Temperature Dependence of Excess Parameters for Binary Mixtures of 1-4 Butanediol and 1-Alkanols by Ultrasonic Technique

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Abstract—Speed of sound (U), Density (\(\rho\)), and viscosity (\(\eta\)) values for the binary mixture systems of 1-4 butanediol with methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol including those of pure liquids were measured from 0.1 to 0.9 mole fraction range at different temperatures (303.15, 308.15, 313.15, 318.15 and 323.15) K. From the experimentally determined values, thermo-acoustic parameters such as excess isentropic compressibility (\(K_sE\)), excess molar volume (\(V^E\)) and excess free length (\(L_fE\)), excess Gibb's free energy (\(\Delta G^E\)) and excess enthalpy (\(\Delta H^E\)) have been calculated. The deviations for excess thermo-acoustic parameters have been explained on the basis of the intermolecular interactions present in these binary mixtures. The theoretical values of speed of sound in the mixtures has been evaluated using various theories and has been compared with experimentally determined speed of sound values in order to validate such theories to the liquid mixture systems under study.

Keywords—Speed Of Sound, Density, Excess Molar Volume, Isentropic Compressibility, Free Length, 1,4- Butanediol.

1. INTRODUCTION

Speed of sound investigations along with the volumetric and viscometric studies of liquids and liquid mixtures are of considerable importance and they play a significant role in understanding the intermolecular interactions occurring among the component molecules besides finding extensive applications in several industrial and technological processes [1,2]. Several researchers [3-8] have measured the density, viscosity, and speed of sound for a wide range of binary mixtures containing alcohols as one of the components, and these properties were interpreted in terms of specific or nonspecific interactions. Alcohols are strongly associated in solution because of dipole-dipole interaction and hydrogen bonding. They are of great importance for their relevant role in chemistry, biology and studies on hydrogen bonding in liquid mixtures. Alcohols are widely used as solvents. The molecules containing –OH group form associative liquids due to hydrogen bonding. The effect shown by the molecules with other functional groups on these molecules plays an important role in understanding the behavior of hydrogen bonding. The investigations regarding the molecular association in liquid mixtures having aromatic group as one of the components are of particular interest, since aromatic group is highly non-polar and can associate with any other group having some degree of polar attractions, Even though considerable work has been reported on alcohols as one of the component in binary and ternary mixtures, the data on binary mixtures of alcohols with 1-4 butanediol with temperature variation is scanty.

The study of thermodynamic properties of multi component liquid mixtures and data on the analysis in terms of various models are important for industrial and pharmaceutical applications [9]. The excess thermodynamic functions [10] are sensitively dependent not only on the differences in intermolecular forces, but also on the differences in the size of the molecules. The signs and magnitudes of these excess values can throw light on the strength of interactions. So from the experimentally determined values of speed of sound density and viscosity, various thermo-acoustic parameters like excess isentropic compressibility (\(K_sE\)), excess molar volume (\(V^E\)), excess free length (\(L_fE\)), excess Gibb’s free energy (\(\Delta G^E\)) and excess enthalpy (\(\Delta H^E\)) have been calculated. The intermolecular interactions have been estimated in the light of these excess parameters. In the present study, theoretical speed of sound and viscosity values have been evaluated using several empirical relations in the liquid mixtures. 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 present study gives information on molecular interactions in the commercially important liquid mixtures 1-4 butanediol with 1-alkanols over the entire composition range. Here we report the results of speed of sound, density and viscosity for the binary liquid mixtures of 1-4 butanediol with five 1-alkanols at temperatures of (303.15, 308.15, 313.15, 318.15 and 323.15) K.
II. MATERIALS AND EXPERIMENTS

a. Materials
The chemicals used in the present study are, 1-4 butanediol with methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol which are of AR grade obtained from Merck Co. Inc., Germany, with purities of greater than 99%. All the chemicals were further purified by standard methods [11] and only middle fractions were collected.

b. 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 ±10^-6 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 0.001 mPa·s. The flow time had 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/m³.

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 ±0.1 m/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.

c. Computational Details
The values of experimentally determined density and speed of sound for the binary mixtures of 1,4 Butane diol with 1-Alkanols at 303.15 K, 308.15 K, 313.15 K, 318.15 K and 323.15 K over the entire composition range.

In the present work, the excess values of isentropic compressibility and excess free length values are calculated to check the applicability of thermo dynamical ideality (the ideal mixing rules) to the components under study.

The excess values of isentropic compressibility \( K \text{E} \) were calculated as follows,

\[
K \text{E} = K - K \text{id}
\]  

Where \( K \text{id} \) represent the calculated value of isentropic compressibility for the mixture

\[
K = \frac{1}{n} U \tag{2}
\]

\( K \text{E} \) is its excess value, \( K \text{id} \) is the ideal isentropic compressibility value, \( n \) is the density and \( U \) represents the speed of sound. \( K \text{id} \) for an ideal mixture was calculated from the relation recommended by Benson and Kiyohara [12, 13] and Douheret et al [14],

\[
K \text{id} = \sum \phi_i \left( K^{(o)}_{i} + \left( \frac{T V^{(o)}_i (\alpha^{(o)}_i)^2}{c^{(o)}_i} \right) - T \left( \sum \phi_i V^{(o)}_i \right) \frac{\sum \phi_i \alpha^{(o)}_i}{\sum \phi_i c^{(o)}_i} \right) \tag{3}
\]

in which \( K^{(o)}_{i}, V^{(o)}_i, \alpha^{(o)}_i, C^{(o)}_i \) are the isentropic compressibility, molar volume, isobaric thermal expansion coefficient and molar isobaric heat capacity of pure component \( i \), \( T \) represents temperature, \( \phi_i \) is the volume fraction and \( \chi_i \) represents the mole fraction of \( i \) in the mixture.

The density values have been used to calculate the excess volumes, \( V \text{E} \), using the following equation,

\[
V \text{E} = \frac{x_1 M_1 + x_2 M_2}{\rho} - \left( \frac{x_1 M_1}{\rho_1} + \frac{x_2 M_2}{\rho_2} \right) \tag{4}
\]

where \( \rho \) is the density of the mixture and \( x_1, M_1, \) and \( \rho_1 \) and \( x_2, M_2, \) and \( \rho_2 \) are the mole fraction, molar mass, and density of pure components 1 and 2, respectively.

The excess values of free length of (\( L \text{E} \)), Gibbs free energy (\( \Delta G \text{E} \)) and enthalpy (\( \Delta H \text{E} \)) were calculated by using the expressions given in literature [15] as follows,

\[
L \text{E} = L - K T \left( K \text{id} \right)^{1/2} \tag{5}
\]

\[
L \text{E} \text{G} = R T \left[ \ln \left( \frac{\eta V}{\eta_2 V_2} \right) - x_1 \ln \left( \frac{\eta_1 V_1}{\eta_2 V_2} \right) \right] \tag{6}
\]

Where \( R \) represents gas constant, \( T \) is absolute temperature, \( \eta \) the viscosities of the mixture and \( \eta_1, \eta_2 \) are the viscosities of the pure compounds, \( V \) is the molar volume of mixture and \( V_1, V_2 \) are the molar volumes of the pure compounds, 

Excess enthalpy for activation \( \Delta H \text{E} \) was calculated as follows,

\[
\Delta H = H - \left( x_1 H_1 + x_2 H_2 \right) \tag{7}
\]

Where \( H \) represents the calculated value of enthalpy for the mixture and \( H_1, H_2 \) represent enthalpy of pure components 1 and 2, respectively.

III. RESULTS AND DISCUSSION
The experimental values of speed of sound, density and viscosity in case of the binary liquid mixtures under study over the entire range of composition and at different temperatures, \( T = (303.15, 308.15, 313.15, 318.15 \text{ and } 323.15) \) K are given in Table 1.
Table 1 Densities ($\rho$), Speed of Sound ($U$) and Viscosities ($\eta$) for the binary mixtures of 1,4-butadiene + 1-alkanols at different temperatures.

| $x_1$ | $\rho_1^{10^3}$ | $U_1^{10^2}$ | $\eta_1^{10^2}$ | $x_1$ | $\rho_2^{10^3}$ | $U_2^{10^2}$ | $\eta_2^{10^2}$ |
|------|------------------|-------------|-----------------|------|------------------|-------------|----------------|
| 0.000 | 0.7820 | 1095. | 0.5210 | 0.000 | 0.7088 | 1471. | 0.4951 |
| 0.048 | 0.7922 | 1118. | 0.0309 | 0.234 | 0.8358 | 1212. | 0.050 |
| 0.103 | 0.8055 | 1147. | 0.5912 | 0.0341 | 0.8541 | 1251. | 0.050 |
| 0.164 | 0.8191 | 1173. | 8.6878 | 0.234 | 0.8358 | 1212. | 12.178 |
| 0.314 | 0.8497 | 4 | 0.79 | 0.314 | 0.8497 | 1222. | 15.085 |
| 0.314 | 0.8775 | 1066. | 0.4693 | 0.000 | 0.7770 | 1053. | 0.4299 |
| 0.048 | 0.7887 | 1101. | 2.5389 | 0.048 | 0.7887 | 1087. | 2.1573 |
| 0.103 | 0.7949 | 1111. | 2.74 | 0.164 | 0.8101 | 1140. | 6.5700 |
| 0.234 | 0.8273 | 1170. | 8.7997 | 0.314 | 0.8446 | 1204. | 12.134 |
| 0.000 | 0.7679 | 1053. | 0.4299 | 0.000 | 0.7679 | 1053. | 0.4299 |
| 0.048 | 0.7771 | 1072. | 1.5766 | 0.048 | 0.7771 | 1072. | 1.5766 |
| 0.103 | 0.7899 | 1092. | 3.3354 | 0.103 | 0.7899 | 1092. | 3.3354 |
| 0.164 | 0.8060 | 1117. | 5.2409 | 0.164 | 0.8060 | 1117. | 5.2409 |
| 0.234 | 0.8238 | 1145. | 7.2419 | 0.234 | 0.8238 | 1145. | 7.2419 |
| 0.000 | 0.7630 | 1040. | 0.3990 | 0.000 | 0.7630 | 1040. | 0.3990 |
| 0.048 | 0.7728 | 1057. | 1.3995 | 0.048 | 0.7728 | 1057. | 1.3995 |
| 0.103 | 0.7860 | 1077. | 2.9300 | 0.103 | 0.7860 | 1077. | 2.9300 |
| 0.164 | 0.8002 | 1100. | 4.2039 | 0.164 | 0.8002 | 1100. | 4.2039 |
| 0.234 | 0.8170 | 1124. | 5.9274 | 0.234 | 0.8170 | 1124. | 5.9274 |
| 0.314 | 0.8348 | 1152. | 8.0744 | 0.314 | 0.8348 | 1152. | 8.0744 |
| 0.000 | 0.7813 | 1149. | 0.9940 | 0.000 | 0.7813 | 1149. | 0.9940 |
| 0.067 | 0.7992 | 1178. | 4.2362 | 0.067 | 0.7992 | 1178. | 4.2362 |
| 0.140 | 0.8159 | 1256. | 7.7551 | 0.140 | 0.8159 | 1256. | 7.7551 |
| 0.218 | 0.8352 | 1279. | 11.542 | 0.218 | 0.8352 | 1279. | 11.542 |
| 0.303 | 0.8539 | 1294. | 15.746 | 0.303 | 0.8539 | 1294. | 15.746 |
| 0.395 | 0.8769 | 1309. | 20.285 | 0.395 | 0.8769 | 1309. | 20.285 |
| 0.480 | 0.8978 | 1324. | 26.053 | 0.480 | 0.8978 | 1324. | 26.053 |
| 0.567 | 0.9184 | 1339. | 32.110 | 0.567 | 0.9184 | 1339. | 32.110 |
| 0.654 | 0.9387 | 1354. | 38.17 | 0.654 | 0.9387 | 1354. | 38.17 |
| 0.741 | 0.9589 | 1369. | 44.23 | 0.741 | 0.9589 | 1369. | 44.23 |
| 0.828 | 0.9787 | 1384. | 50.30 | 0.828 | 0.9787 | 1384. | 50.30 |
| 0.915 | 0.9982 | 1400. | 56.37 | 0.915 | 0.9982 | 1400. | 56.37 |
| 0.982 | 1.0185 | 1415. | 62.44 | 0.982 | 1.0185 | 1415. | 62.44 |

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From the data of speed of sound, density and viscosity, the values of excess isentropic compressibility ($\kappa_v^E$), excess molar volume ($\Psi^E$), excess free length ($L^E$), excess Gibb’s free energy ($\Delta G^E$) and excess enthalpy ($H^E$) were calculated. These excess parameters were plotted against

| T/K | $\Psi^E$ | $\kappa_v^E$ | $H^E$ |
|-----|---------|------------|-------|
| 308.15 | 0.8054 | 1.058 | 1320.15 |
| 313.15 | 0.8124 | 1.065 | 1326.15 |
| 318.15 | 0.8184 | 1.072 | 1332.15 |
| 323.15 | 0.8243 | 1.079 | 1338.15 |
| 328.15 | 0.8302 | 1.086 | 1344.15 |
| 333.15 | 0.8361 | 1.093 | 1350.15 |
| 338.15 | 0.8420 | 1.100 | 1356.15 |
| 343.15 | 0.8479 | 1.107 | 1362.15 |
| 348.15 | 0.8538 | 1.114 | 1368.15 |
| 353.15 | 0.8597 | 1.121 | 1374.15 |

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mole fractions separately over the entire range and at different temperatures. The plots are shown in Fig 1-5. Figs. 1(a) to 1(e) show the excess isentropic compressibility ($K_{s}^{E}$) for the binary liquid mixtures of 1-4 butanediol with 1-alknaols over the entire mole fraction range and at different temperatures $T = (303.15, 308.15, 313.15, 318.15, 323.15)$ K. It is clear from Figs. 1(a) to 1(e) that the $K_{s}^{E}$ values are negative over the entire mole fraction range for the systems under study and at investigated temperatures. This indicates the presence of strong interactions in these mixtures. As the temperature increases, it has been observed that the negative $K_{s}^{E}$ values are found to increase in these systems and the changes in $K_{s}^{E}$ values with respect to temperature are small in these mixtures. Also with the increase in temperature the solute-solvent interactions get weaker causing the excess values to decrease at higher temperature. The sign of excess isentropic compressibility plays a relevant role in assessing the compactness due to molecular interaction in liquid mixtures through charge transfer, dipole-dipole interactions, and dipole induced dipole interactions interstitial accommodation and orientational ordering leading to more compact structure making, which enhances excess isentropic compressibility to have negative values. Fort and Moore [17] suggested that the liquids having different molecular sizes and shapes mix well thereby reducing the volume which causes the values of $K_{s}^{E}$ to be negative.

It also suggests that the liquids are less compressible when compared to their ideal mixtures signifying the chemical effects including charge transfer forces, formation of hydrogen bond and other complex forming interactions. It can also be said that the molecular interactions are strong in these binary liquid mixtures and that the medium is highly packed.
The variation of excess molar volume ($V^E$), with respect to mole fraction, $x_1$, is given in Figs. 2(a) to 2(e) over the entire composition range and at different $T = (303.15, 308.15, 313.15, 318.15$ and 323.15) K. The strength of the intermolecular interactions in binary liquid mixtures can be explained using the sign and magnitude of the $V^E$ values. The factors that are mainly responsible for the contraction of volume causing the $V^E$ values negative are due to strong specific interactions like the association of component molecules through hydrogen bonds, due to dipole-dipole interactions or it may be due to the induced dipole-dipole interactions. Where the expansion of volumes, leading to positive $V^E$ values is due to breaking of one or both of the components in a solution. The geometry of molecular structure does not allow the fitting of one component molecules into the voids created by the molecules of other component and the steric hinderance of the molecules. In our present study the $V^E$ values are mostly negative in both the cases. So this kind of behavior of $V^E$ can be attributed to the formation of hydrogen bond, disruption of alcohol self-associations and the structural characteristics like geometrical fitting of one component into the other as a result of the increase in difference of size and shape of the component molecules. As the temperature increases, it has been observed that, the negative values of $V^E$ are found to decrease indicating the decrease of interactions between the unlike molecules. The expansion in molar volume can be attributed to the presence of weak intermolecular forces of attraction [18]. Similar results were reported by Garcia et al [19]. The negative values of $V^E$ indicate that there is more compact packing of the molecules which implies that the molecular
interactions are strong whereas the positive values indicate a loose packing of molecules in the binary mixture compared to those in the pure component. Similar results were observed by earlier workers [20].

It can be observed from Figs. 3(a) to 3(e) that the $L_f^E$ values have a negative trend similar to what we have observed in case of the $K_f^E$ at all the temperatures under study. The negative values of $L_f^E$ suggest that specific interactions are present between unlike molecules in these binary systems [21].

Figs. 4(a) to 4(e) represent the excess Gibb’s free energy of activation ($\Delta G^E$) with respect to mole fraction $x_1$, over the entire composition range and at $T = (303.15, 308.15, 313.15, 318.51, \text{ and } 323.15) \text{ K}$. It can be observed that the $\Delta G^E$ values are positive at all temperatures and over the entire range of mole fraction. These positive values indicate strong intermolecular interaction through hydrogen bonding between the component molecules of the liquid mixtures under study. The maximum deviation is observed for 1-4 butanediol.
+methanol system indicating the strength of bond formation in this system is more compared to that of other system. Similar results were observed by earlier workers [22].

From Figs. 5(a) to 5(e) it is clear that the excess values of Enthalpy (H^E) are positive with respect to the mole fraction, x_1, over the entire composition range and at T = (303.15, 308.15, 313.15, 318.15, and 323.15) K.
The positive values of $H^E$ tend to decrease with increase in temperature, this insists the fact that there are strong specific interactions between unlike molecules in these liquid mixtures [23]. The positive $H^E$ values also suggest the existence of inter molecular hydrogen bond and the breaking of associated structures in both cases.

The variations in these above excess parameters with mole fraction and temperature predict the presence of hydrogen bonding between the compounds in these binary mixtures. The strength of bond formation between the compounds in the present mixtures decrease, this is because of the increased chain length. Also the excess parameters calculated in the present study are correlated with one another and at the same time each parameter supporting the formation of hydrogen bonding in these binary liquid mixtures.

The deviations observed in the excess parameters indicate the strength of interactions present between the component molecules of the binary mixtures under study [16]. The variations in these excess parameter values reflect the interactions between the mixing species, depending upon the composition, molecular sizes and shapes of the components and temperature. The effects which influence the values of excess thermodynamic functions may be the result of physical, chemical and structural contributions such as:

1. The chemical effects, like the breaking of molecular association present in the pure liquid have resulted in the positive values of $V^E$, $K^S$ and $L_f^E$ and negative $\Delta G^E$, on the other hand charge transfer forces, formation of hydrogen bonds and other complex forming interactions have resulted in the negative values of $V^E$, $K^S$ and $L_f^E$ and positive $\Delta G^E$ [15].

2. Physical contributions are from dispersion forces or weak dipole-dipole interactions causing the positive values of $V^E$, $K^S$, $L_f^E$ and negative $\Delta G^E$.

3. The structural contribution arising from the geometrical fitting of one component into the other because of the differences in the size and shape of the component molecules are resulting in the negative values of $V^E$, $K^S$, $L_f^E$ and positive $\Delta G^E$.

In the present study, theoretical values for speed of sound have been evaluated in the binary mixtures considering 1-4 butanediol as one component and 1-alkanols as the other component at that of all investigated temperatures. 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 theories due to Nomoto (U$_{NM}$) [24], Impedance relation(U$_{IMP}$) [25], Van Dael and Vangeel (U$_{VDV}$) [26], Junjie’s (U$_{JM}$) [27], Free length theory (U$_{FLT}$) [28] and Rao’s (U$_{R}$) [29] are employed and the Average percentage error along with the Chi square fit values for the binary mixture and at all investigated temperatures are compiled in Table.2.
**Table 2: Average percentage error (APE) and Chi Square fit values for Speed of sound computed from different theoretical models.**

| Unom     | Unap     | Uevid   | Um     | Utilt   | Us       | 1,4-butanol + methanol | 1,4-butanol + ethanol | 1,4-butanol + 1-propanol |
|----------|----------|---------|--------|----------|----------|-------------------------|------------------------|--------------------------|
| APE      | 0.0000   | -1.1914 | 13.1395| -2.5444  | 0.0000   | 0.7319                  | 0.0088                 | 0.0000                   | T/K = 303.15             |
| Chi      | 0.0000   | 2.7099  | 442.740| 11.895   | 0.0000   | 1.3849                  | 1.3849                 | 2.8189                   | T/K = 303.15             |
| square   |          |         |        |          |          |                        |                        |                          |                         |
| APE      | 0.0000   | -1.2821 | 12.6040| -2.7728  | 0.0000   | 1.2108                  | 0.9246                 | 1.0116                   | T/K = 315.01             |
| Chi      | 0.0000   | 3.1084  | 391.014| 13.856   | 0.0000   | 3.2457                  | 3.1822                 | 2.5039                   | T/K = 315.01             |
| square   |          |         |        |          |          |                        |                        |                          |                         |
| APE      | 0.0000   | -0.8473 | 12.4405| 2.5362   | 0.0000   | 0.6557                  | 0.0000                 | 0.0000                   | T/K = 318.15             |
| Chi      | 0.0000   | 1.4228  | 372.182| 11.4882  | 0.0000   | 1.4244                  | 1.4244                 | 1.4244                   | T/K = 318.15             |
| square   |          |         |        |          |          |                        |                        |                          |                         |
| APE      | 0.0000   | -0.8711 | 11.9793| -2.6785  | 0.0000   | -1.0005                 | 0.0000                 | 0.0000                   | T/K = 318.15             |
| Chi      | 0.0000   | 1.3538  | 322.990| 12.920   | 0.0000   | 2.4992                  | 2.4992                 | 2.4992                   | T/K = 318.15             |
| square   |          |         |        |          |          |                        |                        |                          |                         |
| APE      | 0.0000   | -0.9734 | 11.5913| -2.8871  | 0.0000   | -1.0805                 | 0.0000                 | 0.0000                   | T/K = 323.15             |
| Chi      | 0.0000   | 1.6645  | 302.786| 13.9597  | 0.0000   | 2.4519                  | 2.4519                 | 2.4519                   | T/K = 323.15             |

The error for average percentage values is 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 binary mixtures at all the temperatures.

**IV. CONCLUSIONS**

The excess parameters like $K^E$, $V^E$, $L^E$, $\Delta G^V$ and $H^E$ are calculated from the experimentally determined speed of sound, density, and viscosity values. The formation of hydrogen bond between the mixtures is identified by studying the variations in these parameters. The values of excess isentropic compressibility, excess free length are found to be negative, excess enthalpy, excess Gibb’s free energy of activation is positive over the entire range of composition at all temperatures for the liquid mixture systems considered in the present study. This is a clear indication for the presence of hydrogen bonding between the component molecules. The difference in molar masses of the liquid molecules is also responsible for the existing specific interactions between the molecules of the component liquids. Besides, the computed speed of sound 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.

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