

# Effect of Temperature on the Molecular Dynamics of Binary Liquid Mixtures by Ultrasonic Method

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**Abstract:** *The ultrasonic velocity, density, viscosity and related thermo-acoustic parameters are the important tools in understanding the nature and extent of pattern of molecular interactions between components of liquid mixture. The ultrasonic velocity ( $u$ ), density ( $\rho$ ) and viscosities ( $\eta$ ) of binary liquid mixture containing Tetrahydrofuran in n-hexane over whole concentration range have been measured at 305.15K. This measured data have been used to compute derived thermo-acoustic parameters like adiabatic compressibility ( $\beta_a$ ), molar free volume ( $V_f$ ) and free length ( $L_f$ ). The related excess thermodynamic parameters are also evaluated by using standard relations. The variation of these parameters with concentration and temperature are also used to correlate with the structural changes observed in binary liquid mixture. The result suggest that a specific strong intermolecular interactions at a particular concentration in binary liquid mixture. The results obtained are also discussed in terms of breakdowns of associated structures of alcohols and formation of complex structure at specific concentration. The observed values of thermo-acoustic and excess parameters indicate the strong molecular interaction at specific mole fraction of constituents of binary liquid mixture.*

**Keywords:** ultrasonic velocity, density, viscosity, thermo-acoustic parameters, like adiabatic compressibility ( $\beta_a$ ), molar free volume ( $V_f$ ) and free length ( $L_f$ )

## 1. Introduction

Ultrasonic investigation find extensive applications in characterizing thermodynamic and physico – chemical behavior of binary liquid mixture. The study of ultrasonic waves in pure and liquid mixtures is useful to examine the nature of intermolecular interactions occurred in these liquids. In recent years ultrasonic is an area of intense scientific and technological research. In view of its extensive scientific and engineering applications it attracts attention of researchers, non- destructive testing professionals, industrialists, technologists, medical practitioners, instrumentation engineers, software engineers and medical scientists. The various acoustic parameters such as ultrasonic velocity, density, viscosity, adiabatic compressibility, free length, acoustic impedance, relaxation time, free volume and internal pressure are useful in understanding molecular structure and molecular interactions in the medium<sup>1-3</sup>.

Development of sensors, electronic instrumentation and computer software added sophistication to the experimental and theoretical agreement of different ultrasonic parameters<sup>4-7</sup>. Thermodynamics studies of binary liquid mixtures have attracted much attention of scientists. These physico-chemical analyses are used to handle the mixtures of hydrocarbons, alcohols, aldehydes, ketones etc. The measurement of ultrasonic speed enables us to the accurate measurement of some useful acoustic and thermodynamic parameters and their excess values<sup>8-13</sup>. These excess values of ultrasonic velocity, adiabatic compressibility, molar volume and viscosity in binary liquid mixture are useful in understanding the solute-solvent interactions. The study of molecular association in binary liquid mixture having alcohol as one of component is of particular interest since alcohols are strongly self associated liquids having three dimensional network of hydrogen bonding and can be associate with any other group having some degree of polar attraction<sup>14-16</sup>. The variation in ultrasonic velocity gives

information about the bonding between molecules and formation of complexes at various concentration and temperature through molecular interactions<sup>17-19</sup>. In order to have clear understanding of intermolecular interaction between component molecules of an attempt has been made to study the ultrasonic behaviors of Tetrahydrofuran in n-hexane at different temperature. Thermo-acoustic parameters are the essential sources of information for better understanding of non-ideal behavior of complex binary liquid system<sup>20-22</sup>.

## 2. Materials and Methods

The chemicals used in the present work were analytical reagent (AR) and spectroscopic reagent (SR) grades with minimum assay of 99.5% were obtained from Merck chemicals private Ltd (India). Various concentrations of the binary liquid mixtures were prepared in terms of mole fraction, out of which the mole fraction of the one component n-hexane and other is tetrahydrofuran.

### Measurements:

#### (i) Velocity Measurement:

The velocity of ultrasonic wave in the binary mixture have been measured using ultrasonic interferometer with an high degree of accuracy operating at 5 MHz frequencies (Model M-84) supplied by M/s Mittal Enterprises, New Delhi. The measuring cell of interferometer is a specially designed double walled vessel with provision for temperature constancy. An electronically operated digital constant temperature bath supplied by M/s Mittal Enterprises, New Delhi, operating in the temperature range -10°C to 85°C with an accuracy of  $\pm 0.1$ K has been used to circulate water through the outer jacket of the double walled measuring cell containing the experimental liquid.

#### (ii) Density Measurement:

The densities of the mixture were measured using a 25ml specific gravity bottle. The specific gravity bottle with the

experimental pure and binary mixture was immersed in a temperature controlled water bath. The density was measured using the formula

$$\rho_2 = \left(\frac{W_2}{W_1}\right)\rho_1$$

Where,  $w_1$  = weight of distilled water,  $w_2$  = Weight of experimental liquid,  
 $\rho_1$  = Density of water,  $\rho_2$  = Density of experimental liquid

**(iii) Viscosity measurement:**

The viscosities of the ternary mixture were measured using an Oswald’s viscometer calibrated with double distilled water. The Oswald’s viscometer with the experimental mixture was immersed in a temperature controlled water bath. The time of flow was measured using a digital racer stop watch with an accuracy of 0.1 sec. The viscosity was determined using the relation,

$$\eta_2 = \eta_1 \left(\frac{t_2}{t_1}\right) \left(\frac{\rho_2}{\rho_1}\right)$$

Where,  $\eta_1$  = Viscosity of water,  $\eta_2$  = Viscosity of mixture,  $\rho_1$  = Density of water,  $\rho_2$  = Density of mixture,  
 $t_1$  = Time of flow of water,  $t_2$  = Time of flow of mixture.

**3. Theoretical Aspect**

The following thermodynamic parameters were calculated from Jacobson’s relation [8–10].

**(i) Adiabatic Compressibility ( $\beta$ ):-**

The adiabatic compressibility is the fractional decrease of volume per unit increase of pressure, when no heat flows in or out. It is calculated from the speed of sound ( $U$ ) and the density ( $\rho$ ) of the medium by using the equation of Newton Laplace as,

$$\beta = \frac{1}{u^2 \rho} \text{ ----- (1)}$$

**(ii) Intermolecular free length ( $L_f$ ):-**

The intermolecular free length is the distance between the surfaces of the neighboring molecules. It is calculated by using the relation

$$L_f = K_T \sqrt{\beta} \text{ ----- (2)}$$

Where  $KT$  is the temperature dependent constant and ‘ $\beta$ ’ is the adiabatic compressibility.

**(iii) Free Volume ( $V_f$ ):-**

Free volume in terms of ultrasonic velocity ( $U$ ) and the viscosity ( $\eta$ ) of liquid is

$$V_f = \left(\frac{M_{eff} \eta}{k \eta}\right)^{\frac{2}{3}} \text{ ----- (3)}$$

Where ‘ $M_{eff}$ ’ is the effective mass of the mixture and ‘ $K$ ’ is a dimensionless constant independent of liquid. Its value is  $4.281 \times 10^9$ .

**(iv) Internal Pressure ( $\Pi_i$ ):-**

The measurement of internal pressure is important in the study of the thermodynamic properties of liquids. The internal pressure is the cohesive force, which is a resultant of force of attraction and force of repulsion between the molecules. It is calculated by using the relation,

$$\pi_i = bRT \left(\frac{K\eta}{U}\right)^{\frac{2}{3}} \left(\frac{\rho}{M_{eff} \eta}\right) \text{ ----- (4)}$$

Where, ‘ $b$ ’ stands for cubic packing, which is assumed to be ‘2’ for all liquids,  
‘ $k$ ’ is a dimensionless constant independent of temperature and nature of liquids. Its value is  $4.281 \times 10^9$ . ‘ $T$ ’ is the absolute temperature in Kelvin, ‘ $M_{eff}$ ’ is the effective molecular weight,  
‘ $R$ ’ is the Universal gas constant, ‘ $\eta$ ’ is the viscosity of solution in N.S.m<sup>-2</sup>,  
‘ $U$ ’ is the ultrasonic velocity in m.s<sup>-1</sup> and ‘ $\rho$ ’ is the density in Kg.m<sup>-3</sup> of solution.

**(v) Relaxation time ( $\tau$ ):-**

Relaxation time is the time taken for the excitation energy to appear as translational energy and it depends on temperature and impurities. The relaxation time can be calculated from the relation,

$$\tau = \frac{4}{3} (\beta \eta) \text{ ----- (5)}$$

Where ‘ $\beta$ ’ is the adiabatic compressibility and ‘ $\eta$ ’ is the viscosity of the mixture.

**(vi) Acoustic impedance ( $Z$ ):-**

The specific acoustic impedance is given by,

$$Z = U \cdot \rho \text{ ----- (6)}$$

Where ‘ $U$ ’ is the velocity and ‘ $\rho$ ’ is the density of the mixture.

**(vii) Gibb’s free energy ( $\Delta G$ ):-**

The Gibb’s free energy is calculated by using the relation

$$\Delta G = KT \ln \left(\frac{KT\tau}{h}\right) \text{ ----- (7)}$$

Where, ‘ $\tau$ ’ is the viscous relaxation time, ‘ $T$ ’ is the absolute temperature, ‘ $k$ ’ is the Boltzmann’s constant and ‘ $h$ ’ is the Planck’s constant.

**4. Results and Discussion**

**Ultrasonic Velocity ( $U$ )**

The measured ultrasonic velocity, with increase in mole fraction of Tetrahydrofuran with n-Hexane at four different temperatures are given in Tables 1-4

**Table 1:** Ultrasonic Velocity ( $U$ ), density ( $\rho$ ), and viscosity ( $\eta$ ) values for the binary mixture of n-Hexane - Tetrahydrofuran at 301.15 K.

Mole fraction of Tetrahydrofuran	Ultrasonic Velocity $U$ (ms <sup>-1</sup> )	Density $\rho$ (Kg m <sup>-3</sup> )	Viscosity $\eta \times 10^{-3}$ (Nm <sup>-2</sup> s)
0.0	940.00	0.6513	0.346
0.1	1013.33	0.6539	0.3596
0.2	1091.00	0.6709	0.3744
0.3	1134.00	0.6843	0.3802
0.4	1151.81	0.7066	0.3982
0.5	1197.63	0.7287	0.4173
0.6	1218.75	0.7499	0.4346
0.7	1253.00	0.7726	0.4577
0.8	1281.81	0.8017	0.4766
0.9	1302.85	0.8288	0.4947
1.0	1326.25	0.8661	0.5228

**Table 2:** Ultrasonic Velocity ( $U$ ), density ( $\rho$ ), and viscosity ( $\eta$ ) values for the binary mixture of n-Hexane - Tetrahydrofuran at 305.15 K

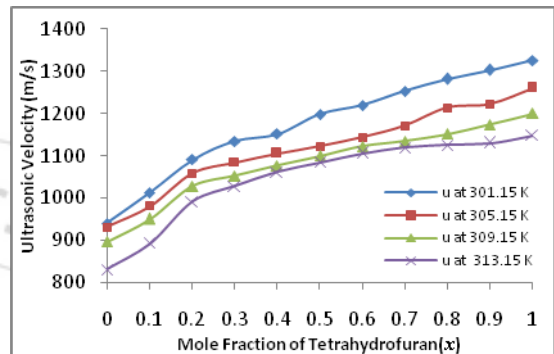
Mole fraction of Tetrahydrofuran	Ultrasonic Velocity $U$ ( $\text{ms}^{-1}$ )	Density $\rho$ ( $\text{Kg m}^{-3}$ )	Viscosity $\eta \times 10^{-3}$ ( $\text{Nm}^{-2} \text{s}$ )
0.0	931.33	0.6473	0.3144
0.1	981.75	0.6515	0.3257
0.2	1059.16	0.6672	0.3349
0.3	1085.00	0.6813	0.3432
0.4	1105.00	0.7039	0.3587
0.5	1121.81	0.7219	0.3727
0.6	1144.28	0.7465	0.3935
0.7	1171.00	0.7689	0.4064
0.8	1214.00	0.7977	0.4257
0.9	1222.22	0.8244	0.4483
1.0	1260.00	0.8613	0.4729

0.7	1119.00	0.7648	0.3761
0.8	1125.00	0.7923	0.3921
0.9	1130.00	0.8202	0.4154
1.0	1148.57	0.8547	0.4408

The ultrasonic velocity increases with increase in concentration of Tetrahydrofuran in n-Hexane system at 301.15K, 305.15K, 309.15K, and 313.15K. This trend suggests that the dipole –induced - dipole interactions are more at higher concentration of Tetrahydrofuran in the binary mixture. When the temperature is increased in, n-Hexane system, the ultrasonic velocity decreases. This trend reveals that at higher temperature the molecular interactions between the components are low.

**Table 3:** Ultrasonic Velocity ( $U$ ), density ( $\rho$ ), and viscosity ( $\eta$ ) values for the binary mixture of n-Hexane- Tetrahydrofuran at 309.15 K

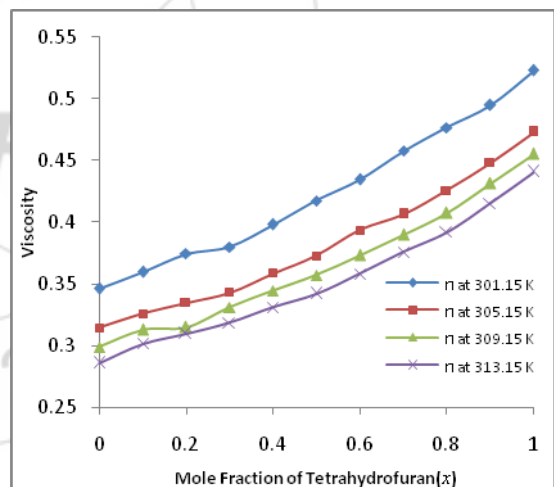
Mole fraction of Tetrahydrofuran	Ultrasonic Velocity $U$ ( $\text{ms}^{-1}$ )	Density $\rho \times 10^3$ ( $\text{Kg m}^{-3}$ )	Viscosity $\eta \times 10^{-3}$ ( $\text{Nm}^{-2} \text{s}$ )
0.0	896.66	0.6433	0.2988
0.1	950.77	0.6505	0.3130
0.2	1027.50	0.6653	0.3149
0.3	1052.50	0.6801	0.3314
0.4	1077.50	0.7016	0.3446
0.5	1100.00	0.7212	0.3571
0.6	1122.00	0.7408	0.3730
0.7	1134.00	0.7668	0.3898
0.8	1151.42	0.7955	0.4076
0.9	1174.00	0.824	0.4315
1.0	1200.00	0.8562	0.4553



**Figure 1:** Plots of Ultrasonic Velocity Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures

**Table 4:** Ultrasonic Velocity ( $U$ ), density ( $\rho$ ), and viscosity ( $\eta$ ) values for the binary Mixture of n-Hexane- Tetrahydrofuran at 313.15 K

Mole fraction of Tetrahydrofuran	Ultrasonic Velocity $U$ ( $\text{ms}^{-1}$ )	Density $\rho$ ( $\text{Kg m}^{-3}$ )	Viscosity $\eta \times 10^{-3}$ ( $\text{Nm}^{-2} \text{s}$ )
0.0	831.20	0.6401	0.2860
0.1	893.33	0.6452	0.3017
0.2	991.00	0.6609	0.3098
0.3	1028.88	0.6766	0.3185
0.4	1062.00	0.6971	0.3313
0.5	1085.00	0.7159	0.3421
0.6	1105.00	0.7378	0.3580



**Figure 3:** Plots of Viscosity Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures

**Acoustical Parameters**

The acoustic parameters for various compositions of n-Hexane with Tetrahydrofuran at various temperatures

301.15K, 305.15K, 309.15K and 313K are calculated from the measured ultrasonic velocity, density and viscosity values. These data's are given in Tables 5-8.

**Table 5:** Acoustic parameters Adiabatic Compressibility( $\beta$ ), Free Length( $L_f$ ), Acoustic Impedance( $Z$ ), Relaxation Time( $T$ ), Free Volume( $V_f$ ), Molar Volume( $V_m$ ) and Internal Pressure( $I_i$ ) for n-Hexane – Tetrahydrofuran binary liquid mixture at 301.15 K.

Mole fraction of Tetrahydrofuran(x)	Adiabatic compressibility $\beta \times 10^{-10}$ ( $\text{Kg}^{-1} \text{ms}^{-2}$ )	Free length $L_f \times 10^{-11}$ (m)	Acoustic impedance $Z$ ( $\text{Kg}^{-2} \text{ms}^{-1}$ )	Relaxation time $\tau \times 10^{-13}$ (s)	Free volume $V_f \times 10^{-3}$ (ml)	Molar volume $V_m \times 10^{-5}$ ( $\text{m}^3$ )	Internal pressure $I_i \times 10^5$ (atm)
0.0	17.376	8.6207	0.6122	8.0163	12.7944	132.319	1.826
0.1	14.893	7.9809	0.6626	7.1407	13.1861	129.642	1.8387

0.2	12.522	7.3182	0.7319	6.2512	13.5223	124.259	1.9161
0.3	11.363	6.9715	0.7759	5.7607	13.6499	119.77	1.9901
0.4	10.667	6.7545	0.8138	5.6637	12.7018	117.71	2.1637
0.5	9.5676	6.3968	0.8727	5.3234	12.2259	108.611	2.3222
0.6	8.9777	6.1965	0.9139	5.2023	11.4953	103.664	2.5043
0.7	8.244	5.9379	0.968	5.031	10.788	98.7975	2.7077
0.8	7.5917	5.6918	1.0276	4.8242	10.2157	93.4564	2.951
0.9	7.1082	5.5137	1.0759	4.6885	9.6215	88.7029	3.2047
1.0	6.5641	5.2985	1.1486	4.5756	8.8361	83.2582	3.5677

**Table 6:** Acoustic parameters Adiabatic Compressibility( $\beta$ ), Free Length( $L_f$ ), Acoustic Impedance( $Z$ ), Relaxation Time( $T$ ), Free Volume( $V_f$ ), Molar Volume( $V_m$ ) and Internal Pressure( $\Pi_i$ ) for n-Hexane – Tetrahydrofuran binary liquid mixture at 305.15 K.

Mole fraction of Tetrahydrofuran( $x$ )	Adiabatic compressibility $\beta \times 10^{-10}$ ( $\text{Kg}^{-1} \text{ms}^{-2}$ )	Free length $L_f \times 10^{-11}$ (m)	Acoustic impedance $Z$ ( $\text{Kg}^{-2} \text{ms}^{-1}$ )	Relaxation time $\tau \times 10^{-13}$ (s)	Free volume $V_f \times 10^{-3}$ (ml)	Molar volume $V_m \times 10^{-5}$ ( $\text{m}^3$ )	Internal pressure $\Pi_i \times 10^5$ (atm)
0.0	17.8109	8.7911	0.6028	7.4663	14.5671	133.1376	1.7536
0.1	15.9251	8.3127	0.6396	6.9157	14.5879	130.1197	1.7894
0.2	13.3604	7.6139	0.7066	5.9658	15.2892	124.9490	1.8462
0.3	12.4681	7.3553	0.7392	5.7054	14.8954	120.2980	1.9436
0.4	11.6349	7.1053	0.7778	5.5646	13.9603	114.4367	2.1099
0.5	11.0073	6.911	0.8098	5.4699	13.1313	109.6343	2.2629
0.6	10.2307	6.6627	0.8542	5.3677	12.1385	104.1366	2.4722
0.7	9.4845	6.4152	0.9003	5.1393	11.649	99.2729	2.6521
0.8	8.5059	6.0752	0.9684	4.8279	11.1541	93.9250	2.8788
0.9	8.1201	5.9335	1.0369	4.8536	10.1341	89.1763	3.1625
1.0	7.3131	5.6331	1.0852	4.6111	9.511	83.7222	3.4941

**Table 7:** Acoustic parameters Adiabatic Compressibility( $\beta$ ), Free Length( $L_f$ ), Acoustic Impedance( $Z$ ), Relaxation Time( $T$ ), Free Volume( $V_f$ ), Molar Volume( $V_m$ ) and Internal Pressure( $\Pi_i$ ) for n-Hexane – Tetrahydrofuran binary liquid mixture at 309.15 K.

Mole fraction of Tetrahydrofuran ( $x$ )	Adiabatic compressibility $\beta \times 10^{-10}$ ( $\text{Kg}^{-1} \text{ms}^{-2}$ )	Free length $L_f \times 10^{-11}$ (m)	Acoustic impedance $Z$ ( $\text{Kg}^{-2} \text{ms}^{-1}$ )	Relaxation time $\tau \times 10^{-13}$ (s)	Free volume $V_f \times 10^{-3}$ (ml)	Molar volume $V_m \times 10^{-5}$ ( $\text{m}^3$ )	Internal pressure $\Pi_i \times 10^5$ (atm)
0.0	19.3344	9.2253	0.5768	7.7028	14.853	133.9655	1.7488
0.1	17.0059	8.652	0.6184	7.0971	14.7576	130.3198	1.8017
0.2	14.237	7.9164	0.6835	5.9776	16.0225	125.3059	1.8335
0.3	13.2734	7.6438	0.7158	5.865	14.998	120.5102	1.9593
0.4	12.2765	7.3511	0.7559	5.6406	14.2758	114.8119	2.1113
0.5	11.4593	7.1022	0.7933	5.4561	13.5948	109.7407	2.2629
0.6	10.7229	6.8702	0.8311	5.3328	12.7705	104.9379	2.4344
0.7	10.1412	6.6813	0.8695	5.2707	11.8117	99.5448	2.663
0.8	9.4818	6.4604	0.9159	5.153	10.9967	94.1847	2.9183
0.9	8.8051	6.2256	0.9673	5.0658	10.102	89.2196	3.2049
1.0	8.1107	5.9751	1.0274	4.9237	9.3573	84.2209	3.5276

**Table 8:** Acoustic parameters Adiabatic Compressibility( $\beta$ ), Free Length( $L_f$ ), Acoustic Impedance( $Z$ ), Relaxation Time( $T$ ), Free Volume( $V_f$ ), Molar Volume( $V_m$ ) and Internal Pressure( $\Pi_i$ ) for n-Hexane – Tetrahydrofuran binary liquid mixture at 313.15 K.

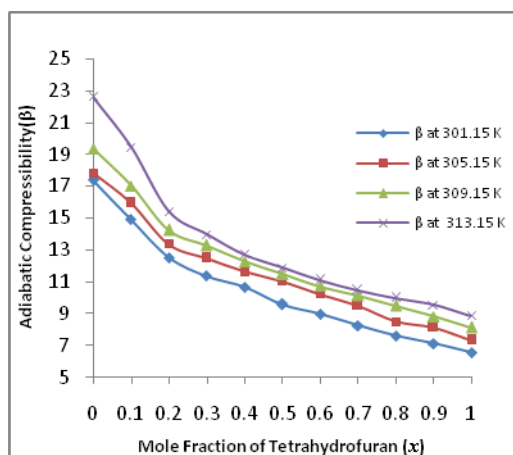
Mole fraction of Tetrahydrofuran( $x$ )	Adiabatic compressibility $\beta \times 10^{-10}$ ( $\text{Kg}^{-1} \text{ms}^{-2}$ )	Free length $L_f \times 10^{-11}$ (m)	Acoustic impedance $Z$ ( $\text{Kg}^{-2} \text{ms}^{-1}$ )	Relaxation time $\tau \times 10^{-13}$ (s)	Free volume $V_f \times 10^{-3}$ (ml)	Molar volume $V_m \times 10^{-5}$ ( $\text{m}^3$ )	Internal pressure $\Pi_i \times 10^5$ (atm)
0.0	22.612	10.048	0.532	8.6227	14.1564	134.6352	1.7866
0.1	19.4214	9.3122	0.5763	7.8126	14.202	131.3903	1.8259
0.2	15.4069	8.2941	0.6549	6.3641	15.5527	126.1401	1.8572
0.3	13.9617	7.8955	0.6961	5.929	15.3855	121.1336	1.9527
0.4	12.719	7.5359	0.7403	5.6184	14.8184	115.553	2.0919
0.5	11.8655	7.2787	0.7767	5.4122	14.2031	110.5531	2.2342
0.6	11.1003	7.0401	0.8152	5.2985	13.274	105.3646	2.4195
0.7	10.4421	6.8282	0.8558	5.2364	12.2229	99.8051	2.6569
0.8	9.9725	6.6729	0.8913	5.2136	11.2563	94.5651	2.9154

0.9	9.5482	6.5294	0.9268	5.2884	10.1002	89.633	3.2242
1.0	8.8689	6.2928	0.9816	5.2125	9.1981	84.3687	3.5843

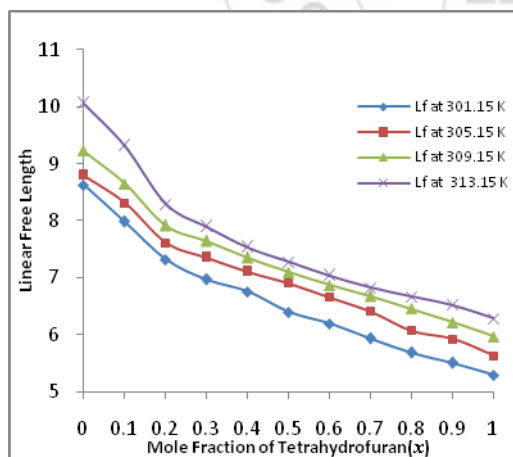
**Adiabatic Compressibility ( $\beta$ ):**

The plots of adiabatic compressibility against mole fraction of Tetrahydrofuran of n-Hexane - Tetrahydrofuran binary mixture at 301.15K, 305.15K, 309.15K and 313.15K are given in fig.4.

According to Forte and Moore [23] hydrogen bonding between unlike components makes a negative contribution to compressibility. It may be noted that in the three different temperatures, the ( $\beta$ ) value decreases with increase in concentration of the first component indicating the possibility of stronger interactions at higher concentration. It is also observed that the interactions are more at lower temperature at a specific concentration.



**Figure 4:** Plots of Adiabatic Compressibility Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures



**Figure 5:** Plots of Linear free Length Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures

**LINEAR FREE LENGTH ( $L_f$ ):**

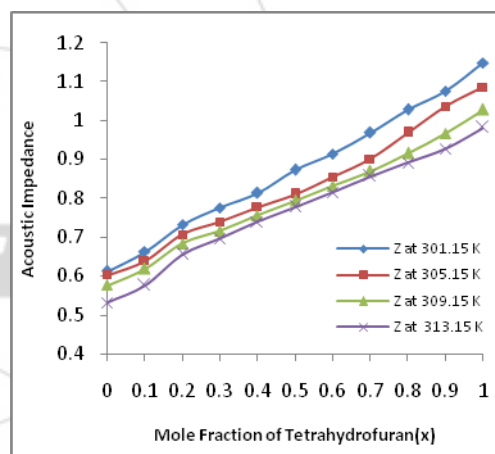
The free length of a system is a measure of intermolecular attraction between the components in binary mixtures. This increase in free length indicates weakening of intermolecular attraction. As the ultrasonic velocity increases due to the increase in concentration, the intermolecular free length has to decrease and vice versa

[24].

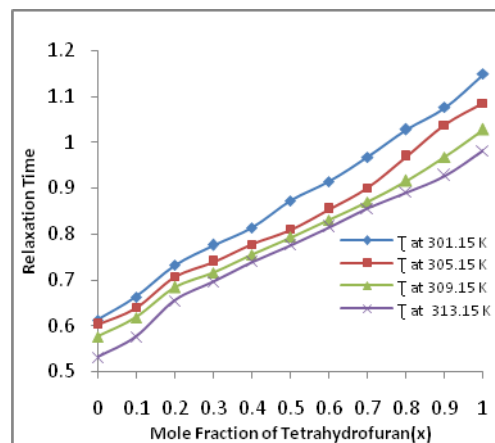
The linear free length values decreases with increase in concentration of Tetrahydrofuran in n-Hexane system at the three different temperatures which shows that the dipole-induced-dipole interactions are more at higher concentration of Tetrahydrofuran in all the systems. But all the four different temperatures which indicates the strong attractions present in lower concentration of Tetrahydrofuran. Fig.5 represents plots of linear free length for n-Hexane – Tetrahydrofuran system at 301.15K, 305.15K, 309.15K and 313.15K.

**ACOUSTIC IMPEDANCE (Z):**

The acoustic impedance increases uniformly in n-Hexane – Tetrahydrofuran system at all the temperatures investigated. The increase in acoustic impedance with concentration can be explained on the basis of lyophobic interaction between solute and solvent molecules [25, 26]. The plots of acoustic impedance versus mole fraction of Tetrahydrofuran in n-Hexane – Tetrahydrofuran system at different temperatures are given in fig.6.



**Figure 6:** Plots of Acoustic Impedance Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures



**Figure 7:** Plots of Relaxation Time Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures

**RELAXATION TIME ( $\tau$ ):**

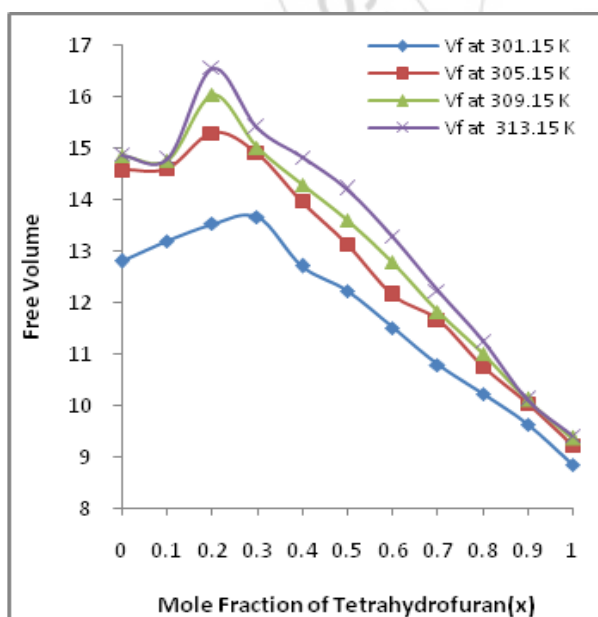
Tables 5- 8 contain the relaxation time values for two systems at four different temperatures. Figure 7 contain plots of relaxation time against mole fraction of Tetrahydrofuran for n-Hexane – Tetrahydrofuran system. In n-Hexane – Tetrahydrofuran system, the relaxation time increases at lower concentration and decreases at higher concentration of Tetrahydrofuran in all the systems. This shows that the molecular interaction is strong at lower concentration and relatively weak at higher concentration.

**FREE VOLUME ( $V_f$ ):**

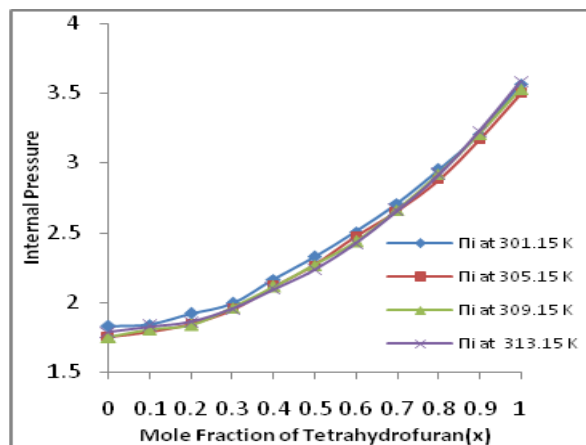
Tables 5-8 contain the free volume values for four different temperatures. Fig.8 contains plots of free volume against mole fraction of Tetrahydrofuran for n-Hexane – Tetrahydrofuran system at 301.15K, 305.15 K, 309.15K and 313.15K. The trend present in n-Hexane – Tetrahydrofuran system is that the free volume increases with increase in concentration of first component.

**INTERNAL PRESSURE ( $\Pi_i$ ):**

The internal pressure in a binary liquid mixture is a measure of cohesive forces between the components. The internal pressure values for all the systems have been obtained from the equation suggested by Suryanarayana [27] Tables 5-8 contain the internal pressure values for n-Hexane – Tetrahydrofuran system at four different temperatures. Fig 9 contains the plots of internal pressure against mole fraction of Tetrahydrofuran for n-Hexane – Tetrahydrofuran system. The internal pressure values decreases when the concentration of n-Hexane decreases which shows the strong interaction present at lower concentration. It is also interesting to observe that the free volume of the system increases as internal pressure decreases. The internal pressure value increases when the free volume of the system decreases.



**Figure 8:** Plots of Free Volume Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures



**Figure 9:** Plots of Internal Pressure Vs Mole Fraction of Tetrahydrofuran(x) for n-Hexane – Tetrahydrofuran System at various Temperatures

**5. Conclusion**

The dependence of ultrasonic velocity and other derived parameters on composition of the mixtures is indication of the presence of molecular interactions. The interaction primarily of dipole –induce- dipole type. The result indicates the existence of molecular interaction between the Tetrahydrofuran and the solvent in their solutions. The result is also shows the presence of higher degree of molecular interaction between n-hexane and tetrahydrofuran in solution.

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