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EXPERIMENTAL AND THEORETICAL STUDIES OF SPEED OF SOUND AND VISCOSITY IN SOME LIQUID MIXTURES OF METHYL BENZOATE: A COMPARATIVE STUDY

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ABSTRACT

Speed of sound and viscosity were measured in the equimolar liquid mixtures of methyl benzoate + 1-propanol/1-butanol/1-pentanol with benzene and theoretical values of speed of sound and viscosity have been evaluated at 303.15K using Nomoto's relation, Impedance relation, Ideal mixture relation, Junjie's method, free length theory and Rao's relation for speed of sound and several empirical relations due to Grunberg-Nissan, Hind, Katti and Chaudari, Heric and Brewer, Frenkel and Tamura-Kurata for viscosity. Theoretical values of speed of sound and viscosity are compared with the experimental values and the validity of these theories is checked. For speed of sound the chi-square test for goodness of fit and the average percentage error (APE) were calculated. A good agreement has been found between experimental and theoretical values of speed of sound and also for viscosity.

Key words: Speed of sound, viscosity, liquid mixtures, alkanols, methyl benzoate.

INTRODUCTION

Measurement of speed of sound gives the valuable information about the physicochemical behaviour[1,2] of the liquid and liquid mixtures. Several relations, semi-empirical formulas and theories are available for the theoretical computation of speed of sound and viscosity in liquid and liquid mixtures[3-16].

Even though considerable work has been reported on alcohols as one of the component in binary and ternary mixtures, the data on equimolar mixtures of alcohols + alkylbenzoates with benzene is scanty. The molecules with –OH group form associative liquids due to hydrogen bonding. The effect shown by the molecules with other functional groups on these molecules plays a vital role in understanding the behaviour of hydrogen bonding. Alcohols are strongly associated in solution because of dipole-dipole interaction and hydrogen bonding. They are of great importance for their vital role in chemistry, biology and studies on hydrogen bonding in liquid mixtures. Alcohols are widely used as solvents. On the other hand alkyl benzoates are non-associated in solution, good hydrogen bonding acceptors. They are widely used in perfumery and pesticides. Benzene is a widely used industrial chemical. Benzene is found in crude oil and is a major part of gasoline. It's used to make plastics, resins, synthetic fibers, rubber lubricants, dyes, detergents, drugs and pesticides

In the present study, the speed of sound and viscosity of the equi molar liquid mixtures of methyl benzoate + 1-propanol/1-butanol/1-pentanol with benzene were measured. From these experimentally measured values of speed of sound and viscosity, theoretical speed of sound and dynamic viscosity values for the equi molar liquid mixtures of methyl benzoate + 1-propanol/1-butanol/1-pentanol have been evaluated using several empirical relations in the liquid mixtures considering methyl benzoate+1-propanol or 1-butanol or 1-pentanol as one component and benzene as the other component at T=303.15K.

In continuation of our work[17-20], we report the speed of sound values evaluated using Nomoto's relation[3], Impedance relation[4], Ideal mixture relation[5], Junjie's method[6] free length theory[7] and Rao's[8] and further, the best suitable theory for the given molecular system under study is also picked out by calculating the average percentage error[9] and chi-square test[10]. The viscosity values were computed from Grunberg-Nissan[11], Hind[12],

Katti and Chaudari[13], Heric and Brewer[14], Frenkel[15] and Tamura and Kurata[16] relations for the liquid mixtures of methyl benzoate + 1-Propanol, 1-Butanol, 1-Pentanol with benzene.
This kind of evaluation of theoretical speed of sound values proves to be useful to verify the applicability of various postulates of these theories of liquid mixtures and to arrive at some useful inferences regarding the strength of molecular interactions between component liquids in some cases.

EXPERIMENTAL

Materials

The chemicals used in the present study are, methyl benzoate and 1-propanol, 1-butanol, 1-pentanol with benzene which are of AR grade obtained from Merck Co. Inc., Germany, with purities of greater than 99%.

Measurements

All binary mixtures were prepared gravimetrically in air-tight bottles and adequate precautions have been taken to minimize evaporation losses. Before use, the chemicals were stored over 0.4nm molecular sieves approximately for 72h to remove water content and then degassed. The mass measurements were performed on a digital electronic balance (Mettler Toledo AB 135, Switzerland) with an uncertainty of $\pm 10^{-8}$ kg. The binary mixtures were prepared just before use. The uncertainty in mole fraction was estimated to be less than ±0.0001. The viscosities were measured with Ostwald viscometer. The viscometer was calibrated at each temperature using redistilled water. The uncertainty in viscosity measurement is up to 0.001mPa-s. The flow time has been measured after the attainment of bath temperature by each mixture. The flow measurements were made with an electronic stop watch with a precision of 0.01s. For all the pure components and mixtures, 3 to 4 readings were taken and the average of these values were used in all the calculations. The densities of the pure compounds and their mixtures were determined accurately using 10 ml specific gravity bottles. The average uncertainty in the measured density was ±0.001 kg/m^3. The speed of sound was measured with a single-crystal variable path interferometer (Mittal Enterprises, New Delhi, India) operating at a frequency of 2 MHz that had been calibrated with water and benzene. The uncertainty in the speed of sound was found to be ±0.1m/s. In all property measurements the temperature was controlled within ± 0.1 K using a constant temperature bath (M/s Sakti Scientific Instruments Company, India) by circulating water from the thermostat.

RESULTS AND DISCUSSION

In the present study, theoretical speed of sound and viscosity values have been evaluated in the liquid mixtures considering methyl benzoate+1-propanol or 1-butanol or 1-pentanol as one component and benzene as the other component at T=303.15K.
Generally, study of thermo-acoustical and excess thermo-acoustical parameters are useful to explain strength of the interactions between the component molecules of liquid mixtures in most of the cases. But in some cases where there is no possibility for the calculation of acoustical and excess acoustical parameters, these theoretical speed of sound and viscosity studies play the major role. Hence this kind of evaluation of theoretical speed of sound values proves to be useful to verify the applicability of various postulates of these theories of liquid mixtures and to arrive at some useful inferences regarding the strength of molecular interactions between component liquids in some cases.
The following relations/theories are used for the prediction of speed of sound in these liquid mixtures.

Nomoto's relation (NOM)[3]

$$U_{NOM} = \left[\frac{x_1R_1 + x_2R_2}{xV_1 + x_2V_2}\right]^3 \quad (1)$$

Where, Molar sound velocity, $R_1 = \frac{m_1}{d_1}.U_1^{1/3}$; $R_2 = \frac{m_2}{d_2}.U_2^{1/3}$

Molar volume $V_1 = \frac{m_1}{d_1}$; $V_2 = \frac{m_2}{d_2}$

Ideal mixture relation (VDV)[5]

$$U_{IMR} = \left[\frac{1}{x_1 m_1 + x_2 m_2}\right]^{1/2} \cdot \left[\frac{x_1}{m_1 U_1^2} + \frac{x_2}{m_2 U_2^2}\right]^{-1/2} \quad (2)$$

Junjie's method (JM)[6]

$$U_{JM} = \left[\frac{x_1 V_1 + x_2 V_2}{(x_1 m_1 + x_2 m_2)^{1/2}}\right] \cdot \left[\frac{x_1 V_1}{d_1 U_1^2} + \frac{x_2 V_2}{d_2 U_2^2}\right]^{-1/2} \quad (3)$$

***Impedance Relation (IMP)*[4]**

$$U_{IMP} = \frac{x_1 Z_1 + x_2 Z_2}{x_1 \rho_1 + x_2 \rho_2} \quad (4)$$

Free length theory (FLT)[7]

$$U_{CFT} = \frac{K}{L_{f_{mix}} d_{exp}^{1/2}} \quad (5)$$

Where, $L_{f_{mix}} = 2\left[\frac{V_m - (x_1 V_{01} + x_2 V_{02})}{x_1 Y_1 + x_2 Y_2}\right]$

Molar volume at absolute zero, $V_{01} = V_1 \frac{U_1}{U_\infty}$; $V_{02} = V_2 \frac{U_2}{U_\infty}$

Surface area per mole, $Y_1 = \frac{2(V_1 - V_{01})}{L_{f_1}}$; $Y_2 = \frac{2(V_2 - V_{02})}{L_{f_2}}$

Where, 1, 2, represents the first and second component of the liquid mixture and the other symbols have their usual meanings.

Rao's relation (Rao)[8]

$$U_{Rao} = \left(\sum x_i r_i \rho_i\right)^3 \quad (6)$$

Where x_i is the mole fraction and ρ_i the density of the mixture.

Percentage deviation in speed of sound

The percentage deviations in speed of sound between the experimental and theoretical values are calculated as follows,

$$\left(\frac{\Delta U}{U}\right)\% = \left(\frac{U_{exp} - U_{theory}}{U_{exp}}\right).100 \quad (7)$$

The validity of the theories is checked by applying Chi-square test and by calculating average percentage error.

Average percentage error (APE)

The average percentage Error[9] is calculated using the relation,

$$APE = \frac{1}{n} \sum \frac{(U_{mix(obs)} - U_{mix(cal)})}{U_{mix(obs)}}.100\% \quad (8)$$

Where, *n*- number of data used.

Umix(obs) = experimental values of speed of sound.

Umix(cal) = computed values of speed of sound.

Chi-square test for goodness of fit

According to Karl Pearson[10], the Chi-square value is calculated using the formula,

$$(x^2) = \sum_{i=1}^{n} \frac{(U_{mix(obs)} - U_{mix(cal)})^2}{U_{mix(cal)}} \quad (9)$$

For (*n*-1) degrees of freedom, where, n is the number of data used.

The theories due to Nomoto's relation[3], Impedance relation[4], Ideal mixture relation[5], Junjie's method[6] free length theory[7] and Rao's[8] are employed and the Average percentage error[9] along with the Chi square fit[10] values for these liquid mixtures are compiled in Table-1. The average percentage error values are small. On comparison, the Nomoto's relation and free length theory relation are found to give some valuable estimate of the experimental values of speed of sound values in these mixtures. The percentage deviations in experimental and theoretical speed of sound values are given in Table-2.

It can be seen from Table 1 that the theoretical values of speed of sound computed by various theories show deviation from experimental values. The predictive abilities of various speeds of sound theories depend upon the strength of interaction prevailing in a system. These theories generally fail to predict accurately the speed of sound where strong interactions are supposed to exist due to the limitations and approximations incorporated in these theories[21]. The extent of deviation may be attributed to the assumptions made in these theories for the non polar- polar and non polar-non polar interaction between the molecules. The Chi-square value and APE value is minimum for Nomoto's relation than those obtained by other theories. An important reason for deviation from experimental values of speed of sound is that the molecular association effects are not taken into account in these theories. When two or more liquids are mixed, the interaction between the molecules of those liquids takes place because of the presence of various forces like dispersive force, charge transfer, hydrogen bonding dipole-dipole and dipole-induced dipole interactions[21]. Thus, the observed deviation of theoretical values of speed of sound from the experimental values shows that the molecular interaction is taking place between the unlike molecules in the liquid mixtures.

Table-1: Experimental and computed values of Speed of sound in liquid mixtures of (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene over the entire mole fraction range along with the average percentage error and Chi square values at T = 303.15 K.

x_1	U_{exp} ms^{-1}	U_{NOM} ms^{-1}	U_{IMP} ms^{-1}	U_{VDV} ms^{-1}	U_{JM} ms^{-1}	U_{FLT} ms^{-1}	U_R ms^{-1}
(Methyl benzoate+1-Propanol) + Benzene							
0.0000	1276.4	1276.4	1276.4	1276.4	1276.4	1276.4	1276.4
0.0604	1277.5	1277.5	1277.7	1275.5	1278.0	1277.5	1280.1
0.1263	1278.9	1278.9	1279.1	1274.8	1279.8	1278.9	1283.5
0.1986	1280.2	1280.2	1280.7	1274.4	1281.7	1280.2	1286.4
0.2782	1281.9	1281.9	1282.3	1274.4	1283.8	1281.9	1288.7
0.3664	1283.6	1283.6	1284.2	1275.0	1286.0	1283.6	1290.2
0.4645	1285.7	1285.7	1286.2	1276.3	1288.3	1285.7	1291.3
0.5743	1287.8	1287.8	1288.4	1278.6	1290.4	1287.8	1293.7
0.6982	1290.4	1290.4	1290.8	1282.3	1292.5	1290.4	1295.4
0.8388	1293.1	1293.1	1293.6	1288.1	1294.7	1293.1	1296.1
1.0000	1296.6	1296.6	1296.6	1296.6	1296.6	1296.6	1296.6
APE		0.0000	-0.0287	0.4225	-0.1155	0.0000	-0.3280
Chi square		0.0000	0.0015	0.3511	0.0263	0.0000	0.1987
(Methyl benzoate+1-Butanol) + Benzene							
0.0000	1277.0	1277.0	1277.0	1277.0	1277.0	1277.0	1277.0
0.0738	1279.0	1279.0	1279.1	1274.6	1280.2	1279.0	1280.2
0.1519	1281.1	1281.1	1281.3	1272.8	1283.4	1281.1	1283.2
0.2350	1283.3	1283.3	1283.7	1271.7	1286.5	1283.3	1285.9
0.3233	1285.9	1285.9	1286.2	1271.6	1289.6	1285.9	1288.5
0.4175	1288.1	1288.1	1288.7	1272.5	1292.5	1288.1	1290.8
0.5181	1291.0	1291.0	1291.5	1274.7	1295.4	1291.0	1293.0
0.6258	1293.7	1293.7	1294.4	1278.5	1298.0	1293.7	1295.1
0.7414	1296.9	1296.9	1297.4	1284.3	1300.4	1296.9	1297.3
0.8658	1300.3	1300.3	1300.6	1292.6	1302.5	1300.3	1299.9
1.0000	1304.0	1304.0	1304.0	1304.0	1304.0	1304.0	1304.0
APE		0.0000	-0.0248	0.7482	-0.2051	0.0000	-0.1017

Chi square		0.0000	0.0013	1.0880	0.0806	0.0000	0.0252
(Methyl benzoate+1-Pentanol) + Benzene							
0.0000	1277.8	1277.8	1277.8	1277.8	1277.8	1277.8	1277.8
0.0712	1280.9	1280.9	1281.0	1274.3	1282.5	1280.9	1282.4
0.1472	1284.1	1284.1	1284.4	1271.6	1287.2	1284.1	1286.7
0.2283	1287.4	1287.4	1288.0	1270.0	1292.0	1287.4	1289.4
0.3151	1291.1	1291.1	1291.7	1269.7	1296.5	1291.1	1294.2
0.4084	1295.0	1295.0	1295.7	1270.9	1300.9	1295.0	1298.4
0.5087	1299.3	1299.3	1300.0	1274.1	1305.1	1299.3	1302.9
0.6169	1303.7	1303.7	1304.5	1279.7	1309.3	1303.7	1307.0
0.7341	1308.7	1308.7	1309.3	1288.6	1313.3	1308.7	1310.3
0.8613	1314.0	1314.0	1314.5	1301.5	1317.0	1314.0	1314.0
1.0000	1320.0	1320.0	1320.0	1320.0	1320.0	1320.0	1320.0
APE		0.0000	-0.034	1.1481	-0.2771	0.0000	-0.1479
Chi square		0.0000	0.0025	2.5960	0.1475	0.0000	0.0464

From Table-2, it is observed that the percentage deviations of the speed of sound are both negative and positive. Such deviations indicate the non-ideal behaviour of liquid mixtures. To measure the non-ideality in the mixtures the ratio U^2_{EXP}/U^2_{IMX} is used as an important tool[21], especially in these cases where the properties other than speed of sound are not known. A perusal of Table 3 indicates considerable deviations from ideality, which may be due to the existence of strong dipole interactions in liquid mixtures[22]. These variations clearly indicate that ratio of U^2_{EXP}/U^2_{IMX} increases from unity with the increase of mole fraction from 0 to 0.5 and above the 0.5 mole fraction range the ratio of U^2_{EXP}/U^2_{IMX} decreases and tend to unity as observed from Figure-1. Also the deviation of the ratio U^2_{EXP}/U^2_{IMX} from unity is a direct measure of non-ideality of the system as a consequence of association or other type of interactions which is called as molecular interaction parameter (α). The positive values of α in the present systems clearly indicate the existence of strong interactions in the liquid mixtures[23].

Hence the observed deviation shows that the molecular interaction is taking place between the unlike molecules in the liquid mixture[22]. The agreement between experimental and theoretical velocities of Nomoto's relation in all the three systems, suggests that R is additive property in all the systems. Higher deviations are observed in some intermediate concentration range. This suggests the existence of strong tendency for the association between component molecules as a result of Hydrogen bonding. The theories used at present are inadequate to explain the intermolecular interactions at the fullest, because in order to explain intermolecular interactions we at least need to know about the dipole interactions, collision factors, hydrogen bond forces etc. Such an expression has not yet been developed.

The dynamic viscosities of the liquid mixtures have been calculated using several empirical relations due to Grunberg-Nissan[11], Hind *et al.*[12], Katti and Chaudari[13], Heric and Brewer[14], Frenkel[15] and Tamura and Kurata[16]. Figure-2 shows the experimental values of viscosity for liquid mixture of (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene at T = 303.15 K. Figure-3 shows the variations of η over the entire mole fraction range at temperatures T =303.15 K for different theories in the liquid mixtures (a) (Methyl benzoate+1-propanol) + benzene, (b) (Methyl benzoate+1-butanol) + benzene, (c) (Methyl benzoate+1-pentanol) + benzene. It is clear that Hind theory could not give accurate values compared to experimental values. These theories generally fail to predict accurately the values where strong interactions are supposed to exist due to the limitations and approximations incorporated in these theories.

Various interaction parameters and their corresponding standard deviations (σ) of viscosity computed from different theories in liquid mixture of (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene at T = 303.15 K are compiled in Table-4. All the empirical models gave a reasonable fit in all these mixture. The estimated standard deviations are smaller in all cases indicating that the present mixture viscosities are well correlated by these viscosity models.

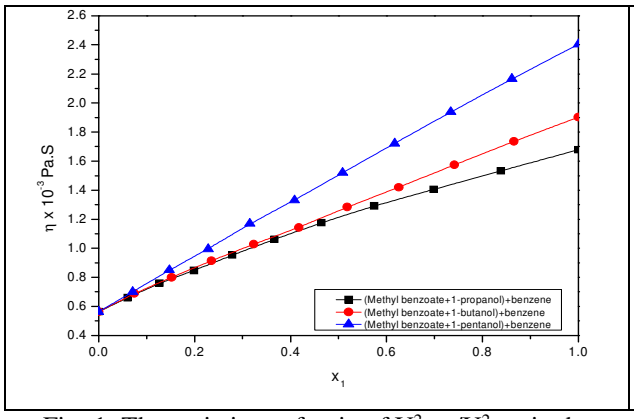

Fig.-1: The variations of ratio of U^2_{EXP}/U^2_{IMX} in the liquid mixtures (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene over the entire mole fraction range at temperatures T =303.15 K.

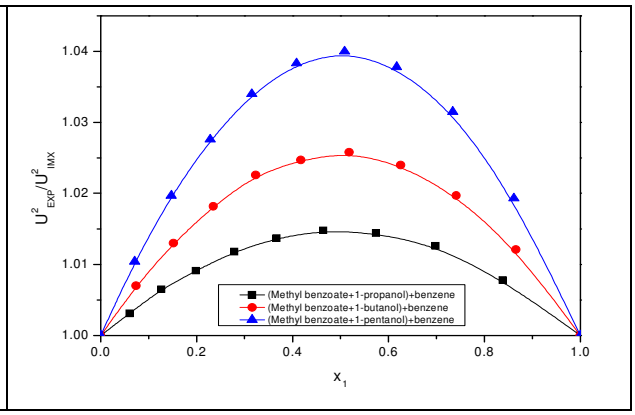

Fig.-2:The variations of η in the liquid mixtures (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene over the entire mole fraction range at temperatures T =303.15 K.

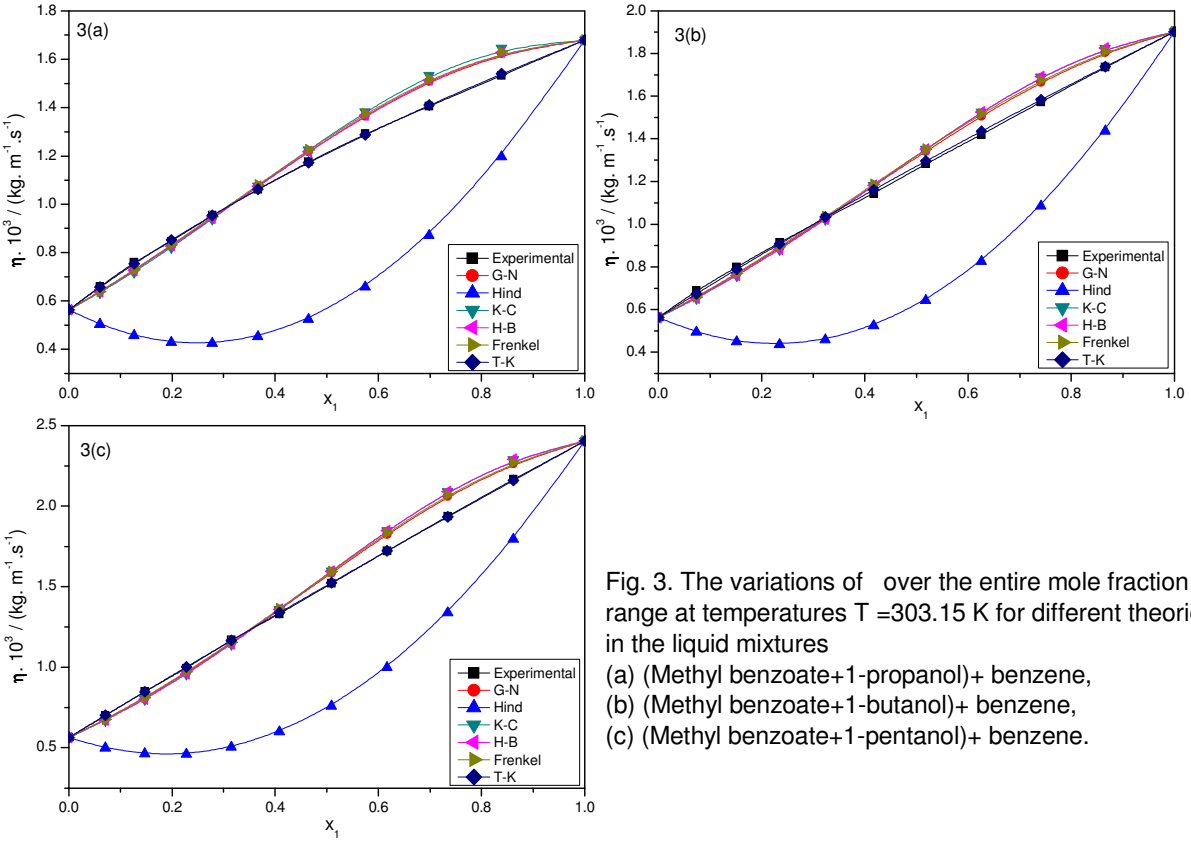

Fig. 3. The variations of over the entire mole fraction range at temperatures T =303.15 K for different theories in the liquid mixtures
(a) (Methyl benzoate+1-propanol)+ benzene,
(b) (Methyl benzoate+1-butanol)+ benzene,
(c) (Methyl benzoate+1-pentanol)+ benzene.

Fig.-3

Table-2: Percentage deviations between experimental and theoretical values of Speed of sound in (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene over the entire mole fraction range at T = 303.15 K.

x_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JM}$	$\%U_{FLT}$	$\%U_R$
(Methyl benzoate+1-Propanol) + Benzene						
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0604	0.0000	-0.0200	0.1556	-0.0459	0.0000	-0.2055

0.1263	0.0000	-0.0186	0.3225	-0.0704	0.0000	-0.3636
0.1986	0.0000	-0.0403	0.4516	-0.1218	0.0000	-0.4862
0.2782	0.0000	-0.0348	0.5860	-0.1463	0.0000	-0.5289
0.3664	0.0000	-0.0426	0.6758	-0.1857	0.0000	-0.5091
0.4645	0.0000	-0.0401	0.7310	-0.2063	0.0000	-0.4393
0.5743	0.0000	-0.0476	0.7127	-0.2041	0.0000	-0.4576
0.6982	0.0000	-0.0349	0.6234	-0.1664	0.0000	-0.3860
0.8388	0.0000	-0.0366	0.3888	-0.1235	0.0000	-0.2313
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
(Methyl benzoate+1-Butanol) + Benzene						
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0738	0.0000	-0.0077	0.3470	-0.0918	0.0000	-0.0925
0.1519	0.0000	-0.0220	0.6455	-0.1795	0.0000	-0.1642
0.2350	0.0000	-0.0325	0.8984	-0.2520	0.0000	-0.2006
0.3233	0.0000	-0.0200	1.1132	-0.2847	0.0000	-0.1985
0.4175	0.0000	-0.0482	1.2138	-0.3412	0.0000	-0.2090
0.5181	0.0000	-0.0358	1.2639	-0.3359	0.0000	-0.1571
0.6258	0.0000	-0.0485	1.1770	-0.3322	0.0000	-0.1033
0.7414	0.0000	-0.0384	0.9723	-0.2729	0.0000	-0.0317
0.8658	0.0000	-0.0193	0.5995	-0.1663	0.0000	0.0378
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
(Methyl benzoate+1-Pentanol) + Benzene						
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0712	0.0000	-0.0077	0.5173	-0.1218	0.0000	-0.1192
0.1472	0.0000	-0.0221	0.9723	-0.2375	0.0000	-0.2012
0.2283	0.0000	-0.0439	1.3508	-0.3598	0.0000	-0.1562
0.3151	0.0000	-0.0492	1.6602	-0.4156	0.0000	-0.2388
0.4084	0.0000	-0.0581	1.8605	-0.4559	0.0000	-0.2635
0.5087	0.0000	-0.0537	1.9405	-0.4496	0.0000	-0.2735
0.6169	0.0000	-0.0628	1.8380	-0.4266	0.0000	-0.2520
0.7341	0.0000	-0.0488	1.5390	-0.3515	0.0000	-0.1233
0.8613	0.0000	-0.0374	0.9503	-0.2294	0.0000	0.0005
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table-3: Values of U^2_{EXP}/U^2_{IMX} and molecular interaction parameter (α) and average molecular interaction Parameter (α_{AVG}) in the liquid mixture (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene over the entire mole fraction range at T = 303.15 K.

x_1	U^2_{EXP}/U^2_{IMX}	α	x_1	U^2_{EXP}/U^2_{IMX}	α	x_1	U^2_{EXP}/U^2_{IMX}	α
(Methyl benzoate+1-Propanol) + Benzene			(Methyl benzoate+1-Butanol) + Benzene			(Methyl benzoate+1-Pentanol) + Benzene		
0.0000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000	0.0000
0.0604	1.0031	0.0031	0.0738	1.0070	0.0070	0.0712	1.0104	0.0104
0.1263	1.0065	0.0065	0.1519	1.0130	0.0130	0.1472	1.0197	0.0197
0.1986	1.0091	0.0091	0.2350	1.0182	0.0182	0.2283	1.0276	0.0276
0.2782	1.0118	0.0118	0.3233	1.0226	0.0226	0.3151	1.0340	0.0340
0.3664	1.0137	0.0137	0.4175	1.0247	0.0247	0.4084	1.0383	0.0383
0.4645	1.0148	0.0148	0.5181	1.0258	0.0258	0.5087	1.0400	0.0400
0.5743	1.0144	0.0144	0.6258	1.0240	0.0240	0.6169	1.0378	0.0378
0.6982	1.0126	0.0126	0.7414	1.0197	0.0197	0.7341	1.0315	0.0315
0.8388	1.0078	0.0078	0.8658	1.0121	0.0121	0.8613	1.0193	0.0193
1.0000	1.0000	0.0000	1.0000	1.0000	0.0000	1.0000	1.0000	0.0000

Average molecular interaction Parameter (α_{AVG})	0.0085	0.0152	0.0235

Table-4: Various interaction parameters and their corresponding standard deviations (σ) of viscosity computed from different theories in liquid mixture of (Methyl benzoate+1-propanol/1-butanol/1-pentanol) + benzene at T = 303.15 K.

	G_{12}	H_{12}	W_{vis}/RT	Δ_{12}	F_{12}	T_{12}
(Methyl benzoate+1-Propanol) + Benzene						
Interaction Parameter	1.0578	0.0013	1.4952	1.1817	1.6711	1.1943
σ	0.0595	0.5212	0.0735	0.0617	0.0642	0.0048
(Methyl benzoate+1-Butanol) + Benzene						
Interaction Parameter	0.9515	0.0013	1.3834	1.3836	1.6890	1.2170
σ	0.0599	0.5240	0.0735	0.0739	0.656	0.0127
(Methyl benzoate+1-Pentanol) + Benzene						
Interaction Parameter	1.1858	0.0015	1.6178	1.6197	2.1295	1.3885
σ	0.0738	0.6184	0.0913	0.0916	0.0794	0.0058

Various interactions parameters are: G12 - Grunberg and Nissan, H12 – Hind, Mc Laughlin and Ubbelohde, Wvis/RT – Katti and Chaudari, Δ12 – Heric and Brewer, F12 – Frenkel, T12 – Tamura and Kurata.

CONCLUSION

The computed speed of sound and viscosity values from different theories have been correlated with the experimentally measured values. Speed of sound values obtained from Nomoto's and free length theory relations are in good agreement with the experimental values. It may be concluded that out of these theories, Nomoto's relation is best suited for all the liquid mixtures under study. The Chi square values also support this theory. The observed deviation of theoretical values of speed of sound from the experimental values is attributed to the presence of intermolecular interactions. The experimental viscosity values are also compared with the viscosity values obtained from different empirical relations and these are in good agreement with the experimental values.

REFERENCES

1. S.K. Fakruddin, M.Pushpalatha, Ch.Srinivasu and K. Narendra, K. *Karbala International Journal of Modern Science*, **1**, 97(2015).
2. Sk. Fakruddin Babavali, Ch. Srinivasu, K. Narendra and Ch.Sridhar Yesaswi, *Rasayan J.Chem.,* **9(3),** 544(2016).
3. O.Nomoto, *J. Phys. Soc. Jpn.,* **13**, 1528(1958).
4. S.Baluja and P.H.Parrania, *Asian J.Chem.,* **7**, 417 (1995).
5. W.Van Dael, *Thermodynamic properties and velocity of sound*, Butterworth, London, (**1975**)
6. G.Savaroglu and E.Aral, *Fluid Phase Equilib.*, **215**, 253(2004).
7. Z.Junjie, *J. China. Univ. Sci. Technol.*, **14**, 298(1984).
8. B.Jacobson, *J.Chem.Phys.*, **20**, 927(1952).
9. G.V.R.Rao, A.V.V.Sarma, J.S.Krishna and C.Rambabu, C. *Indian J. Pure Appl. Phys.*, **43**, 345 (2005).
10. J.S.R.Jang, *IEEE Trans. Syst. Man. Cybern.,* **23(3),** 665(1993).
11. K.Pearson, Fundamentals of Mathematical Statistics. In: S.G.Gupta, V.K.Kapoor, S.Chand and sons Company, New Delhi, India, 903(**1973**).
12. L.Grunberg and A.H.Nissan, *Nature*, **164**, 799(1949).
13. R.K.Hind and E. Mc Laughlin, A.R.Ubbelohde, *Trans. Faraday Soc.*, **56**, 328(1960).
14. P.K.Katti and M.M.Chaudari, *J.Chem Eng. Data*, **9**, 442(1964).

15. E.L Heric, J.C.Brewer, *J.Chem Eng. Data*, **11**, 66(1966).
16. Y.I.Frenkel, *Petroleum,* **9**, 27(1946).
17. M.Tamura and M.Kurata, *Bull. Chem. Soc. Jpn.*, **25**, 32(1952).
18. S.S.Sastry, S.Babu, T.Vishwam, K.Parvateesam and H.S.Tiong, *Physica B*, **420**, 40(2013).
19. S.S.Sastry, S.Babu, T.Vishwam and H.S.Tiong, *J.Therm. Anal. Calorim.,* **116**, 923(2014).
20. S.S.Sastry, S.Babu, T.Vishwam and H.S.Tiong, *Phys. Chem. Liq.*, **52(2)**, 272(2014).
21. S.S.Sastry, S.Babu, T.Vishwam and H.S.Tiong, *J. Chem. Thermodyn.*, **68**, 183(2014).
22. B.Zareena, P.B.Sandhyasri, D.B.Karuna kumar and C. Rambabu, *J. Mol. Liq.,* **178**, 99 (2013).
23. G.V.Ramarao, M.Triveni and D.Ramachandran, *Int. J. Eng. Res.*, **3**, 101(2015).
24. R. Bhaskaran and T.R. Kubendran, *Int. J. Appl. Sci. Eng.,* **5**, 115(2007).

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