EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 5
Issue: 02
1194-1203
Year: 2018

ULTRASONIC STUDIES OF MOLECULAR INTERACTIONS IN BINARY LIQUID MIXTURES

Dr. A. Suryanarayana Reddy[1] and M. Satyanarayana[2]*

[1]Department of Physics, S.V Degree College, Kadapha, Andhra Pradesh-516004.
[2*]Department of Physics, Osmania University, Hyderabad, Telangana.

***Corresponding Author: M. Satyanarayana**
Department of Physics, Osmania University, Hyderabad, Telangana.

Article Received on 20/12/2017 **Article Revised on 10/01/2018** **Article Accepted on 31/01/2018**

ABSTRACT
The various acoustical parameters such as adiabatic compressibility, absorption coefficient, relaxation time, free length, free volume, internal pressure, cohesive energy, acoustic impedance and available volume, have been evaluated from the measured ultrasonic velocity, density and viscosity values for the six binary mixtures. The value of molecular interaction parameter (X U) indicates the strength of molecular interactions. The excess thermodynamic parameters such as excess ultrasonic velocity, excess compressibility, excess free volume, excess free length and excess impedance have been determined for all the six binary liquid mixtures.

KEYWORDS: Binary Liquid Mixture, absorption coefficient, Benzene and carbon tetrachloride.

1. INTRODUCTION
In recent years, the measurement of ultrasonic velocity has been successfully employed in understanding the nature of molecular interactions in pure liquids and liquid mixtures. Ultrasonic velocity measurements are highly sensitive to molecular interactions and can be used to provide qualitative information about the physical nature and strength of molecular interaction in liquid mixtures. The ultrasonic velocity of a liquid is fundamentally related to the binding forces between atom and molecules and has been successfully employed in understanding the nature of molecular interaction in pure liquids and binary and ternary mixtures. Variations in ultrasonic velocity and related parameters have shed much light upon the structural changes associated with liquid mixtures of weakly or strongly interacting compounds. The study of molecular associations in ternary mixtures having an alcohol as one component is of particular interest since alcohols are strongly self-associated liquids with a three-dimensional network of hydrogen bonds and can be associated with any other group having some degree of polar attractions. A survey of literature has shown that a few attempts have been made to obtain ultrasonic velocity data for ternary liquid mixtures.

The molecular interactions in pure and binary liquid mixtures can be analyzed using ultrasonic velocity measurements which are of considerable interest for the physicists in the last few decades. Excess free length (L_f E) can be used to access the molecular interactions in binary liquids and a comparison of the sign of L_f E with excess volume (V^E) or with other thermodynamic parameters has been made by several workers.

2. EXPERIMENTAL METHODS
2.1Materials
The chemicals used were of analytical reagent (AR) and spectroscopic reagent (SR) grade which were obtained from E Merck Ltd (India) and were used as such without further purification. The ternary liquid mixtures of various concentrations were prepared out of which the mole fraction of isobutyl methyl ketone was kept fixed at 0.4. The mole fractions of DMAC and diethyl ether were varied from 0 to 0.6 to have the mixture of different compositions. Liquid mixtures of different mole fractions were prepared with a precision of 0.0001g using an electronic digital balance.

2.2. Density Measurement
The density of liquid mixture was determined by a specific gravity bottle of 10ml capacity. The specific gravity bottle with the liquid mixture was immersed in a temperature controlled water bath. The density was determined using the relation.

$\rho 2 = (w2/w1)\ \rho 1$

Where w1, w2, ρ1 and ρ2 are mass of distilled water, mass of liquid mixture, density of distilled water and density of liquid mixture respectively.

2.3 Velocity Measurement
The velocity of ultrasonic waves in the liquid mixture was measured by using multi frequency interferometer

(Model M-82S) with a high degree of accuracy operating at different frequencies supplied by Mittal Enterprises, New Delhi. The measuring cell of the interferometer is a specially designed double walled vessel with provision to circulate water at constant temperature i.e.308K. The high frequency generator excites a quartz crystal fixed at the bottom of the vessel, at its resonant frequency. A fine micrometer screw at the top of the cell is used to raise or lower the reflector plate in the liquid through a known distance. The measuring cell is connected to the output terminals of the high frequency generator through a cable. Ultrasonic waves normal to quartz crystal are reflected from the reflector plate. Stationary waves are formed in the region between reflector plate and the quartz crystal. The micrometer is slowly moved till a number of maximum readings (N) of the anode current is passed. The total distance (d) moved by the micrometer is noted. The ultrasonic velocity was determined using the relation

$U = \lambda f$ (14)

Where wavelength of the ultrasonic waves in the binary liquid mixture $\lambda = 2d/N$ and f is the frequency of the generator.

2.4 Theory

The acoustical parameters such as adiabatic compressibility (Ks), intermolecular free length (Lf), acoustic Impedance (Z), molar volume (Vm) and available volume (Va) have been calculated using the measured data (U and ρ) from the following relations.

$Ks = (U2\rho)-1$

$Lf = k (KS) 1/2$

$Z = \rho U$

$Vm = M/\rho$

$Va = (M / \rho) [1-(U/ U\infty)]$

Where k is a temperature dependent constant, M is the molecular mass of the liquid mixture and $U\infty$=1600 m/s.

The excess values of the above acoustical parameters have been calculated from the following relations.

$AE = Aexp – (X1A1 + X 2A2+ X3A3)$

Where X1, X1 and X3 are mole fractions of DMAC, isobutyl methyl ketone and diethyl ether respectively and A is any acoustic parameter.

Molar sound velocity(R), molar compressibility (B), Lennard Jones potential repulsive term exponent (n), relative association (RA) and interaction parameter (χ) have been calculated from the following relations.

$R = (M/\rho) U1/3$

$B = (M/ \rho) (Ks)-1/7$

$n = (6 Vm / Va) – 1/3$

$RA = (\rho / \rho0) (U0/ U) 1/3$

$\chi = (U/Uideal) 2 -1$

Where ρ0 and U0 are density and ultrasonic velocity of DMAC respectively.

The ideal mixing velocity Uideal is given by

$U ideal = X1U1+X2U2+ X3U3$

3. RESULT AND DISCUSSION

The results obtained in the ultrasonic velocity investigations of the following six binary systems are presented and discussed.

1. Benzene – carbon tetrachloride
2. Bromobenzene – chlorobenzene
3. Ethanol – water
4. Ethanol – p-cresol
5. Ethanol – phenol
6. Ethanol – pyridine

Benzene and carbon tetrachloride are non-polar and there are only induced dipole-induced dipole interactions in the mixture of benzene and carbon tetrachloride. However, dipole-dipole attraction exists in bromobenzene-chlorobenzene system. Phenols are dipolar molecules and they are associated through hydrogen bonding which is evident from the spectra. Four binary systems are chosen such that they contain ethanolas the common component and the second component is varied. In these four systems, the variation in the intermolecular attraction is mainly due to the second component. Thus, acoustical studies are made on six binary liquid mixtures such that different types of molecular attractions could be assessed.

The acoustical parameters were calculated for benzene-carbon tetrachloride and bromobenzene-chlorobenzene systems of various compositions, from ultrasonic velocities, densities and viscosities at 303 K and they are given in Tables 1 – 4. The data for the other four systems at303 K are given in Tables 5 – 12. These data are discussed in the light of molecular interactions between the components which exist in the six binary liquid systems

The adiabatic compressibility (κ) values for various compositions of six binary mixtures have been computed from the measured values of ultrasonic velocities and densities (Tables 1, 3, 5, 7, 9 and 11). The plots of adiabatic compressibility vs mole fraction of the first component are given inFig.2 for benzene-carbon tetrachloride and bromobenzene-chlorobenzene systems. In both the cases the value of compressibility decreases with increase in concentration indicating strong molecular interaction over a wide range of concentration. Slightly steeper curve obtained in bromobenzene-chlorobenzene system shows that the molecular attractions (dipole-dipole) in these systems are slightly stronger than induced dipole-induced dipole attractions in benzene-carbon tetrachloride system.

The absorption coefficient (α/f2) values in a system can be used to ascertain the variation in intermolecular attraction and also to establish the existence of similar types of interaction in different binary systems. In the binary systems studied, the absorption coefficient values increase with increase in the mole fraction of the first component in three systems namely, bromobenzene-chlorobenzene, ethanol-water and ethanol-pyridine

systems, while it decreases in other systems (Tables 1, 3, 5, 7, 9 and 11). This trend suggests that different types of molecular interaction exist in these binary systems.

The molecular interaction parameter (χU) values are calculated and presented in Tables 1, 3, 5, 7, 9 and 11 for the six binary systems. These values are negative for benzene-carbon tetrachloride andbromobenzene-chlorobenzene mixtures indicating the presence of attractive forces. In benzene-carbon tetrachloride system. The internal pressure (π^i) in a binary mixture is a measure of intermolecular attraction between the components. The internal pressure values for various compositions for all the six systems have been obtained from the equation suggested by Suryanarayana. The internal pressure values for benzene-carbon tetrachloride system and bromobenzene-chlorobenzene system are given in Tables 1 and 3 respectively. The internal pressure values increase slightly with increase in concentration for both the systems indicating the existence of relatively weak interactions in these two systems.

Table 1: Acoustical impedance (z), available volume (v^a), Lenard Jones potential (LJP), excess ultrasonic velocity (u^e), excess viscosity (η^E), excess adiabatic compressibility (κ^e),excess free length (l_f^e), excess free volume (v_f^e), excess acoustical impedance (z^e) and excess available volume (v_a^e) values at various mole fractions of benzene - carbon tetrachloride system.

x_1	ρ 10^3 (kg m^{-3})			u (ms^{-1})			η 10^3 (N s m^{-2})		
***T*/K**	**298.15**	**303.15**	**308.15**	**298.15**	**303.15**	**308.15**	**298.15**	**303.15**	**308.15**
Benzene-carbon tetrachloride									
0.0000	0.7843	0.7790	0.7735	1162.0	1141.2	1121.4	0.3027	0.2918	0.2809
0.0702	0.7925	0.7876	0.7828	1174.8	1152.9	1132.7	0.3418	0.3218	0.3021
0.1468	0.8013	0.7967	0.7922	1188.7	1166.1	1145.3	0.3759	0.3527	0.3267
0.2269	0.8100	0.8057	0.8013	1202.5	1179.5	1158.5	0.4076	0.3810	0.3517
0.3135	0.8187	0.8144	0.8101	1216.6	1193.4	1172.4	0.4383	0.4098	0.3785
0.4051	0.8270	0.8227	0.8183	1230.8	1207.4	1186.4	0.4662	0.4358	0.4040
0.5072	0.8344	0.8300	0.8259	1244.7	1221.0	1200.0	0.4893	0.4553	0.4250
0.6160	0.8412	0.8369	0.8329	1258.0	1234.7	1214.0	0.5092	0.4750	0.4443
0.7355	0.8479	0.8436	0.8396	1271.8	1249.2	1228.8	0.5293	0.4947	0.4638
0.8629	0.8543	0.8498	0.8458	1285.8	1264.2	1244.3	0.5462	0.5144	0.4848
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0023	0.0023	0.0024	4.1703	4.1788	4.2027	0.0078	0.0073	0.0069

Ethanol-water

0.0000	0.7982	0.7947	0.7885	1191.6	1173.5	1153.8	0.3856	0.3653	0.3440
0.0856	0.8053	0.8020	0.7963	1205.5	1185.9	1165.1	0.4052	0.3822	0.3593
0.1724	0.8123	0.8091	0.8038	1218.5	1198.2	1176.8	0.4244	0.3996	0.3756
0.2624	0.8193	0.8160	0.8109	1231.6	1210.5	1188.9	0.4439	0.4176	0.3922
0.3370	0.8248	0.8214	0.8165	1241.7	1220.3	1198.7	0.4594	0.4320	0.4061
0.4330	0.8314	0.8278	0.8230	1253.4	1231.5	1210.3	0.4781	0.4494	0.4230
0.5555	0.8388	0.8350	0.8304	1264.8	1242.9	1221.9	0.4987	0.4688	0.4417
0.6600	0.8446	0.8407	0.8362	1273.5	1251.8	1231.1	0.5145	0.4844	0.4575
0.7690	0.8503	0.8462	0.8419	1282.2	1260.7	1240.3	0.5308	0.5002	0.4738
0.8831	0.8558	0.8514	0.8472	1291.2	1269.8	1250.2	0.5472	0.5168	0.4909
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0019	0.0018	0.0019	3.2507	3.1806	3.2177	0.0054	0.0051	0.0050

Table-2: Acoustical Impedance (Z), Available Volume (Va), Lenard Jones Potential (LJP),Excess Ultrasonic Velosity (U^e), Excess Viscosity ($H\eta^e$), Excess Adiabatic Compressibility (K_E),Excess Free Length (L_fe), Excess Free Volume (V_fe), Excess Acoustical Impedance (Ze) And Excessavailable Volume (V^ae) Values At Various Mole Fractions Of Benzene - Carbon Tetrachloride System.

x_1	ρ (10³ kg m⁻³)			u (m s⁻¹)			η (10³ N s m⁻²)		
T/K	298.15	303.15	308.15	298.15	303.15	308.15	298.15	303.15	308.15
Benzene-carbon tetrachloride									
0.0000	0.7843	0.7790	0.7735	1162.0	1141.2	1121.4	0.3027	0.2918	0.2809
0.0702	0.7925	0.7876	0.7828	1174.8	1152.9	1132.7	0.3418	0.3218	0.3021
0.1468	0.8013	0.7967	0.7922	1188.7	1166.1	1145.3	0.3759	0.3527	0.3267
0.2269	0.8100	0.8057	0.8013	1202.5	1179.5	1158.5	0.4076	0.3810	0.3517
0.3135	0.8187	0.8144	0.8101	1216.6	1193.4	1172.4	0.4383	0.4098	0.3785
0.4051	0.8270	0.8227	0.8183	1230.8	1207.4	1186.4	0.4662	0.4358	0.4040
0.5072	0.8344	0.8300	0.8259	1244.7	1221.0	1200.0	0.4893	0.4553	0.4250
0.6160	0.8412	0.8369	0.8329	1258.0	1234.7	1214.0	0.5092	0.4750	0.4443
0.7355	0.8479	0.8436	0.8396	1271.8	1249.2	1228.8	0.5293	0.4947	0.4638
0.8629	0.8543	0.8498	0.8458	1285.8	1264.2	1244.3	0.5462	0.5144	0.4848
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0023	0.0023	0.0024	4.1703	4.1788	4.2027	0.0078	0.0073	0.0069
Ethanol-water									
0.0000	0.7982	0.7947	0.7885	1191.6	1173.5	1153.8	0.3856	0.3653	0.3440
0.0856	0.8053	0.8020	0.7963	1205.5	1185.9	1165.1	0.4052	0.3822	0.3593
0.1724	0.8123	0.8091	0.8038	1218.5	1198.2	1176.8	0.4244	0.3996	0.3756
0.2624	0.8193	0.8160	0.8109	1231.6	1210.5	1188.9	0.4439	0.4176	0.3922
0.3370	0.8248	0.8214	0.8165	1241.7	1220.3	1198.7	0.4594	0.4320	0.4061
0.4330	0.8314	0.8278	0.8230	1253.4	1231.5	1210.3	0.4781	0.4494	0.4230
0.5555	0.8388	0.8350	0.8304	1264.8	1242.9	1221.9	0.4987	0.4688	0.4417
0.6600	0.8446	0.8407	0.8362	1273.5	1251.8	1231.1	0.5145	0.4844	0.4575
0.7690	0.8503	0.8462	0.8419	1282.2	1260.7	1240.3	0.5308	0.5002	0.4738
0.8831	0.8558	0.8514	0.8472	1291.2	1269.8	1250.2	0.5472	0.5168	0.4909
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0019	0.0018	0.0019	3.2507	3.1806	3.2177	0.0054	0.0051	0.0050

Table 3: The values of molar volume, Vm and free volume, VF as functions of mole fraction, x_1 of Ethanol-water/P-cresol/Phenol/Pyridine mixtures at different temperatures.

x_1	ρ (10³ kg m⁻³)			u (m s⁻¹)			η (10³ N s m⁻²)		
T/K	298.15	303.15	308.15	298.15	303.15	308.15	298.15	303.15	308.15
Benzene-Carbon Tetrachloride									
0.0000	0.7982	0.7947	0.7885	1191.6	1173.5	1153.8	0.3856	0.3653	0.3440
0.0856	0.8053	0.8020	0.7963	1205.5	1185.9	1165.1	0.4052	0.3822	0.3593
0.1724	0.8123	0.8091	0.8038	1218.5	1198.2	1176.8	0.4244	0.3996	0.3756
0.2624	0.8193	0.8160	0.8109	1231.6	1210.5	1188.9	0.4439	0.4176	0.3922
0.3370	0.8248	0.8214	0.8165	1241.7	1220.3	1198.7	0.4594	0.4320	0.4061
0.4330	0.8314	0.8278	0.8230	1253.4	1231.5	1210.3	0.4781	0.4494	0.4230
0.5555	0.8388	0.8350	0.8304	1264.8	1242.9	1221.9	0.4987	0.4688	0.4417
0.6600	0.8446	0.8407	0.8362	1273.5	1251.8	1231.1	0.5145	0.4844	0.4575
0.7690	0.8503	0.8462	0.8419	1282.2	1260.7	1240.3	0.5308	0.5002	0.4738
0.8831	0.8558	0.8514	0.8472	1291.2	1269.8	1250.2	0.5472	0.5168	0.4909
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0019	0.0018	0.0019	3.2507	3.1806	3.2177	0.0054	0.0051	0.0050

Bromo benzene-chlorobenzene									
0.0000	1.0224	1.0179	1.0135	1476.2	1457.2	1441.2	1.6788	1.5328	1.4073
0.1093	1.0068	1.0027	0.9987	1463.8	1440.8	1423.3	1.5606	1.4257	1.3102
0.2145	0.9917	0.9874	0.9835	1449.6	1425.8	1407.6	1.4457	1.3225	1.2170
0.3206	0.9759	0.9717	0.9678	1434.7	1410.6	1391.3	1.3292	1.2180	1.1228
0.4281	0.9595	0.9551	0.9511	1417.5	1394.6	1374.8	1.2105	1.1121	1.0272
0.5229	0.9445	0.9400	0.9360	1401.0	1379.0	1358.9	1.1055	1.0180	0.9425
0.6213	0.9282	0.9237	0.9196	1381.9	1359.6	1339.4	0.9949	0.9188	0.8535
0.7157	0.9121	0.9076	0.9035	1362.6	1339.8	1319.7	0.8879	0.8233	0.7678
0.8392	0.8904	0.8859	0.8818	1336.6	1313.9	1294.2	0.7472	0.6978	0.6554
0.9074	0.8780	0.8735	0.8695	1321.1	1299.4	1279.4	0.6694	0.6286	0.5933
1.0000	0.8609	0.8560	0.8516	1299.8	1279.5	1260.7	0.5635	0.5344	0.5091
Uncertainty	0.0049	0.0049	0.0049	5.4228	5.4031	5.4819	0.0338	0.0303	0.0272

Table-4: Acoustical impedance (z), available volume (v_a), lenard jones potential (ljp), excess ultrasonic velosity (ue), excess viscosity (H^e), excess adiabatic compressibility (κ_e),excess free engths (l_f^e), excess free volume (v_f^e), excess acoustical mpedance (ze) andexcess available volume (^{vae}) values t various mole fractions of bromobenzene - chlorobenzene system.

x1	$V_m \times 10^6$ (m^3 mol^{-1})			$V_f \times 10^6$ (m^3 mol^{-1})		
***T*/K**	**298.15**	**303.15**	**308.15**	**298.15**	**303.15**	**308.15**
0.4330	97.1650	97.5876	98.1567	0.3481	0.3720	0.3969
0.5555	99.2330	99.6846	100.2368	0.3464	0.3702	0.3946
0.6600	101.0298	101.4985	102.0447	0.3467	0.3698	0.3930
0.7690	102.9202	103.4189	103.9471	0.3471	0.3700	0.3916
0.8831	104.9293	105.4716	105.9944	0.3483	0.3701	0.3906
1.0000	107.0275	107.6402	108.1963	0.3499	0.3701	0.3892
		Bromobenze-Chlorobenze				
0.0000	117.5176	118.0371	118.5496	0.1226	0.1379	0.1541
0.1093	116.2977	116.7732	117.2409	0.1300	0.1454	0.1620
0.2145	115.0972	115.5984	116.0568	0.1383	0.1542	0.1713
0.3206	113.9154	114.4077	114.8688	0.1484	0.1650	0.1826
0.4281	112.7243	113.2436	113.7198	0.1610	0.1784	0.1967
0.5229	111.7031	112.2378	112.7175	0.1746	0.1930	0.2119
0.6213	110.6953	111.2346	111.7305	0.1925	0.2117	0.2312
0.7157	109.7503	110.2945	110.7950	0.2150	0.2348	0.2549
0.8392	108.5400	109.0913	109.5986	0.2567	0.2772	0.2977
0.9074	107.8972	108.4530	108.9520	0.2887	0.3095	0.3298
1.0000	107.0275	107.6402	108.1963	0.3499	0.3701	0.3892

Table 5: A_i Coefficients of Equation with the standard Deviations σ for the binary mixtures at different Temperatures.

***T* / (K)**	A_0	A_1	A_2	A_3	A_4	
Ethanol+water V_m^E (10^{-6} m^3mol^{-1})						
298.15	-1.9224	-0.9872	2.3450	1.4860	-1.6635	0.0082
303.15	-2.2686	-1.0140	1.6468	1.4092	-0.9604	0.0101
308.15	-2.6057	-0.8674	1.0659	0.9284	-0.9258	0.0034
V_f^E (10^{-6} m^3mol^{-1})						
298.15	-2.5856	-1.6664	0.3982	-0.5531	-2.5899	0.0037
303.15	-2.2268	-1.7222	0.1060	0.4469	-1.0494	0.0101
308.15	-1.7817	-1.2999	1.0367	1.0007	-0.8080	0.0062
***T* / (K)**	A_0	A_1	A_2	A_3	A_4	
Ethanol + P-cresol V_m^E (10^{-6} m^3mol^{-1})						
298.15	-1.5965	-0.3040	0.9209	0.6892	-0.8566	0.0028
303.15	-1.8597	-0.3201	0.3294	0.6563	-0.4370	0.0038
308.15	-2.1559	-0.4652	0.0428	0.8964	-0.5529	0.0046
V_f^E (10^{-6} m^3mol^{-1})						

298.15	-0.6386	-0.2668	0.2451	0.1297	-0.2813	0.0001
303.15	-0.5374	-0.2610	0.2419	0.1713	-0.1116	0.0006
308.15	-0.4692	-0.2704	0.2473	0.2427	-0.1326	0.0026
Ethanol + Phenol V_m^E **(10^{-6} m^3mol^{-1})**						
298.15	-1.2979	0.2301	0.8311	0.0876	-0.5183	0.0034
303.15	-1.4402	0.1594	0.3688	0.1868	-0.8120	0.0032
308.15	-1.6536	-0.0388	0.1964	0.5702	-1.4043	0.0056
V_f^E **(10^{-6} m^3mol^{-1})**						
298.15	-2.6109	1.4846	-0.7965	0.5393	-0.3172	0.0001
303.15	-2.5917	1.4106	-0.8352	0.4944	-0.1970	0.0001
308.15	-2.5503	1.3369	-0.7972	0.4626	-0.1588	0.0001

Table- 6: The values of $\bar{V}_{m,1}$, $\bar{V}_{,1}$, $V^*_{m,1}$, $\bar{V}^{E}_{m,1}$, $\bar{V}^{E}_{,1}$, $\bar{V}_{m,2}$, $\bar{V}_{,2}$, $V^*_{m,2}$, $\bar{V}^{E}_{m,2}$, and $\bar{V}^{E}_{,2}$ for the binary mixtures at different temperatures

T/(K)	$\bar{V}_{m,1}$	$\bar{V}_{,1}$	$V^*_{m,1}$	$\bar{V}^{E}_{m,1}$	$\bar{V}^{E}_{,1}$	$\bar{V}_{m,2}$	$\bar{V}_{,2}$	$V^*_{m,2}$	$\bar{V}^{E}_{m,2}$	$\bar{V}^{E}_{,2}$
(10^{-6} $m^3 \cdot mol^{-1}$)										
Ethanol + P-cresol										
298.15	105.402	105.589	107.026	-1.626	-1.439	72.772	72.746	74.053	-1.281	-1.308
303.15	106.398	105.683	107.640	-1.842	-1.957	72.965	72.829	74.557	-1.593	-1.728
308.15	106.088	105.568	108.196	-2.100	-2.629	73.225	72.911	75.087	-1.863	-2.177
Ethanol + Phenol										
298.15	105.708	105.641	107.026	-1.319	-1.386	89.194	88.888	90.341	-1.147	-1.453
303.15	106.203	105.823	107.640	-1.437	-1.817	89.358	88.919	90.739	-1.381	-1.820
308.15	106.264	105.920	108.196	-1.932	-2.276	89.886	89.241	91.452	-1.567	-2.211
Ethanol + Pyridine										
298.15	106.054	106.078	107.026	-0.974	-0.949	116.455	116.235	117.518	-1.063	-1.282
303.15	106.596	106.344	107.640	-1.044	-1.296	116.876	116.388	118.037	-1.161	-1.649
308.15	106.648	106.511	108.196	-1.548	-1.685	117.295	116.515	118.550	-1.255	-2.035

Table 7: The values of isentropic compressibility, k_s, isothermal compressibility, thermal expansion coefficient, and intermolecular free length, L_f as functions of mole fraction, x_1.

x1	*ks*	*T*		*Lf*
T/K	$_{10}$-10 $_{m}$2 $_{N}$-1	$_{10}$14 $_{m}$2 $_{N}$-1	10^4 K^{-1}	$_{10}$-11 $_{m}$
Benzene-Carbon Tetra Chloride				
T = 298.15 K				
0.0000	9.4429	1.3916	1.2768	6.3204
0.0702	9.1427	1.3427	1.2655	6.2192
0.1468	8.8320	1.2923	1.2534	6.1126
0.2269	8.5378	1.2448	1.2417	6.0099
0.3135	8.2524	1.1989	1.2301	5.9086
0.4051	7.9821	1.1558	1.2189	5.8110
0.5072	7.7356	1.1167	1.2085	5.7206
0.6160	7.5117	1.0815	1.1988	5.6372
0.7355	7.2915	1.0470	1.1892	5.5540
0.8629	7.0802	1.0141	1.1797	5.4729
1.0000	6.8753	0.9823	1.1703	5.3931
T = 303.15 K				

0.0000	9.8569	1.4452	1.2890	6.5164
0.0702	9.5524	1.3954	1.2777	6.4149
0.1468	9.2307	1.3433	1.2656	6.3060
0.2269	8.9214	1.2934	1.2537	6.1994
0.3135	8.6216	1.2455	1.2419	6.0944
0.4051	8.3379	1.2005	1.2305	5.9933
0.5072	8.0815	1.1601	1.2201	5.9004
0.6160	7.8380	1.1221	1.2099	5.8108
0.7355	7.5963	1.0846	1.1997	5.7205
0.8629	7.3629	1.0487	1.1897	5.6320
1.0000	7.1358	1.0139	1.1797	5.5445
T = 308.15 K				
0.0000	10.2806	1.5000	1.3010	6.7151
0.0702	9.9568	1.4469	1.2893	6.6085
0.1468	9.6234	1.3929	1.2771	6.4969
0.2269	9.2985	1.3408	1.2650	6.3863
0.3135	8.9807	1.2903	1.2529	6.2762
0.4051	8.6821	1.2432	1.2413	6.1710
0.5072	8.4083	1.2003	1.2305	6.0729
0.6160	8.1465	1.1596	1.2199	5.9776

Table -8: Ai Coefficients of Equation with the standard deviations σ for the binary mixtures at different Temperatures.

T / (K)	$A0$	$A1$	$A2$	$A3$	$A4$	
Bromobenzene - Chloro benzene						
k_s (10^{-10} m^2 N^{-1})						
298.15	-1.6301	-0.6206	0.3016	0.3875	-0.2712	0.0018
303.15	-1.6029	-0.6508	0.2563	0.5031	-0.1663	0.0026
308.15	-1.6493	-0.6545	0.3469	0.4464	-0.3344	0.0022
$_T^E$ (10^{-14} m^2 N^{-1})						
298.15	-0.2709	-0.1054	0.0474	0.0628	-0.0429	0.0003
303.15	-0.2689	-0.1103	0.0372	0.0776	-0.0232	0.0004
308.15	-0.2779	-0.1112	0.0475	0.0669	-0.0487	0.0003
^{E} (10^{-5} K^{-1})						
298.15	-0.5771	-0.2049	0.1664	0.1660	-0.1335	0.0008
303.15	-0.5468	-0.2124	0.1401	0.2012	-0.0934	0.0011
308.15	-0.5439	-0.2047	0.1553	0.1672	-0.1382	0.0008
L_f^E(10^{11} m)						
298.15	-0.5211	-0.1872	0.1317	0.1409	-0.1116	0.0006
303.15	-0.4993	-0.1971	0.1143	0.1810	-0.0756	0.0010
308.15	-0.5037	-0.1937	0.1416	0.1573	-0.1262	0.0008
Ethanol - Water						
k_s (10^{-10} m^2 N^{-1})						
298.15	-1.2495	-0.5098	0.5086	0.3179	-0.6087	0.0019
303.15	-1.1807	-0.4723	0.4277	0.2938	-0.3682	0.0021
308.15	-1.1821	-0.4601	0.5723	0.3810	-0.4946	0.0027
$_T^E$ (10^{-14} m^2 N^{-1})						
298.15	-0.0791	0.0743	0.0471	-0.0883	0.0003	-0.0791
303.15	-0.0744	0.0593	0.0457	-0.0511	0.0003	-0.0744
308.15	-0.0726	0.0793	0.0562	-0.0704	0.0002	-0.0726
^{E} (10^{-5} K^{-1})						
298.15	-0.4565	-0.1717	0.2271	0.1342	-0.2552	0.0008
303.15	-0.4192	-0.1550	0.1829	0.1159	-0.1536	0.0008
308.15	-0.4054	-0.1473	0.2269	0.1450	-0.1995	0.0011

Table-9: The values of $\overline{K}_{m,1}$, $\overline{K}_{\phi,1}$, $\overline{K}_{s,1}$, $\overline{K}^{E}_{m,1}$, $\overline{K}^{E}_{\phi,1}$, $\overline{K}_{m,2}$, $\overline{K}_{\phi,2}$, $\overline{K}_{s,2}$, $\overline{K}^{E}_{m,2}$ and $\overline{K}^{E}_{\phi,2}$ for the binary mixtures at different temperatures

T /(K)	$\overline{K}_{m,1}$	$\overline{K}_{\phi,1}$	$\overline{K}_{s,1}$	$\overline{K}^{E}_{m,1}$	$\overline{K}^{E}_{\phi,1}$	$\overline{K}_{m,2}$	$\overline{K}_{\phi,2}$	$\overline{K}_{s,2}$	$\overline{K}^{E}_{m,2}$	$\overline{K}^{E}_{\phi,2}$
					(10^{-14} m^5 N^{-1} mol^{-1})					
Ethanol-Water										
298.15	6.738	6.606	7.359	-0.620	-0.753	6.398	6.417	6.993	-0.595	-0.576
303.15	7.1028	6.965	7.681	-0.578	-0.716	6.772	6.799	7.349	-0.577	-0.549
308.15	7.352	7.197	7.994	-0.642	-0.797	7.125	7.153	7.719	-0.594	-0.567
Ethanol-P-cresol										
298.15	6.488	6.255	7.359	-0.871	-1.104	7.182	7.187	7.971	-0.789	-0.784
303.15	6.864	6.641	7.681	-0.817	-1.040	7.549	7.552	8.291	-0.742	-0.739
308.15	7.180	6.978	7.994	-0.813	-1.016	7.947	7.949	8.712	-0.765	-0.763
Ethanol-Phenol										
298.15	6.316	6.173	7.359	-1.042	-1.185	4.116	3.811	5.275	-1.158	-1.463
303.15	6.671	6.618	7.681	-1.010	-1.063	4.306	4.024	5.461	-1.155	-1.437
308.15	6.976	6.916	7.994	-1.018	-1.077	4.481	4.197	5.632	-1.151	-1.435

Table-10: Values of acoustic impedance, Z as functions of mole fraction, x_1 of Ethanol- water mixtures at different temperatures.

x_1		Z (10^5 kg m^{-2} s^{-1})	
T/K	298.15	303.15	308.15
Ethanol - water			
0.0000	9.1136	8.8899	8.6740
0.0702	9.3103	9.0802	8.8668
0.1468	9.5251	9.2903	9.0731
0.2269	9.7403	9.5032	9.2831
0.3135	9.9603	9.7190	9.4976
0.4051	10.1787	9.9333	9.7083
0.5072	10.3858	10.1343	9.9108
0.6160	10.5823	10.3332	10.1114
0.7355	10.7836	10.5383	10.3170
0.8629	10.9846	10.7432	10.5243
1.0000	11.1900	10.9525	10.7361

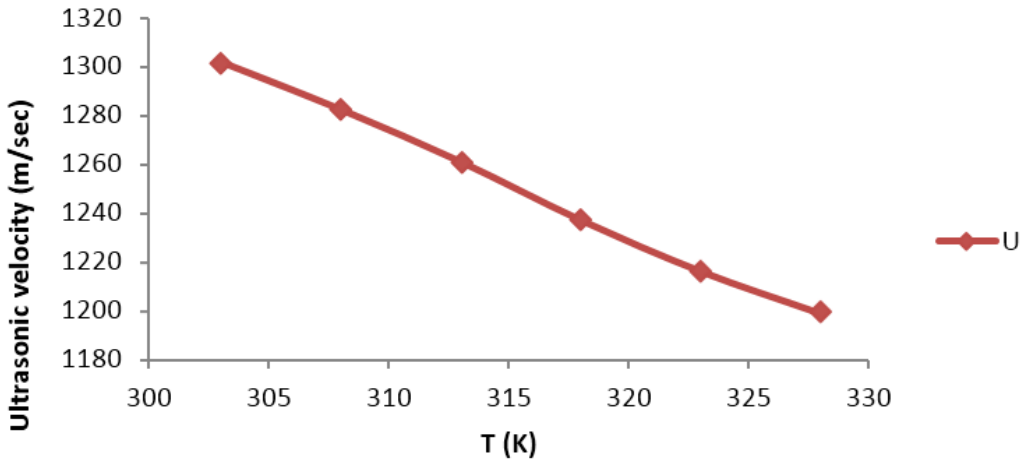
Table 11: Values of free energy of activation, ΔG^* and internal pressure, π_i as functions of mole fraction, x_1 Ethanol-water/P-cresol/phenol mixtures at different temperatures.

x1	ΔG^* (10^4 J mol^{-1})			π_i (10^6 atm)		
T/K	298.15	303.15	308.15	298.15	303.15	308.15
Ethanol-water						
0.0000	2.7109	2.7488	2.7862	3.8951	3.9061	3.9114
0.0702	2.7484	2.7809	2.8121	3.9545	3.9221	3.8812
0.1468	2.7797	2.8118	2.8400	3.9535	3.9163	3.8514
0.2269	2.8076	2.8391	2.8668	3.9240	3.8811	3.8106
0.3135	2.8339	2.8658	2.8940	3.8712	3.8294	3.7610
0.4051	2.8577	2.8899	2.9195	3.7946	3.7532	3.6924
0.5072	2.8791	2.9106	2.9422	3.6802	3.6316	3.5858
0.6160	2.8989	2.9313	2.9638	3.5501	3.5071	3.4660
0.7355	2.9190	2.9522	2.9856	3.4131	3.3737	3.3374
0.8629	2.9375	2.9730	3.0081	3.2658	3.2384	3.2111
1.0000	2.9562	2.9939	3.0322	3.1209	3.1028	3.0907
Ethanol-P-cresol						

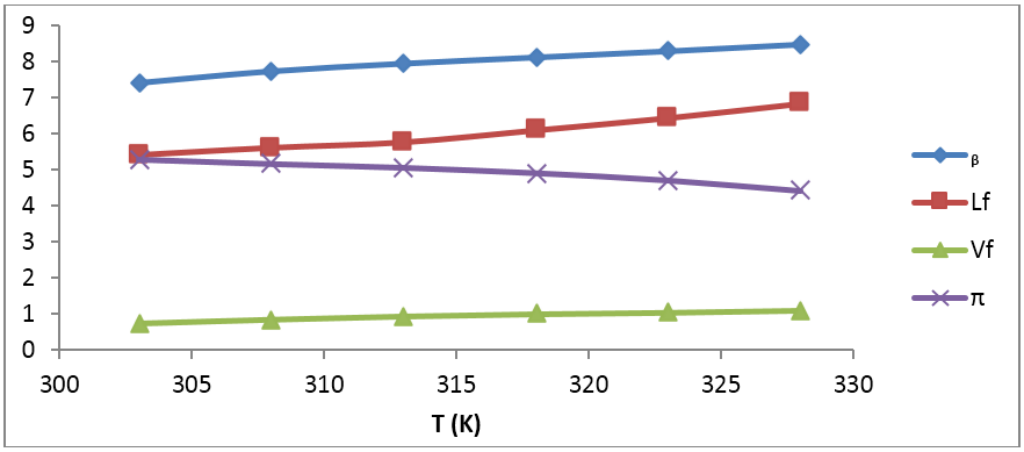
0.0000	2.8202	2.8550	2.8887	3.4126	3.3932	3.3580
0.0856	2.8361	2.8700	2.9033	3.4040	3.3798	3.3447
0.1724	2.8512	2.8848	2.9182	3.3917	3.3657	3.3323
0.2624	2.8661	2.8997	2.9331	3.3759	3.3492	3.3152
0.3370	2.8777	2.9115	2.9452	3.3598	3.3325	3.3006
0.4330	2.8915	2.9255	2.9598	3.3346	3.3067	3.2767
0.5555	2.9072	2.9415	2.9762	3.2934	3.2653	3.2374
0.6600	2.9194	2.9543	2.9898	3.2534	3.2275	3.2035
0.7690	2.9317	2.9671	3.0035	3.2120	3.1870	3.1680
0.8831	2.9441	2.9803	3.0176	3.1672	3.1450	3.1297
1.0000	2.9562	2.9939	3.0322	3.1209	3.1028	3.0907
		Ethanol-phenol				
0.0000	3.2500	3.2827	3.3161	4.1590	4.0550	3.9600
0.1093	3.2293	3.2617	3.2949	4.1077	4.0128	3.9238
0.2145	3.2078	3.2403	3.2734	4.0518	3.9615	3.8776
0.3206	3.1844	3.2169	3.2501	3.9844	3.8998	3.8221
0.4281	3.1586	3.1914	3.2248	3.9055	3.8255	3.7536
0.5229	3.1339	3.1669	3.2004	3.8243	3.7490	3.6834
0.6213	3.1055	3.1388	3.1728	3.7240	3.6566	3.5986
0.7157	3.0752	3.1090	3.1435	3.6099	3.5526	3.5033
0.8392	3.0297	3.0645	3.1002	3.4282	3.3860	3.3506
0.9074	3.0009	3.0367	3.0732	3.3096	3.2768	3.2512
1.0000	2.9562	2.9939	3.0322	3.1209	3.1028	3.0907

Table 12: A_i Coefficients of Equation with the standard deviations σ for the binary mixtures at different Temperatures.

***T* / (K)**	***A*0**	***A*1**	***A*2**	***A*3**	***A*4**	
Ethanol-phenol (10^3 N s m^{-2})						
298.15	0.2216	0.1046	-0.0939	-0.0294	0.1765	0.0003
303.15	0.1684	0.1056	-0.0729	-0.0859	0.0943	0.0009
308.15	0.1171	0.0684	-0.1316	-0.0844	0.1036	0.0005
ΔG^{*E} (kJ mol^{-1})						
298.15	0.1784	0.0935	-0.0220	0.0115	0.1131	0.0001
303.15	0.1539	0.0932	-0.0119	-0.0351	0.0500	0.0005
308.15	0.1277	0.0688	-0.0601	-0.0565	0.0485	0.0003
$\overset{E}{i}$ (10^6 atm)						
298.15	0.7386	0.7530	-0.2085	0.0247	0.9164	0.0017
303.15	0.5643	0.7201	-0.0783	-0.3061	0.3526	0.0040
308.15	0.3814	0.5016	-0.3890	-0.4292	0.3247	0.0023
Ethanol-pyridine (10^3 N s m^{-2})						
298.15	0.0610	0.0192	-0.0471	-0.0188	0.0477	0.0000
303.15	0.0423	0.0182	-0.0412	-0.0184	0.0258	0.0000
308.15	0.0281	0.0173	-0.0405	-0.0215	0.0285	0.0002



Variation of ultrasonic velocity U ($msec^{-1}$) with temperature T (K)



Variation of adiabatic compressibility β (×1010Pa-1), free length L_f (×1011m), free volume V_f(×107m3mol-1) and internal pressure πi(×10-8Pa) of mixture with temperature.

REFERENCES

1. S Thirumaran; K Ramya; Asian Journ Chem, 2009; 21(8): 6359
2. S Thirumaran; P Anbuselvi; Asian Journ Chem, 2009; 21(9): 7261
3. S Thirumaran; Deepesh George; ARPN Journ of Engg & Appl Sci, 2008; 27D(2): 281.
4. RJ Fort; and WB Moore; Trans Faraday Soc, 1965; 61: 2102.
5. Fulrio Coordini, Lugi Marchaselli and Giurappa Tosi, Can. Journ. Chem, 1992; 70: 2895.
6. JMG Cowie; Journ. Polyner Sci, 1968; 23C: 264.
7. TM Aminabhavi; & P Munk; Macromolecules, 1999; 12: 607.
8. AH Absood; MS Tutunji; KT Hsu; HL Clevier; J. Chem. Engg. Data, 1976; 21: 304.
9. San Jun Peng, Hzi-Yun Hou, Cong-Shu& Tao YangJourn Chem. Thermodys, 2007; 39: 474.
10. S Thirumaran; K Jayalakshmi; and K Job Sabu; Rasayan Journ Chem, 2009; 2(2): 424.
11. A Ali; K Tiwari; AK Nain; and V Chakaravorthy; Ind. Journ. Phys, 2000; 74B: 351.
12. S Thirumaran; J Earnest Jayakumar; Ind. Journ Pure & Appli Phys, 2009; 47: 265.
13. PL Soni; A Text Book of Organic Chemistry, Sultan & Chand Sons Ltd, New Delhi, 1988.
14. S.Thirumaran: K.Jayalakshmi: Archieves of Applied Science Research, 2009; 1(2): 24.
15. LE Kinser; AR Fray; Fundamentals of Acoustics, Wisely Eastern, New Delhi, 1989.
16. A Ali; S Hyder and AK Nain; Indian Journal Physics, 2000; 74B(1): 63.
17. RJ Fort; and WR Moore; Trans. Faraday, Soc, 1962; 61: 2102.
18. Amalendupal; BR Harsh Kumar; AB Takal; Indian J. Pure & Appl. Physics, 2003; 41: 113.
19. Shirpa Baluja and Swati Oza, Fluid Phase Equilibria, 2001; 178: 233.
20. M Alcolea Palofox; Ind. Journ. Pure & Appl. Phys, 1993; 31: 90.
21. V Rajendiren; and AN Kannappan; Ind. Journ. Phys, 1994; 68B: 131.
22. AN Kannappan; and V Rajendiran; J. Pure & Appl. Ultrasonics, 1991; 13: 60.
23. DV Reddy; K Ramananjeyalu; and A Krishnaih; Ind. Journ. Pure & Appl. Phys, 1990; 28: 107.