

# Acoustical and Excess Thermo Dynamical Properties of Ternary Liquid Mixtures at 303.15k

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## ABSTRACT

The observed experimental parameters such as density ( $\rho$ ), viscosity ( $\eta$ ) and ultrasonic velocity ( $U$ ) of ternary liquid mixtures of substituted benzenes such as chloro benzene, bromo benzene, nitrobenzene and toluene with acetophenone in 1-pentanol at 301.15K were determined. The observed experimental data have been utilized to evaluate some of the excess thermo acoustical parameters such as adiabatic compressibility ( $\beta^E$ ), intermolecular free length ( $L_f^E$ ), free volume ( $V_f^E$ ), internal pressure ( $\pi_i^E$ ), Gibb's energy ( $\Delta G^E$ ), and viscosity ( $\eta^E$ ). The present study observes that existing of molecular interaction between the acetophenone and 1-heptanol is through hydrogen bonding and with substituted benzenes through dipole-dipole interactions. The strength of the molecular interactions gets weakened on further addition of substituted benzenes. Weak dipolar and cohesive forces are identified in the present systems of liquid mixtures. The present study also predicts the formation of donor-acceptor complexes in the component mixtures.

**Keywords:** *Adiabatic compressibility, dipole-dipole interaction, hydrogen bonding, internal pressure, intermolecular free length*

## 1. INTRODUCTION

In recent years, the 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 the liquid mixtures [4]. Ultrasonic velocity of a liquid is fundamentally related to the binding forces between the atoms or the molecules and has been adequately employed in understanding the nature of molecular interaction in pure liquids [5,6]. The variation of ultrasonic velocity and related parameters throw much light upon the structural changes associated with the liquid mixtures having weakly interacting components [7,8] as well as strongly interacting components.

The study of molecular association in organic ternary mixtures having alcohol as one of the components is of particular interest, since alcohols are strongly self-associated liquid having a three dimensional network of hydrogen bond [9] and can be associated with any other group having some degree of polar attractions [10]. Accurate knowledge of thermodynamic mixing properties such as adiabatic compressibility, intermolecular free length, free volume, internal pressure and molar volume and their excess values for mixtures of protic, non-protic and associated liquids has a great importance in theoretical and applied areas of research. The deviations from ideality and specific or non-specific interactions have been revealed. Alcohols and aniline [9] exist as associated structures in liquid state. Thus, upon mixing aniline with alcohols of varying chain lengths and provide interesting properties due to specific interactions arising from charge-transfer, dipole-dipole, donor-acceptor and hydrogen bond formation forces may be observed.

Nitrobenzene have higher dipole moment and dielectric constant values than those of chlorobenzene and bromobenzene. Nitrobenzene is supposed to be a relatively complex molecule [11] and its non-ideality in all probability may be due to the polarity arisen out of nitro-group is concerned, it rotates freely along the C-N axis where it likely to give more flexibility to the interactions arising due to the two highly polar N→O bonds. Chlorine atom in chlorobenzene is an electron-withdrawing atom, tends to attract to  $\pi$ -electrons of the benzene ring, thereby, decreases the electron density of ring. As a result, the benzene ring in chlorobenzene becomes relatively poor electron-donor towards the electron-seeking proton of any groups. Chlorobenzene has low dielectric constant  $\epsilon' = 5.649$  and dipole moment  $\mu = 1.69D$ . Its boiling point and melting points are 132°C and -45°C respectively. Chlorobenzene is neither acidic nor basic colorless, liquid with a pleasant smell. Chlorobenzene is insoluble in water and soluble in alcohol, benzene and ether. Chlorobenzene is more reactive because the chlorine atom is bonded with  $sp^3$  hybridized carbon atom and consequently can be removed easily. So, the rate of reaction with chlorobenzene is faster. Bromobenzene is less reactive because of its double bond character between carbon and bromine atom. The slow reactions in case of bromobenzene may also be attributed to its being heavier. Thus, the molecular interactions is likely to be more affected resulting in a greater degree of variation with respect to the ultrasonic related parameters.

The above characteristics physical nature of substituted benzenes had motivated the authors to study the molecular interactions of ternary liquids mixtures of substituted benzenes with acetophenone in 1-pentanol at 303.15K and carried out the present investigation.

The present ternary liquid systems taken up for investigation at 301.15K are

<b>System –I</b>	Chlorobenzene	1- pentanol	Acetophenone
<b>System–II</b>	Bromobenzene	1-pentanol	Acetophenone
<b>System- III</b>	Nitrobenzene	1-pentanol	Acetophenone
<b>System–IV</b>	Toluene	1-pentanol	Acetophenone

### a. Experimental

In the present work, we have used chemicals, which are analytical reagent (AR) and spectroscopic reagent (SR) grades of minimum assay of 99.9% obtained from E-Merk, Germany and Sd fine chemicals, India. The purities of the above chemicals were checked and were compared with available literature values. The ternary liquid mixtures of different known composition were prepared by mole fraction basis. In all systems, the mole fraction of the second component, 1-pentanol ( $X_2 = 0.2$ ) was kept fixed while the mole fractions of the remaining two ( $X_1$  and  $X_3$ ) were varied from 0.0 to 0.9 so as to have the mixtures of different compositions. The density was determined using a specific gravity bottle by relative measurement method. The weight of the sample was measured using a electronic digital balance with an accuracy of  $\pm 0.1$  mg (Model: Shimadzu, Japan Make, AX-200). An Ostwald's viscometer (10ml) was used for the viscosity measurement. Efflux time was determined by using a digital chronometer to within  $\pm 0.001$ s. An Ultrasonic Interferometer having a frequency of 2 MHz (Mittal Enterprises, New Delhi. Model: F-81) has been used for velocity measurement. The overall accuracy in the velocity measurement is  $\pm 2\text{ms}^{-1}$ . An electronically digital operated constant temperature water bath (RAAGA Industries, Chennai) has been used to circulate water through the double walled measuring cell make up of steel containing the experimental solution at the desired temperature. The accuracy in the temperature measurement is  $\pm 0.1\text{K}$ .

### b. Theory

Various acoustical and thermodynamical parameters are calculated from the measured data such as

$$\text{Adiabatic Compressibility } \beta = \frac{1}{U^2 \rho} \quad (1)$$

$$\text{Intermolecular free length } L_f = K \sqrt{\beta} \quad (2)$$

Where K is a temperature dependent constant.

$$\text{Free volume } V_f = \left( \frac{M_{\text{eff}} U}{K * \eta} \right)^{3/2} \quad (3)$$

Where  $M_{\text{eff}}$  is the effective molecular weight  $K^*$  is a temperature independent constant for all liquids.

$$\text{Internal Pressure } \pi_i = bRT \left( \frac{K\eta}{U} \right)^{1/2} \left( \frac{\rho^{2/3}}{M_{\text{eff}}^{7/6}} \right) \quad (4)$$

Where the terms have usual meaning.

The Gibb's free energy can be estimated from the following relation.

$$\Delta G = KT \ln \left( \frac{KT\tau}{h} \right) \quad (5)$$

Where K is the Boltzmaan's constant, and  $\tau$  is the relaxation time.

Excess values of the above parameters can be determined using

$$A^E = A_{\text{exp}} - A_{\text{id}} \quad (6)$$

Where  $A_{\text{id}} = \sum A_i X_i$ ,  $A_i$  is any acoustical parameters and  $X_i$  the molefraction of the liquid component?

## 2. RESULTS AND DISCUSSION

The experimentally determined values of density ( $\rho$ ), viscosity ( $\eta$ ) and ultrasonic velocity (U) of all the pure liquids at 303.15K are presented in Table 1 and the same for the ternary systems (I to IV) are listed in Table 2. The excess values of adiabatic compressibility ( $\beta^E$ ), free length ( $L_f^E$ ), free volume ( $V_f^E$ ), internal pressure ( $\pi_i^E$ ), Gibb's Free Energy ( $\Delta G^E$ ) and viscosity ( $\eta^E$ ) of the ternary liquid systems are reported in Table 3 and 4.

... (2)

**Table 1:** Values of density ( $\rho$ ), viscosity ( $\eta$ ) and Ultrasonic Velocity (U) of Pure Organic liquids at 303.15 K

ORGANIC LIQUIDS	DENSITY $\rho/(\text{Kgm}^{-3})$		VISCOSITY $\eta/(\times 10^{-3} \text{NSm}^{-2})$		ULTRASONIC VELOCITY $U/(\text{ms}^{-1})$	
	Ref.value	P.work	Ref.value	P.work	Ref.value	P.work
CHOLOROBENZENE	1095.1[1]	1093.5	0.7292[1]	0.8477	1239.6[1]	1240.5
BROMOBENZENE	1481.9[1]	1475.5	1.0138[1]	1.1815	1131.6[1]	1133.3
NITOBENZENE	1193.9[1]	1193.7	1.6089[1]	1.5746	1432.8[1]	1430.6
TOLUENE	857.8[1]	848.6	0.5264[1]	0.5639	1270.6[1]	1280.0
1-PENTANOL	807.2[2]	806.8	2.7656[2]	2.3232	1253.2[2]	1253.8
ACETOPHENONE	1019.7[3]	1017.5	1.5323[3]	1.3436	1454.4[3]	1459.2

Ref.value – Reference value

P.work - Present work

It is seen that in the present systems of first three ternary liquid mixtures, the viscosity ( $\eta$ ) and the ultrasonic velocity (U) decreases and the density( $\rho$ ) increases with increasing concentrations of substituted benzenes, such as chlorobenzene, bromobenzene, nitrobenzene, and toluene. However, for the fourth system is concerned, all the three parameters found to be decreased, which are tabulated in Table 2. The variation of ultrasonic velocity in a mixture depends upon the increase (or) decrease of intermolecular free length after mixing the components. On the basis of a model, for sound propagation proposed by Eyring and Kincaid [12], ultrasonic velocity should decrease, if the intermolecular free length increase and vice-versa. This is in fact observed in the present investigation for all the four liquid systems.

The thermodynamic excess properties are found to be more sensitive towards intermolecular interaction between the component molecules of liquid mixtures. The sign and magnitude of deviation of excess properties depend on strength of interaction between unlike molecules. That is in order to understand the nature of molecular interactions between the components of the liquid mixtures, it is of interest to discuss the same in term of excess parameter rather than actual values. Non-ideal liquid mixtures show considerable deviation from linearity in their physical behaviour with respect to concentration and these have been interpreted as arising from the presence of strong or weak interactions [13].

**Table 2:** Values of density ( $\rho$ ), Viscosity ( $\eta$ ) and Ultrasonic Velocity (U) at 303.15K

Mole Fraction		DENSITY $\rho/(\text{Kgm}^{-3})$	VISCOSITY $\eta/(\times 10^{-3} \text{NSm}^{-2})$	ULTRASONIC VELOCITY $U/(\text{ms}^{-1})$
$X_1$	$X_3$			
<b>System-I Chlorobenzene + 1-Pentanol + Acetophenone</b>				
0.0000	0.7997	978.1821	1.2750	1419.2
0.2008	0.5992	989.7312	1.1383	1369.6
0.4001	0.3999	1005.1747	1.0190	1338.0
0.5989	0.2011	1017.7982	0.8887	1289.2
0.8000	0.0000	1031.8988	0.7912	1233.9
<b>System-II: Bromobenzene + 1-Pentanol + Acetophenone</b>				
0.0000	0.8001	978.5849	1.2838	1416.0
0.2001	0.5999	1064.2632	1.2194	1341.8
0.3999	0.4003	1149.1356	1.1062	1272.5
0.5996	0.2002	1245.1543	1.0926	1204.8

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0.7999	0.0000	1337.6814	1.0370	1145.4
<b>System-III: Nitrobenzene + 1-Pentanol + Acetophenone</b>				
0.0000	0.7999	978.7192	1.2840	1417.5
0.2000	0.5997	1007.9948	1.1498	1365.2
0.4001	0.3998	1041.9707	1.0177	1303.6
0.5999	0.1999	1076.0808	0.8889	1244.4
0.8000	0.0000	1112.7425	0.7524	1181.8
<b>System-IV: Toluene + 1-Pentanol + Acetophenone</b>				
0.0000	0.7999	978.5849	1.2838	1416.0
0.1999	0.5999	950.1450	1.0765	1388.0
0.4001	0.4001	917.4371	0.8910	1351.4
0.6001	0.1999	882.8448	0.7521	1320.3
0.8504	0.0000	846.6372	0.6203	1255.6

The perusal of Table 3 exhibits the values of excess adiabatic compressibility ( $\beta^E$ ) for all the four liquid systems. The negative values of  $\beta^E$  are associated with a structure-forming tendency, while positive values are an indication of structure-breaking tendency due to hetero-molecular interaction between the component molecules of the mixtures. The positive values of excess adiabatic compressibility which indicates the loosely packed molecules in the mixtures resulting due to shape and size. From the present Figs, it is evident that the excess adiabatic compressibility are all almost negative in all the three ternary liquid system, except in system III, where a positive deviations are seen in higher mole fraction range. The negative values of the  $\beta^E$  increase with increasing concentrations of substituted benzenes in the systems I & II and decreases in system IV. This may be ascribed as that in acetophenone, the carbonyl group is highly polar and hence has a high percentage of ionic character [14] and there exists is a negative charge on the carbonyl oxygen atom of acetophenone. Hence, the decreasing trend of negative values will make one would expect a weak interactions with substituted benzenes such as chlorobenzene, bromobenzene, nitrobenzene, and toluene due to weak dipole-dipole interactive forces. Also, in the case of substituted benzenes, the bromine, chlorine and nitrogen all having a tendency to act as an electron acceptors. The decrease in adiabatic compressibility may further be attributed to the internal interactions between  $\pi$ -electrons of C = O bond and  $\pi$ -electrons of the benzene ring [15]. A plausible explanation may be that the oxygen atom of carbonyl group of acetophenone being strongly electronegative would act as a good electron acceptor towards the  $\pi$ -electrons of the aromatic ring, forming donor-acceptor complexes [1]. It is observed that decreasing negative deviations in  $\beta^E$  increasing with molar concentrations seems to be an indication of weak molecular interaction between unlike molecules increases. Such decreasing negative values of  $\beta^E$  may also due to the dominance of dispersive interaction forces resulting from the breaking up of the hydrogen bonds of substituted benzenes makes the compressibility to decrease.

The perusal of Table 3 shows the values of excess free length ( $L_f^E$ ) for all the four ternary liquid systems. It is noticed that the  $L_f^E$  values are negative in all the liquid systems (except in System-III) and found to be increased with increasing molar concentration of substituted benzenes except in I, where as a reverse trend is observed. According to Kannappan et al. [16], the negative values of  $L_f^E$  indicate that sound waves cover long distances due to decrease in intermolecular free length describing the dominant nature of hydrogen bond interaction between unlike molecules. Fort and Moore[17] indicated that the positive excess values of free length should be attributed to the dispersive forces and negative excess values of should be due to charge transfer and hydrogen bond formation. In the present investigation, one can notice that the decreasing trend of negative excess values of intermolecular free length ( $L_f^E$ ) with the increasing concentration of substituted benzenes may be interpreted as aromatic ketones such as acetophenone which is being a highly polar molecule ( $\mu = 2.96$ ) and it may enhance the polarities of the substituted benzenes. The  $\pi$  - electron density in derivatives of benzene ring depends upon that is attached to it. The heteromolecular interaction between component molecules necessarily depends upon the net electron density in the ring. Further, these interactions seemed to depend on relative orientation of the two groups in the ring. As the separation between the two groups increases, the intermolecular interaction is expected to decrease. Hence, a decrease in excess free length ( $L_f$ ) is noticed.

From the Table 3, one can notice that a qualitative picture of excess free volume ( $V_f^E$ ) values for all the four ternary liquid systems. The present parameter indicates the extent of deviation from ideal with the mole fraction of the mixtures. The present study shows that the excess values of free volume for all the four ternary liquid systems found to be positive. These values found to be increased on increasing the molar concentration of substituted benzenes in all the systems except in system IV. The results can be explained in terms of molecular interaction, structural effect and interstitial accommodation along with the changes in free volume. The sign of the  $V_f^E$  depends on the relative strength

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between the contractive forces and expansive forces. The factors responsible for volume contraction are (i) specific interactions between the component molecules and (ii) weak physical forces, such as dipole-dipole or dipole-induced dipole interactions or Vanderwaal's forces. The factors that cause expansion in volume are dispersive forces, steric hindrance of component molecules, unfavourable geometric fitting and electrostatic repulsion. The positive values of excess free volume in all the systems assert that the combined effect of the factors responsible for volume contraction and vice-versa [18]. Adgaonkaret al. [19] showed positive values of  $V_f^E$  indicating the existence of weak molecular interactions in the liquid mixtures and the negative values of excess free volume suggesting the specific interactions among unlike molecules.

In our one of the solvents, 1-pentanol, a primary alcohol also a polar one which is in association with acetophenone forms hydrogen bonding. Thirumaran et al. [3] had made it clear that the molecular association is due to the hydroxyl group of 1-alkanol and acetophenone. According to them, aromatic ketones such as acetophenone are more associated with alcohols than the aliphatic one. Since alkanols are liquids which are associated through hydrogen bonding and in the pure state, they exhibit equilibrium between multimer and

monomer species. Further, when the substituted benzenes such as Nitrobenzene is mixed with 1-pentanol, the  $\text{NO}_2$  group can interact with OH group [20,21]. The aromatic derivatives set up on interaction between the  $\pi$ -electrons cloud and the hydroxyl group. Though, this interaction is of minor intensity compared with hydrogen bonding, but they may lead to formation of intermolecular complexes [22]. In the study of liquid mixtures, the variation of internal pressure may give some suitable information regarding the nature and strength of the forces existing between the molecules. In fact, the internal pressure is a broader concept and it is a measure of the totality of forces of the dispersion, ionic and dipolar interaction that contribute to be overall cohesion of the liquid systems. The present study shows that the excess internal pressure values ( $\pi_i^E$ ) are negative in all the four liquid systems. Such negative values of  $\pi_i^E$  are decreasing on increasing the molar concentration of substituted benzenes indicate that only dipolar forces are operating between the unlike molecules. Further, the observed decreasing behavior of excess internal pressure values reveals that the weakening of cohesive forces resulting in weaker molecular interactions in the liquid mixtures.

**Table 3:** Excess Values of Adiabatic Compressibility ( $\beta^E$ ), Free Length ( $L_f^E$ ), Free Volume ( $V_f^E$ ) and Internal Pressure ( $\pi_i^E$ ) at 303.15K

Mole Fraction		Excess Adiabatic compressibility $\beta^E/(\times 10^{-10} \text{ m}^2 \text{ N}^{-1})$	Excess Free Length $L_f^E/(\times 10^{-10} \text{ m})$	Excess Free Volume $V_f^E/(\times 10^{-7} \text{ m}^3 \text{ mol}^{-1})$	Internal Pressure $\pi_i^E/(\times 10^6 \text{ Nm}^{-2})$
$X_1$	$X_3$				
<b>System-I Chlorobenzene + 1-Pentanol + Acetophenone</b>					
0.0000	0.7997	-0.1924	-0.0054	0.1880	-46.3528
0.2008	0.5992	-0.1495	-0.0036	0.2100	-50.5345
0.4001	0.3999	-0.2433	-0.0077	0.2770	-55.3614
0.5989	0.2011	-0.1527	-0.0045	0.4090	-62.8979
0.8000	0.0000	0.0340	-0.0022	0.4174	-64.8282
<b>System-II: Bromobenzene + 1-Pentanol + Acetophenone</b>					
0.0000	0.8001	-0.1734	-0.0047	0.1664	-44.8234
0.2001	0.5999	-0.1829	-0.0052	0.2361	-47.3414
0.3999	0.4003	-0.1606	-0.0034	0.4473	-58.5377
0.5996	0.2002	-0.1322	-0.0033	0.4075	-62.3825
0.7999	0.0000	-0.0997	-0.0024	0.5033	-63.8045
<b>System-III: Nitrobenzene + 1-Pentanol + Acetophenone</b>					
0.0000	0.7999	-0.1811	-0.0049	0.1683	-44.7220
0.2000	0.5997	0.1593	0.0104	0.4349	-67.1027
0.4001	0.3998	0.5875	0.0292	0.7355	-89.3287
0.5999	0.1999	1.0460	0.0488	1.1100	-113.6324
0.8000	0.0000	1.5830	0.0710	1.6389	-142.2054
<b>System-IV: Toluene + 1-Pentanol + Acetophenone</b>					
0.0000	0.7999	-0.1725	-0.0046	0.1662	-44.6426
0.1999	0.5999	-0.3207	-0.0099	0.0922	-47.4181
0.4001	0.4001	-0.3329	-0.0102	0.077	-51.2923
0.6001	0.1999	-0.3179	-0.0103	0.0467	-50.8363
0.8504	0.0000	-0.2014	-0.021	0.0795	-90.528

One should observe that the values of variation of excess Gibbs energy  $\Delta G^E$  for the four ternary liquid systems. The values of  $\Delta G^E$  are all negative in all the systems concerned and decrease with molar concentration of substituted benzenes [See Table 4]. According to Read et al.[23], the positive values of excess Gibbs energy values may be attributed to specific interactions like hydrogen bonding and charge transfer, while negative  $\Delta G^E$  values may be ascribed to the dominance of dispersion forces [24]. In the present investigation, our close observation suggest that the decreasing negative values of  $\Delta G^E$  indicates the strength of interaction gets weakened with increasing of substituted benzenes. Further, the negative values of  $\Delta G^E$  indicate the easier flow of ternary mixture compared with the behaviour of pure components. According to Fort et al. [17] the variation of excess viscosity ( $\eta^E$ ) gives the strength of molecular interaction between the molecules.

For systems, where dispersion, induction, and dipolar forces which are operated by the values of excess viscosity are found to be negative, whereas the existence of specific interactions leading to the formation of complexes in liquid mixtures tends to make excess viscosity positive. It is reported from the present study, the excess viscosities are negative in all the four ternary liquid systems and decrease with the further addition of substituted benzenes. Hence, our present close observation of excess viscosity reveals that presence of weak dipolar forces are existing in the liquid mixtures. Such a decreasing trend of negative values of  $\eta^E$  further suggesting that the dominance of dispersive interaction resulting from the breaking up of the hydrogen bonds of substituted benzenes make the mixture to flow more easily suggesting that the strength of interaction gets weakened.

**Table 4:** Excess Values of Gibb's Free Energy ( $\Delta G^{*E}$ ) and Viscosity ( $\eta^E$ ) at 303.15K

Mole Fraction		Gibb's Free Energy $\Delta G^{*E}/(x10^{-20} \text{KJ mol}^{-1})$	Excess viscosity $\eta^E/(x10^{-3} \text{NSm}^{-2})$
$X_1$	$X_3$		
<b>System-I Chlorobenzene + 1-Pentanol + Acetophenone</b>			
0.0000	0.7997	-0.1585	-0.2641
0.2008	0.5992	-0.1619	-0.3016
0.4001	0.3999	-0.1778	-0.3221
0.5989	0.2011	-0.1915	-0.3538
0.8000	0.0000	-0.1920	-0.3516
<b>System-II: Bromobenzene + 1-Pentanol + Acetophenone</b>			
0.0000	0.8001	-0.1522	-0.2558
0.2001	0.5999	-0.1642	-0.2876
0.3999	0.4003	-0.1833	-0.3687
0.5996	0.2002	-0.1907	-0.3494
0.7999	0.0000	-0.1970	-0.3727
<b>System-III: Nitrobenzene + 1-Pentanol + Acetophenone</b>			
0.0000	0.7999	-0.1527	-0.2553
0.2000	0.5997	-0.1831	-0.4355
0.4001	0.3998	-0.2128	-0.6141
0.5999	0.1999	-0.2472	-0.7889
0.8000	0.0000	-0.2911	-0.9719
<b>System-IV: Toluene + 1-Pentanol + Acetophenone</b>			
0.0000	0.7999	-0.1521	-0.2555
0.1999	0.5999	-0.1611	-0.3068
0.4001	0.4001	-0.1680	-0.3368
0.6001	0.1999	-0.1674	-0.3195
0.8504	0.0000	-0.1791	-0.3238

### 3. CONCLUSION

From the trends and behaviour of the evaluated excess values of ternary mixtures of substituted benzenes with acetophenone in 1-pentanol at 303.15K, which may eventually concluded as

- There exist a molecular interaction between the acetophenone and 1-heptanol is through hydrogen bonding and with substituted benzenes through dipole-dipole interactions.
- The strength of the molecular interactions gets weakened on further addition of substituted benzenes.

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- Weak dipolar and cohesive forces are existing in the present systems of liquid mixtures.
- The present study also predicts the formation of donor-acceptor complexes in the component mixtures.

(C<sub>6</sub>,C<sub>8</sub>,C<sub>10</sub>) binary mixtures at different temperature. *J. Chinese. Chem. Soci*,51,477.

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