classical}}}$
0	1057.4	765	0.4562	26.5984	13.3754	13.223	1.9886
0.1	1082.5	789.7	0.6042	36.8202	15.859	20.9612	2.3217
0.2	1093.78	820.5	0.7521	45.0389	18.418	26.6209	2.4454
0.3	1118.82	848.7	0.9001	53.0751	19.911	33.1641	2.6656
0.4	1158.99	854.7	1.0480	59.6855	20.708	38.9775	2.8822
0.5	1174.18	876.8	1.1961	65.2067	22.156	43.0507	2.9431
0.6	1196.8	892.2	1.3439	69.8302	23.103	46.7272	3.0226
0.7	1221.7	914.2	1.4919	74.2511	23.531	50.7201	3.1555
0.8	1264.3	937.2	1.6399	77.7728	22.765	55.0078	3.4163
0.9	1301.68	947.9	1.7878	80.2946	22.484	57.8106	3.5712
1.0	1339.75	969.85	1.9358	81.808	21.8229	59.9851	3.7487

5. CONCLUSIONS

1. The nonlinear variation of absorption coefficient with molar concentration provides useful information about nature of intermolecular forces existing in binary liquid mixtures.
2. In this binary system 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.
3. Increase in ultrasonic absorption with increase in molar concentration in this binary liquid system is due to more stability of cinnamaldehyde molecules in these binary liquid system. Molecules of the cinnamaldehyde has three resonating structure which increases the relaxation time. Increase in relaxation time increases the ultrasonic absorption in these binary liquid system.
4. The observed molecular association in this binary liquid mixture may be due to the formation hydrogen bond or due to interstitial accommodation or due to induction or due to London dispersion forces in the constituents molecules.
5. Decrease in adiabatic compressibility and free length with increase in molar concentration is due to association.
6. Thermo-acoustic parameters such as ultrasonic velocity, adiabatic compressibility, density, viscosity, relaxation time, free length, molar volume, acoustic impedance, internal pressure, molecular radius, etc indicates the strength of molecular interactions in the binary liquid mixture.

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