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# Intermolecular interactions in ternary liquid mixtures by ultrasonic measurements

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The excess adiabatic compressibility ( $\beta^{E}$ ), excess free length ( $L_{f}^{E}$ ), excess free volume ( $V_{f}^{E}$ ) and excess internal pressure ( $\pi_{i}^{E}$ ) have been investigated from density, ultrasonic velocity and viscosity measurements for three ternary mixtures of methyl benzoate + cyclohexane + 1-propanol, methyl benzoate + cyclohexane + 1-butanol, methyl benzoate + cyclohexane + 1-pentanol and methyl benzoate + cyclohexane + 1-hexanol at 303, 308 and 313 K and atmospheric pressure, respectively over the entire range of composition. From the experimental data, adiabatic compressibility ( $\beta$ ), free length ( $L_{f}$ ), free volume ( $V_{f_{f}}$ ), internal pressure ( $\pi_{i}$ ), have been calculated. The results are discussed in terms of the molecular interactions between the components of the mixture.

Keywords: Excess values, Viscosity, Ultrasonic velocity, Ternary mixtures, Molecular interactions

## **1** Introduction

The study of thermodynamic properties of ternary mixtures contributes to an understanding of behaviour of different liquids and their functional groups<sup>1-6</sup>. This information is very useful in the design of industrial processes and development of theories for the liquid state and predictive methods. Further, the study of excess thermodynamic properties of liquid mixtures is a subject of great theoretical interest because it gives information about molecular interactions and packing phenomenon or structural contributions. This paper is a continuation of earlier work on excess thermodynamic properties of ternary liquid mixtures<sup>7-11</sup>. In general, mixtures of associated liquids exhibit non-ideal behaviour with respect to properties like excess volume<sup>12</sup>. Any excess thermodynamic property<sup>13,14</sup> may be considered as made up of two parts, one corresponding to breaking up of the hydrogen bonds in component liquids and the other is due to Vander Waals-type interactions between the chain of the alcohol and other solvents.

Oxygenated compounds such as esters and alcohol are used as gasoline additives and have been extensively investigated due to their great industrial interest<sup>15-18</sup>. Methyl benzoate is an ester, reacts with acids to liberate heat along with alcohols and acids.

Methyl benzoate is used as a source of benzoyl radical. Cyclohexane is non-polar, a solvent and used in the production of nylon. Propanol is a colourless liquid, used as a solvent for waxes polyamides, synthetic resins. It is also used to manufacture pesticides and surface active substance and antiseptic. Butanol is a four straight chain alcohol, a volatile and polar which is used as a direct solvent. Pentanol (or n-pentanol, pentan-1-ol), is an alcohol with five carbon atoms and the molecular formula is  $C_5H_{12}O$ . It is a colourless liquid with an unpleasant aroma. Pentanol can be used as a solvent for coating CDs and DVDs. Hexanol is an organic alcohol with a sixcarbon chain and a condensed structural formula of CH<sub>3</sub>(CH<sub>2</sub>)<sub>5</sub>OH. This colourless liquid is slightly soluble in water, but miscible with ether and ethanol.

## **2** Experimental Details

All the chemicals used in the present work are Analar grade. The purity of the chemicals was ascertained by comparing their densities, viscosities and ultrasonic velocities at 303, 308 and 313 K which agrees with the corresponding literature values. The mixtures of methyl benzoate+cyclohexane+1-propanol, methyl benzoate+cyclohexane+1-butanol, methyl benzoate+cyclohexane+1-butanol, methyl

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benzoate +cyclohexane+1-hexanol were prepared by weight. The mole fraction of the second component, cyclohexane ( $x_2$ =0.4) was kept constant, while the mole fractions of the remaining two ( $x_1$ ,  $x_3$ ) were varied from 0.1 to 0.6. The ultrasonic velocity was measured by a single crystal interferometer with a high degree of accuracy operating at a frequency of 3 MHz (model F-05, with digital micrometer) at 303, 308 and 313 K. The viscosity was measured by Ostwald's viscometer. An electronically operated constant temperature water bath is used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. Densities of the mixtures have been found by relative measurement method.

#### **3** Theory and Calculations

Intermolecular free length  $(L_f)$  is calculated using the standard expression:

$$L_{\rm f} = K \beta^{1/2} \qquad \dots (1)$$

where *K* is a temperature dependent constant known as Jacobson constant and  $\beta$  is the adiabatic compressibility that can be calculated from the speed of sound (*U*) and the density of the medium ( $\rho$ ) as:

$$\beta = \frac{1}{U^2 \rho} \qquad \dots (2)$$

The relation for free volume in terms of ultrasonic velocity (*U*) and the viscosity ( $\eta$ ) of the liquid as:

$$V_{\rm f} = \left(\frac{M_{\rm eff}U}{\eta K}\right)^{3/2} \qquad \dots (3)$$

Expression for the determination of internal pressure  $(\pi_i)$  by the use of free volume  $(V_{f})$  as:

$$\pi_{\rm i} = bRT \left(\frac{K\eta}{U}\right)^{1/2} \left(\frac{\rho^{2/3}}{H_{\rm eff}^{7/6}}\right)$$
 ....(4)

where *b* stands for cubic packing which is assumed to be 2 for liquids and *K* is a dimensionless constant independent of temperature and nature of liquids and its value is  $4.281 \times 10^9$ , *T* is the absolute temperature and  $M_{\rm eff}$  is the effective molecular weight.

In order to study the non-ideality of the liquid mixtures, namely excess parameters  $(A^{E})$  of all the acoustic parameter were computed by:

$$A^{\rm E} = A_{\rm exp} - A_{\rm id} \qquad \dots (5)$$

$$A_{id} = \Sigma A_i X_i \qquad \dots (6)$$

where,  $A_i$  is any acoustical parameter and  $X_i$  is the mole fraction of the liquid components.

#### 4 Results and Discussion

The density  $(\rho)$ , viscosity  $(\eta)$  and ultrasonic velocity (U) of the mixtures methyl benzoate+ cyclohexane +1-propanol (System I), methyl benzoate +cyclohexane+1-butanol (System II), methyl benzoate + cyclohexane +1-pentanol (System III) and methyl benzoate + cyclohexane +1-hexanol (System IV) at different temperatures have been measured and given in Table 1. From these observed values, various acoustical parameters like adiabatic compressibility  $(\beta)$ , free length  $(L_f)$ , free volume  $(V_f)$ , internal pressure  $(\pi_i)$ , have been evaluated for all systems and it is presented in Table 2. These data were correlated by polynomial expressions which fits the data well. From Table 1, it was observed that the ultrasonic velocity, density of the ternary liquid mixtures decrease with increasing mole fraction of propanol, butanol, pentanol and hexanol while the viscosity increases. However, the ultrasonic velocity, density and viscosity decrease in all the cases as temperature increases. The same result was obtained<sup>19-21</sup>, when the compounds are mixed; the changes that occur in association with equilibrium were evidently due to the rupture of the hydrogen bonds in pure cyclohexane, methyl benzoate and alcohol.

Thus, the additional of methyl benzoate to an alcohol may result in the following effects:

- (i) rupturing or disruption of associate structures in alcohols,
- (ii) formation of new species because of interaction between ester and alcohols,
- (iii) free volume changes upon mixing of components of different sizes<sup>22</sup>

Further, the adiabatic compressibility and free length show an inverse behaviour as compared to the ultrasonic velocity in the mixtures. It is primarily the compressibility that changes with the structure and this leads to the change in ultrasonic velocity. The addition of interacting molecules breaks up the molecular clustering of the other releasing several dipoles for the interactions. Thus structural arrangement of molecules results in increasing

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Table 1 — Density ( $\rho$ ), viscosity ( $\eta$ ) and velocity (U) at 303, 308 and 313 K of methyl benzoate, cyclohexane and propanol, butanol,

pentanol, hexanol											
$x_1$	<i>x</i> <sub>3</sub>		ho Kg/m <sup>3</sup>			$\eta \times 10^{-3}$ Ns/m	2	<i>U</i> (m/s)			
		303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K	
System I : methyl benzoate + cyclohexane +propanol											
0.6	0.0	957.9	957.0	953.0	0.93	0.88	0.84	1282	1270	1246	
0.5	0.1	930.0	928.7	926.3	0.95	0.90	0.84	1279	1256	1227	
0.4	0.2	889.2	886.6	883.0	0.96	0.91	0.85	1246	1220	1207	
0.3	0.3	874.3	874.0	870.8	0.97	0.92	0.87	1232	1208	1199	
0.2	0.4	846.0	844.5	836.6	1.00	0.95	0.88	1219	1198	1181	
0.1	0.5	812.6	811.4	802.8	1.01	0.96	0.90	1190	1177	1148	
0.0	0.6	778.9	775.2	771.3	1.10	1.02	0.94	1175	1148	1118	
System II : methyl benzoate + cyclohexane +butanol											
0.6	0.0	957.9	957.0	953.0	0.93	0.88	0.84	1282	1270	1246	
0.5	0.1	901.8	900.7	897.5	0.93	0.87	0.82	1361	1338	1316	
0.4	0.2	876.6	874.8	871.6	0.96	0.89	0.83	1295	1244	1226	
0.3	0.3	848.8	846.4	841.3	0.96	0.89	0.85	1256	1194	1184	
0.2	0.4	822.5	820.9	814.2	1.01	0.93	0.89	1224	1193	1178	
0.1	0.5	815.0	813.0	809.0	1.06	1.00	0.93	1187	1172	1127	
0.0	0.6	782.4	779.2	774.8	1.20	1.08	0.99	1046	1010	986	
			Sy	stem III : met	hyl benzoate	+ cyclohexane	e +pentanol				
0.6	0.0	957.9	957.0	953.0	0.93	0.88	0.84	1282	1270	1246	
0.5	0.1	937.9	935.9	932.2	1.11	1.00	0.95	1356	1315	1301	
0.4	0.2	910.3	904.6	901.0	1.13	1.03	0.96	1326	1290	1281	
0.3	0.3	878.6	875.8	873.3	1.14	1.03	0.98	1296	1253	1224	
0.2	0.4	853.8	846.6	842.5	1.14	1.08	1.00	1260	1234	1217	
0.1	0.5	823.0	816.1	813.2	1.23	1.11	1.06	1226	1212	1188	
0.0	0.6	790.5	787.3	783.6	1.53	1.45	1.33	1214	1205	1200	
System IV : methyl benzoate + cyclohexane + hexanol											
0.6	0.0	957.9	957.0	953.0	0.93	0.88	0.84	1282	1270	1246	
0.5	0.1	933.9	931.8	930.6	1.06	0.99	0.91	1387	1348	1313	
0.4	0.2	905.4	901.8	900.6	1.08	1.01	0.93	1353	1317	1297	
0.3	0.3	867.6	864.4	863.6	1.25	1.15	1.08	1311	1265	1248	
0.2	0.4	848.1	845.7	841.2	1.27	1.19	1.14	1297	1245	1234	
0.1	0.5	823.4	820.2	814.8	1.53	1.43	1.32	1254	1230	1220	
0.0	0.6	798.6	794.2	792.1	1.90	1.70	1.62	1239	1227	1216	

adiabatic compressibility thereby showing intermolecular interactions. Similar results in some liquid mixtures were also reported by researchers<sup>19-22</sup>.

From Table 2, it was observed that as the concentration of primary alcohol increases, free volume decreases. Internal pressure increases with increase in concentration of alcohol. However, with rise in temperature increase in free volume and decrease in internal pressure are noticed. This suggests the closed packing of molecules inside the shield. Such an increase in internal pressure generally, indicates association through hydrogen bonding and hence supports the present investigation. In the methyl benzoate structure, there are a lot voids available for O-H to penetrate and enter into complexion, and also provides information regarding the hydrogen bond between interacting components<sup>16</sup>.

At high concentration of alcohol in the mixture, there are a large number of alcohol molecules surrounding the ester molecules. At low concentration of alcohol in the mixtures, there are only a small number of alcohol molecules to enable dipole-dipole interaction through hydrogen bonding with the non associative ester molecules. The associative alcohol molecules act as proton donor enabling hydrogen bonding with methyl benzoate molecules. In order to understand more about the nature of the interaction between the components of liquid mixture, it is necessary to discuss the same in terms of excess parameters rather than the actual values. They can yield an idea about the non linearity of the system as association or other type of interactions<sup>17</sup>.

The results in Table 3 and Figs (1-4) show that the ternary excess values data (except excess free

Internal pressure $\pi_{\rm i} \times 10^6$ N/ m <sup>2</sup>			Adiabatic compressibility $\beta \times 10^{-10} \text{ m}^2/\text{N}$			Free length $L_{\rm F} \times 10^{-10}  {\rm m}$			Free volume $V_{\rm F} \times 10^{-7}  {\rm m}^3  {\rm mol}^{-1}$		
303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System I: methyl benzoate + cyclobexane +propanol											
340	337	337	6.34	6.48	6.76	0.50	0.51	0.53	2.25	2.41	2.52
368	367	365	6.58	6.82	7.17	0.51	0.53	0.54	1.95	2.07	2.18
438	436	432	7.24	7.58	7.77	0.54	0.55	0.57	1.45	1.53	1.65
441	441	436	7.54	7.84	7.99	0.55	0.56	0.57	1.39	1.47	1.58
488	487	480	7.96	8.26	8.56	0.56	0.58	0.59	1.15	1.21	1.33
538	535	530	8.68	8.90	9.45	0.59	0.60	0.62	0.95	1.01	1.07
617	609	599	9.30	9.78	10.37	0.61	0.63	0.65	0.71	0.76	0.83
System II : methyl benzoate $\pm$ cyclobexane $\pm$ butanol											
340	337	337	6 34	6 48	6 76	0 50	0.51	0 53	2.25	2.41	2.52
337	334	331	5.98	6.20	6.43	0.49	0.51	0.55	2.25	2.41	2.52
368	366	363	6 79	7 39	7.63	0.52	0.50	0.51	1.86	1.98	2.03
395	395	392	7 47	8 27	8 48	0.52	0.55	0.50	1.60	1.50	1 77
432	428	425	8 11	8 55	8 85	0.57	0.50	0.60	1 31	1.00	1.48
486	484	481	8 70	8 94	9.72	0.59	0.60	0.63	1.04	1 10	1.10
586	575	563	11.68	12.56	13.27	0.68	0.71	0.74	0.64	0.70	0.78
			Sv	stem III · m	ethyl benzo	ate + cycloh	exane +nen	tanol			
340	337	337	6 34	6 48	6 76	0.50	0.51	0.53	2.25	2.41	2.52
372	365	363	5 79	6.18	6 34	0.48	0.50	0.55	1 78	1 99	2.09
393	385	378	6.25	6.64	676	0.50	0.50	0.53	1.70	1 73	1.90
411	404	404	6.77	7.26	7.64	0.52	0.52	0.55	1 39	1.73	1.60
434	431	424	7 37	7.20	8.01	0.54	0.56	0.50	1.23	1.30	1.00
474	457	457	8.08	8.34	8.71	0.57	0.58	0.60	0.98	1.12	1.17
550	545	529	8.58	8.75	8.86	0.58	0.59	0.60	0.64	0.69	0.78
550	515	52)	0.50	0.75	0.00	0.50	0.57		0.01	0.07	0.70
System IV : methyl benzoate + cyclohexane + hexanol											
340	337	337	6.34	6.48	6.76	0.50	0.51	0.53	2.25	2.41	2.52
354	353	348	5.56	5.90	6.23	0.47	0.49	0.51	2.00	2.12	2.31
368	365	359	6.03	6.39	6.60	0.49	0.51	0.52	1.79	1.90	2.09
405	402	399	6.70	7.22	7.43	0.52	0.54	0.55	1.31	1.40	1.50
431	423	420	7.00	7.62	7.80	0.53	0.55	0.57	1.19	1.23	1.30
480	4/4	467	7.72	8.05	8.52	0.55	0.57	0.59	0.81	0.88	0.95
551	546	537	8.29	8.92	9.28	0.57	0.60	0.62	0.54	0.61	0.63

Table 2 — Adiabatic compressibility ( $\beta$ ), free length ( $l_f$ ) free volume ( $v_f$ ) and Internal pressure ( $\pi_i$ ), of methyl benzoate, cyclohexane and propanol, butanol, pentanol, hexanol

volume) in all the three mixtures for all system are negative at higher alcohol composition and the quantity tends to become positive as the alcohol composition gradually decreases. This can be explained based on the following factors: According to Saleh *et al*<sup>11</sup>. the sign of excess molar values depends upon the relative magnitude of contractive and expansive effects which arises on mixing of liquid components.

The factors that are responsible for contraction in volume on mixing are: (a) strong specific interaction, usually a kind of chemical interaction, (b) strong physical interaction such as dipole-dipole (or) dipole induced dipole interaction,(c) favourable geometrical fitting of component molecules and (d) occupation of void spaces of one component by the other, may be due to when the molecular sizes of the compounds differ by a large magnitude.

The factors that lead to expansion of volume on mixing of the components are: (a) dissociation of one component (or) all the components, (b) steric hindrance due to branching of chains and (c) formation of weaker solute–solvent bond than solute-solute and solvent–solvent bonds.

The thermodynamic excess properties are found to be more sensitive towards intermolecular interaction between the component molecules of liquid mixtures. The sign and extent of deviation of excess parameters depend on the strength of interaction between unlike molecules<sup>23</sup>. The excess values of adiabatic compressibility are negative and it tend to be positive with increasing the concentration of  $X_3$  as well as

Excess adiabatic compressibility $\beta \times 10^{-10} \text{ m}^2/\text{N}$			Excess free length $L_{\rm F} \pm 10^{-10} { m m}$			Excess free volume $V_{\rm F} \times 10^{-7} \text{ m}^3 \text{ mol}^{-1}$			Excess internal pressure $\pi_i \times 10^6 \text{ N/m}^2$		
303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System I : methyl benzoate + cyclohexane +propanol											
-0.16	-0.32	-0.34	0.00	-0.01	-0.01	0.72	0.74	0.67	-49	-46	-38
-0.34	-0.53	-0.35	-0.01	-0.01	-0.01	0.55	0.53	0.48	-80	-71	-61
-0.34	-0.38	-0.42	-0.01	-0.01	-0.01	0.37	0.32	0.30	-139	-121	-107
-0.14	-0.21	-0.30	-0.01	0.01	-0.01	0.25	0.19	0.16	-119	-100	-88
-0.08	-0.12	0.09	0.02	0.01	0.01	0.13	0.05	0.03	-124	-102	-88
0.31	0.20	0.44	0.01	0.01	0.02	0.04	0.03	0.10	-124	-100	-82
0.59	0.79	1.03	0.02	0.03	0.03	0.09	0.17	0.21	-94	-71	-55
System II : methyl benzoate + cyclohexane +butanol											
-0.16	-0.32	-0.34	0.00	-0.01	-0.01	0.72	0.74	0.67	-49	-46	-38
-0.83	-1.06	-0.98	-0.03	-0.03	-0.03	0.86	0.9	0.9	-92	-86	-78
-0.33	-0.15	-0.09	-0.01	0.01	0.01	0.55	0.53	0.51	-102	-90	-80
0.03	0.46	0.45	0.01	0.02	0.02	0.41	0.34	0.28	-116	-98	-85
0.37	0.45	0.52	0.02	0.02	0.02	0.23	0.19	0.12	-119	-102	-86
0.65	0.57	1.07	0.02	0.02	0.04	0.08	0	0.07	-106	-82	-64
3.31	3.90	4.31	0.10	0.12	0.13	0.21	0.29	0.34	-47	-28	-16
			System III	: methyl b	enzoate +	cyclohexan	e +pentano	1			
-0.16	-0.32	-0.34	0.00	-0.01	-0.01	0.72	0.74	0.67	-49	-46	-38
-0.99	-1.04	-1.04	-0.04	-0.03	-0.04	0.37	0.43	0.36	-51	-49	-40
-0.81	-0.82	-0.90	-0.03	-0.02	-0.03	0.27	0.29	0.29	-65	-59	-53
-0.57	-0.44	-0.31	-0.02	-0.01	-0.01	0.21	0.21	0.13	-80	-71	-56
-0.25	-0.19	-0.22	-0.01	0.00	-0.01	0.17	0.09	0.08	-91	-74	-64
0.19	0.16	0.21	0.01	0.01	0.01	0.03	0.03	0.05	-85	-78	-59
0.41	0.32	0.07	0.01	0.01	0.00	0.22	0.29	0.32	-42	-19	-14
System IV : methyl benzoate + cyclohexane + hexanol											
-0.16	-0.32	-0.34	0.00	-0.01	-0.01	0.72	0.74	0.67	-49	-46	-38
-1.17	-1.27	-1.10	-0.04	-0.04	-0.04	0.61	0.6	0.62	-70	-64	-57
-0.94	-0.98	-0.96	-0.03	-0.03	-0.03	0.73	0.73	0.79	-133	-123	-113
-0.50	-0.35	-0.35	-0.02	-0.01	-0.01	0.19	0.16	0.11	-86	-77	-64
-0.43	-0.15	-0.21	-0.01	-0.01	-0.01	0.21	0.12	0.06	-92	-85	-70
0.06	0.09	0.28	0.00	0.01	0.01	0.05	0.1	0.15	-73	-62	-48
0.39	0.76	0.81	0.01	0.03	0.03	0.21	0.25	0.34	-30	-16	-3

Table 3 — Excess adiabatic compressibility ( $\beta^{e}$ ), excess free length ( $l_{f}^{e}$ ), Excess free volume ( $V_{f}^{e}$ ) and excess internal pressure ( $\pi_{i}^{e}$ ) of methyl benzoate, cyclohexane and propanol, butanol, pentanol, hexanol

rising of temperature in all systems studied. Fort *et al*<sup>24</sup>. found that the increasing negative value of excess compressibilites indicates greater interaction between the components of the mixtures. Positive values in excess properties correspond mainly to the existence of dispersive forces. The negative value of  $\beta^{E}$  is associated with a structure forming tendency while a positive value is taken to indicate a structure breaking tendency due to heteromolecular interaction between the component molecules of the mixtures. The negative  $\beta^{E}$  values for ternary mixtures indicate the formation of H bonds. The positive excess adiabatic compressibility which indicates loosely packed molecules in the mixtures results due to shape and size.

According to Ramamoorthy *et al*<sup>25</sup>. negative values of excess intermolecular free length  $L_{\rm f}^{\rm E}$  indicate that

sound waves cover longer distances due to decrease in intermolecular free length ascribing the dominant nature of hydrogen bond interaction between unlike molecules. Fort *et al*<sup>24</sup>, indicated that the positive values of excess free length should be attributed to the dispersive forces and negative excess values should be due to charge transfer, dipole-induced dipole and dipole-dipole interactions. In the present study, the negative contribution of  $L_f^E$  in all systems shows the existence of strong interaction between the component of the mixtures and the positive contribution of  $L_f^E$  in all systems shows the existence of dispersive forces between the component of the mixtures. Treszc Zanowicz *et al*<sup>26</sup>, have also reported a similar observation on the basis of excess values of free length.

The experimental ternary excess molar volume data in the present investigation exhibits an inversion in





Fig. 2 - Excess values of system II

the ternary mixtures that contain propanol, butanol, pentanol, and hexanol. On the other hand, the property is positive for all composition in the mixture. Methyl benzoate is highly polar when compared to 1alcohol. Mixing of cyclohexane and alcohol with methyl benzoate tends to break dipolar association releasing several dipoles. Consequently, the free dipoles of methyl benzoate would induce moments in the neighbouring cyclohexane and alcohol molecules resulting in dipole-induced dipole interactions leading to contraction in volume. Another important factor is the large magnitude in excess values is the lower



Fig. 4 — Excess values of system IV

alcohol which corresponds to strong self association of pure alcohol, which suggests that the existence of strong interaction. The magnitude of values excess molar volume follows the sequence: 1-pentanol > 1-butanol > 1-hexanol > 1-propanol.

The excess internal pressure values are found to be negative and decrease with increasing the mole fraction of ( $X_3$ ) as well as temperature in all the three systems studied. The negative values of  $\pi_i^{E}$  indicates

that only dispersion and dipolar forces are operating with complete absence of specific interaction<sup>27</sup>. In the present paper, the observed behaviour of  $\pi_i^E$  shows the existence of dispersive forces in all systems studied, but the strength of interaction decreases with raising of temperature results in decreasing of  $\pi_i^E$  values.

The higher negative values for all the system are due to high dipole moment and high dielectric constant leading to an increase in alcohol polarity resulting into stronger hetero-association. Thus, mixing of methyl benzoate, cyclohexane with an alcohol can be expected to induce changes in hydrogen bonding equilibria and electrostatic interactions with different resultant contributions to the volumes of the mixtures.

# **5** Conclusions

Ultrasonic method is a powerful probe for characterising the physico-chemical properties and existence of molecular interaction in the mixture. In addition, the density, viscosity and the derived excess parameters provide acoustical evidence of confirmation. It is well known that when non-polar compounds are mixed, slight variation in the intermolecular interactions takes place. The new specific dispersive interactions that appear should be suitably measured by volumetric techniques. All the determinations experimental of adiabatic compressibility, free volume, internal pressure and free length are strongly correlated with each other and support for strong interaction. Furthermore, when an alcohol molecule is mixed with other organic liquids, part of the alcohol molecules will tend to dissociate from the polymeric aggregates through the hydrogen bond to form other kinds of hydrogen bonds with different kinds of molecules. From the magnitude of velocity, the existence of molecular interaction in the mixture is in the order: 1-hexanol > 1-pentano> 1propanol > 1-butanol.

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