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**Research Article**

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# Ultrasonic studies of molecular interaction of alcohols with non-polar solvents

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**ABSTRACT**

*The ultrasonic velocity, density and viscosity for binary liquid mixtures of the n-alcohols namely 1-pentanol, 1-hexanol and 1-heptanol in toluene, carbon tetra chloride, benzene and dioxane at 301K have been measured. From these measured parameters adiabatic compressibility, free length, free volume and their excess values have been measured. The results have been analyzed and interpreted in terms of molecular interactions such as dipole-dipole interaction through hydrogen bonding between solvents and 1-alkanols have been observed. Further the experimental ultrasonic velocities of all these binary systems are compared with theoretical ultrasonic velocity.*

**Key words**: ultrasonic velocity, density, Binary mixtures, dipole- dipole interaction.

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## INTRODUCTION

Ultrasonic methods find extensive applications for characterizing aspects of physicochemical behaviour such as the nature of molecular interactions in pure liquids as well as liquid mixtures[1-5]. The study of the solution properties of liquid mixtures consisting of polar as well as non - polar components finds applications in industrial and technological processes. Most of the work on binary mixtures is channelized towards the estimation of thermodynamic parameters like adiabatic compressibility, free length, etc., and their excess values so as to relate them towards explaining the molecular interactions taking place between the components of the binary mixtures. Further, such studies as a function of concentration are useful in gaining insight into the structure and bonding of associated molecular complexes and other molecular processes [5-10]. Ultrasonic velocity measurements have been successfully employed to detect and assess weak and strong molecular interactions, present in binary and ternary liquid mixtures. In this paper, an attempt to investigate the ultrasonic studies of n-alcohol like 1-pentanol, 1-hexanol, 1-heptanol in benzene, carbon tetrachloride, toluene and dioxane binary liquid mixture systems at 301 K are made. We have measured density ($\rho$), ultrasonic velocity (u), viscosity ($\eta$) of mixtures of n-alcohol + benzene + carbon tetra chloride + toluene + dioxane with different mole fractions at a temperature of 301 K. From this data, acoustical parameters like adiabatic compressibility ($\beta$), Inter molecular free length ($L_f$), free volume (Vf), and their excess values are computed. Results are used to explain the nature of molecular interactions between mixing compounds. Further, the experimentally measured ultrasonic velocities at various molar concentrations have been compared with

the theoretically estimated velocities based on empirical, semi empirical and statistical models for the binary systems.

## EXPERIMENTAL SECTION

All the chemicals used in present work were analytical reagent (AR) grade (99.9% pure) and were supplied by SD fine chemicals Ltd India. The liquids were thoroughly distilled to remove dissolved impurities using standard chemical procedures. The purity of the samples was checked by the density measurements and the results were compared with the literature values. Ultrasonic velocities were measured with ultrasonic interferometer (model F80) supplied by Mittal enterprises, New Delhi, operating at a frequency of 2 MHz. It has an accuracy of ±0.1%. Viscosities of pure compounds and their mixtures were determined using Ostwald's viscometer with an accuracy of ±0.002%, calibrated with double distilled water. The densities of pure compounds and their solutions were measured accurately using 10 ml specific gravity bottles in Dhona electric balance precisely and the accuracy in weighing is ±0.1 mg. Acoustic parameters such as adiabatic compressibility ($\beta$), acoustic impedance (Z),free length ($L_f$), and free volume ($V_f$) were determined using the following relations.

Adiabatic compressibility $\beta = \frac{1}{u^2\rho}$ …(1)

Intermolecular free length $L_f = K_T\beta$ …(2)

Free volume $V_f = \left[\frac{M_{eff}\,u}{\eta K}\right]$ …(3)

Acoustic impedance $Z = u\rho$ …(4)

Where KT is the temperature dependent constant having a value of $199.53 \times 10^{-8}$ in MKS system, K is temperature independent constant whose value is $4.28 \times 10^{9}$ in MKS system, b is a factor depending on packing pattern which is 1.78, R is the gas constant and T is temperature in K, U is ultrasonic velocity in m/s, ρ is the density in Kg/m3 and Meff is the effective molecular weight, given by Meff = Σximi where x is the mole fraction and m is the molecular weight of the ith component.

## RESULTS AND DISCUSSION

The binary mixture systems taken up for the present study are: 1- Pentanol + toluene, benzene, carbon tetrachloride, dioxane and 1-hexanol+ toluene, benzene, carbontetra chloride, dioxane and 1-heptanol + toluene, benzene, carbon tetrachloride, dioxane). The experimentally determined values of velocity, density and along with the calculated values of free volume ($V_f$), adiabatic compressibility ($\beta$), free length ($L_f$), acoustic impedance (Z) for all the systems at 301 K are reported in Table I & II

**Table 1. Experimental values of ultrasonic velocity and density of pure liquids (at 301 K) used as a component of binary mixtures reported in this work**

| Liquids | Ultrasonic velocity(m/s) | Density(Kg/m$^3$) |
|---|---|---|
| 1-Pentanol | 1256 | 814 |
| 1-Hexanol | 1288 | 820 |
| 1-Heptanol | 1207 | 818 |
| Benzene | 1294 | 874 |
| Toluene | 1282 | 855 |
| Carbontetra chloride | 893 | 1512 |
| Dioxane | 1305 | 1011 |

In all the three binary systems, the ultrasonic velocity increases with increasing concentration of alcohols. The variation of ultrasonic velocity in a solution depends upon the increase or decrease of intermolecular free length after mixing the components.

**Table 2. Values of ultrasonic velocity (u m/s), density (ρ kg/m$^3$) adiabatic compressibility ($\beta$ m$^2$ N$^{-1}$) intermolecular free length ($L_f$ m), acoustic impedance (Z Kgm$^{-2}$s$^{-1}$) and free volume ($V_f$ m$^3$mol$^{-1}$) of binary systems as a function of molar concentration of components "B" at 301 K**

| X2 | u | ρ | $\beta \times 10^{10}$ | $L_f \times 10^{11}$ | $V_f$ | $Z \times 10^{-6}$ |
|---|---|---|---|---|---|---|
| **Pentanol + Toluene** | | | | | | |
| 0 | 1256 | 814 | 7.7874 | 5.7695 | 2.17 | 1022.3 |
| 0.1 | 1262 | 823 | 7.6292 | 5.7106 | 2.2003 | 1038.6 |
| 0.2 | 1266 | 828 | 7.5353 | 5.6754 | 2.1841 | 1048.2 |
| 0.3 | 1267 | 834 | 7.4693 | 5.6504 | 2.1623 | 1056.6 |
| 0.4 | 1270 | 836 | 7.4162 | 5.6303 | 2.1373 | 1061.7 |
| 0.5 | 1271 | 840 | 7.3693 | 5.6125 | 2.1202 | 1067.6 |
| 0.6 | 1274 | 842 | 7.3172 | 5.5926 | 2.1051 | 1072.7 |
| 0.7 | 1278 | 848 | 7.22 | 5.5554 | 2.0901 | 1083.7 |
| 0.8 | 1279 | 848 | 7.2088 | 5.551 | 2.0818 | 1084.5 |
| 0.9 | 1282 | 853 | 7.133 | 5.5218 | 2.064 | 1093.5 |
| 1 | 1282 | 855 | 7.1163 | 5.5153 | 2.042 | 1096.1 |
| **Pentanol + Dioxane** | | | | | | |
| 0 | 1403 | 910 | 5.5826 | 4.885 | 2.3725 | 1276.7 |
| 0.1 | 1262 | 840 | 7.4748 | 5.6525 | 2.1257 | 1060 |
| 0.2 | 1268 | 862 | 7.2153 | 5.5535 | 2.1363 | 1093 |
| 0.3 | 1274 | 885 | 6.9617 | 5.4551 | 2.1472 | 1127.4 |
| 0.4 | 1281 | 902 | 6.756 | 5.3739 | 2.1594 | 1155.4 |
| 0.5 | 1289 | 930 | 6.4715 | 5.2595 | 2.1734 | 1198.7 |
| 0.6 | 1287 | 950 | 6.355 | 5.212 | 2.1705 | 1222.6 |
| 0.7 | 1300 | 967 | 6.119 | 5.1143 | 2.1929 | 1257.1 |
| 0.8 | 1292 | 967 | 6.1951 | 5.146 | 2.1795 | 1249.3 |
| 0.9 | 1299 | 989 | 5.9921 | 5.061 | 2.1921 | 1284.7 |
| 1 | 1305 | 1011 | 5.808 | 4.9826 | 2.2027 | 1319.3 |
| **Hexanol + Toluene** | | | | | | |
| 0 | 1288 | 820.1 | 7.3502 | 5.6052 | 1.1749 | 1056.2 |
| 0.1 | 1291 | 827 | 7.2552 | 5.5689 | 7.1908 | 1067.3 |
| 0.2 | 1299 | 835 | 7.1016 | 5.5096 | 5.4215 | 1084.4 |
| 0.3 | 1302 | 841 | 7.0129 | 5.4751 | 4.3135 | 1095.3 |
| 0.4 | 1305 | 848 | 6.9258 | 5.441 | 3.5965 | 1106.3 |
| 0.5 | 1301 | 850 | 6.951 | 5.4509 | 2.9787 | 1105.8 |
| 0.6 | 1299 | 852 | 6.9587 | 5.4539 | 2.6976 | 1106.4 |
| 0.7 | 1297 | 855 | 6.9607 | 5.4547 | 2.4228 | 1107.9 |
| 0.8 | 1292 | 852 | 7.0282 | 5.4811 | 2.1692 | 1100.9 |
| 0.9 | 1289 | 854 | 7.0477 | 5.4887 | 1.9818 | 1100.7 |
| 1 | 1284 | 855 | 7.0917 | 5.5058 | 1.8247 | 1098 |
| **Hexanol + Benzene** | | | | | | |
| 0 | 1288 | 820 | 7.3502 | 5.6052 | 1.8026 | 1056.2 |
| 0.1 | 1291 | 828 | 7.2456 | 5.5652 | 1.1765 | 1068.8 |
| 0.2 | 1293 | 834 | 7.1711 | 5.5365 | 9.166 | 1078.4 |
| 0.3 | 1298 | 842 | 7.0521 | 5.4904 | 7.5172 | 1092.7 |
| 0.4 | 1303 | 851 | 6.9144 | 5.4365 | 6.4382 | 1109.5 |
| 0.5 | 1303 | 857 | 6.8688 | 5.4186 | 5.4715 | 1117.1 |
| 0.6 | 1302 | 861 | 6.847 | 5.4099 | 5.0561 | 1121.3 |
| 0.7 | 1302 | 866 | 6.8103 | 5.3954 | 4.6324 | 1127.4 |
| 0.8 | 1301 | 865 | 6.83 | 5.4032 | 4.2303 | 1125.3 |
| 0.9 | 1302 | 871 | 6.7807 | 5.3837 | 3.9406 | 1133 |
| 1 | 1301 | 875 | 6.757 | 5.3743 | 3.6962 | 1137.8 |
| **Heptanol + Toluene** | | | | | | |
| 0 | 1207 | 818 | 8.3893 | 5.9883 | 2.202 | 987.5 |
| 0.1 | 1231 | 835 | 7.9018 | 5.8117 | 1.583 | 1027.8 |
| 0.2 | 1245 | 844 | 7.652 | 5.7191 | 1.2867 | 1050 |
| 0.3 | 1259 | 853 | 7.3991 | 5.6238 | 1.0855 | 1073.6 |
| 0.4 | 1263 | 855 | 7.3331 | 5.5987 | 9.4022 | 1079.8 |
| 0.5 | 1268 | 857 | 7.2562 | 5.5693 | 8.1079 | 1086.9 |
| 0.6 | 1262 | 853 | 7.3621 | 5.6097 | 7.4871 | 1076.1 |
| 0.7 | 1263 | 852 | 7.3545 | 5.6069 | 6.8523 | 1076.2 |
| 0.8 | 1261 | 850 | 7.3942 | 5.622 | 6.3038 | 1072.3 |
| 0.9 | 1267 | 852 | 7.3056 | 5.5882 | 5.9064 | 1080.2 |
| 1 | 1272 | 853 | 7.2488 | 5.5664 | 5.5679 | 1084.9 |

| Heptanol + Carbon tetra chloride | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1207 | 818 | 8.3913 | 5.9891 | 2.223 | 987.3 |
| 0.1 | 1183 | 905 | 7.892 | 5.8081 | 1.7224 | 1070.8 |
| 0.2 | 1160 | 982 | 7.5657 | 5.6868 | 1.4111 | 1139.2 |
| 0.3 | 1133 | 1064 | 7.3214 | 5.5942 | 1.1662 | 1205.5 |
| 0.4 | 1107 | 1148 | 7.1082 | 5.5122 | 9.8062 | 1270.8 |
| 0.5 | 1064 | 1244 | 7.1006 | 5.5092 | 8.0306 | 1323.6 |
| 0.6 | 1033 | 1303 | 7.192 | 5.5446 | 7.0226 | 1345.9 |
| 0.7 | 994 | 1374 | 7.3661 | 5.6113 | 6.0052 | 1365.7 |
| 0.8 | 984 | 1367 | 7.5551 | 5.6828 | 5.3041 | 1345.1 |
| 0.9 | 941 | 1443 | 7.8262 | 5.7839 | 4.5612 | 1357.8 |

Based on the model for sound propagation proposed by Eyring and Kincaid[11], ultrasonic velocity should increase, if the inter molecular free length decreases and vice verse. This fact was noticed in the present study for all the three binary liquid systems. Same trend was noticed by earlier workers in their liquid mixtures [12-18].

In fact, the molecular association increases ultrasonic velocity (u) and acoustic impedance (Z), decreases intermolecular free length ($L_f$) and adiabatic compressibility ($\beta$). A reduction in adiabatic compressibility ($K_s$) is an indication that component molecules are held close to each other. The decrease in the values of adiabatic compressibility ($\beta$) and inter molecular free length ($L_f$) with increase in ultrasonic velocity (u) further strengthens the strong molecular association between the unlike molecules through hydrogen bonding. Carbon tetra chloride is a non polar liquid and the parameters are same as for benzene. This fact is reflected clearly from the values of ultrasonic velocity (u), intermolecular free length ($L_f$), adiabatic compressibility ($\beta$) and acoustic impedance (Z) for system.

Alcohols usually exist in polymeric form. In the presence of polar molecules, they dissociate into monomers. With the increase of alcohol, the tendency for intermolecular hydrogen bonding increases. The association is stronger and we expect a larger variation in the parameters. Eventually ultrasonic velocities (u) of both the components are nearly equal. In this fact is reflected in increase of ultrasonic velocity (u) and hence decrease in inter molecular free length ($L_f$) also it can be observed that adiabatic compressibility values decrease with increasing concentrations of alcohol. Similar results were obtained by earlier workers in their liquid mixtures. [19-21].

Acoustic impedance (Z) of a material is the opposition exerted by the medium to displacement of the medium's particles by the sound energy. It is important to measure acoustic impedance because studies have shown that in solvent mixtures when molecular interactions occurs, acoustic impedance exhibits a non-linear variation with increasing mole fraction of solute. This was used as an essential tool to predict molecular level interactions in binary and ternary liquid mixtures. In systems of binary liquid mixtures is always much greater than either of the polar solutes in the inert solvent. Further, the increase in free volume ($V_f$) with rise in concentration of alcohols in all the systems under study, clearly indicate the increasing magnitude of interactions.

**Table 3. Theoretical values of ultrasonic velocity calculated from Nomoto (NOMO), Impedence, Ideal mixtures relation, Rao's relation and Junjie's relations along with experimental ultrasonic velocity and percentage error for n-alcohols + toluene,benzene,carbontetra chloride,dioxane of binary systems at 301 K**

| X2 | Expt | NOM | IDEAL | JUN | IMP | Rao's | NOMO | IDEAL | JUN | IMP | Rao's |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pentanol + Toluene | | | | | | | | | | |
| 0 | 1256 | 1256 | 1256 | 1256 | 1256 | 1256 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1262 | 1258.6 | 1258.3 | 1258.3 | 1259 | 1259 | 0.2716 | 0.2917 | 0.2954 | 0.2601 | 0.2707 |
| 0.2 | 1266 | 1261.2 | 1260.7 | 1260.6 | 1261 | 1261 | 0.383 | 0.4188 | 0.4255 | 0.3628 | 0.3814 |
| 0.3 | 1267 | 1263.7 | 1263.1 | 1263 | 1264 | 1264 | 0.2576 | 0.3049 | 0.3137 | 0.2312 | 0.2555 |
| 0.4 | 1270 | 1266.3 | 1265.6 | 1265.5 | 1267 | 1266 | 0.2892 | 0.3435 | 0.3536 | 0.2592 | 0.2868 |
| 0.5 | 1271 | 1268.9 | 1268.2 | 1268.1 | 1269 | 1269 | 0.1633 | 0.2201 | 0.2308 | 0.1322 | 0.1608 |
| 0.6 | 1274 | 1271.5 | 1270.8 | 1270.7 | 1272 | 1272 | 0.1941 | 0.2488 | 0.2592 | 0.1644 | 0.1917 |
| 0.7 | 1278 | 1274.1 | 1273.5 | 1273.4 | 1275 | 1274 | 0.3023 | 0.3504 | 0.3595 | 0.2766 | 0.3003 |
| 0.8 | 1279 | 1276.8 | 1276.3 | 1276.2 | 1277 | 1277 | 0.1758 | 0.2126 | 0.2196 | 0.1563 | 0.1742 |
| 0.9 | 1282 | 1279.4 | 1279.1 | 1279.1 | 1280 | 1279 | 0.205 | 0.2257 | 0.2297 | 0.194 | 0.2041 |
| 1 | 1282 | 1282 | 1282 | 1282 | 1282 | 1282 | 0 | 0 | 0 | 0 | 0 |
| | Pentanol + Dioxane | | | | | | | | | | |
| 0 | 1403 | 1403 | 1403 | 1403 | 1403 | 1403 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1262 | 1393.9 | 1392.2 | 1393.4 | 1392 | 1393 | -10.451 | -10.317 | -10.4133 | -10.32 | -10.379 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.2 | 1268 | 1384.6 | 1381.6 | 1383.8 | 1382 | 1383 | -9.1984 | -8.9623 | -9.1314 | -8.966 | -9.071 |
| 0.3 | 1274 | 1375.2 | 1371.3 | 1374.1 | 1371 | 1373 | -7.9462 | -7.6391 | -7.8578 | -7.644 | -7.778 |
| 0.4 | 1281 | 1365.7 | 1361.2 | 1364.4 | 1361 | 1363 | -6.6106 | -6.2629 | -6.5093 | -6.268 | -6.419 |
| 0.5 | 1289 | 1356 | 1351.4 | 1354.6 | 1351 | 1353 | -5.1959 | -4.8373 | -5.0901 | -4.842 | -4.996 |
| 0.6 | 1287 | 1346.1 | 1341.7 | 1344.8 | 1342 | 1344 | -4.5929 | -4.2494 | -4.4902 | -4.254 | -4.400 |
| 0.7 | 1300 | 1336.1 | 1332.2 | 1334.9 | 1332 | 1334 | -2.7758 | -2.4791 | -2.686 | -2.483 | -2.608 |
| 0.8 | 1292 | 1325.9 | 1323 | 1325 | 1323 | 1324 | -2.6233 | -2.3967 | -2.5539 | -2.399 | -2.494 |
| 0.9 | 1299 | 1315.5 | 1313.9 | 1315 | 1314 | 1315 | -1.2728 | -1.1463 | -1.2336 | -1.147 | -1.2 |
| 1 | 1305 | 1305 | 1305 | 1305 | 1305 | 1305 | 0 | 0 | 0 | 0 | 0 |
| | **Hexanol + Toluene** | | | | | | | | | | |
| 0 | 1288 | 1288 | 1288 | 1288 | 1288 | 1288 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1291 | 1287.6 | 1287 | 1287.5 | 1288 | 1288 | 0.2882 | 0.3317 | 0.2953 | 0.2876 | 0.2864 |
| 0.2 | 1299 | 1287.2 | 1286.2 | 1287 | 1287 | 1287 | 0.8741 | 0.9508 | 0.8864 | 0.873 | 0.871 |
| 0.3 | 1302 | 1286.7 | 1285.4 | 1286.5 | 1287 | 1287 | 1.157 | 1.2574 | 1.1729 | 1.1556 | 1.1529 |
| 0.4 | 1305 | 1286.3 | 1284.8 | 1286.1 | 1286 | 1286 | 1.4365 | 1.5508 | 1.4545 | 1.4349 | 1.4319 |
| 0.5 | 1301 | 1285.9 | 1284.4 | 1285.7 | 1286 | 1286 | 1.1492 | 1.2686 | 1.1677 | 1.1476 | 1.1445 |
| 0.6 | 1299 | 1285.5 | 1284.1 | 1285.3 | 1286 | 1286 | 1.016 | 1.1308 | 1.0336 | 1.0145 | 1.0115 |
| 0.7 | 1297 | 1285.1 | 1283.8 | 1285 | 1285 | 1285 | 0.8835 | 0.984 | 0.8987 | 0.8821 | 0.8795 |
| 0.8 | 1292 | 1284.8 | 1283.8 | 1284.6 | 1285 | 1285 | 0.586 | 0.6628 | 0.5975 | 0.585 | 0.583 |
| 0.9 | 1289 | 1284.4 | 1283.8 | 1284.3 | 1284 | 1284 | 0.3569 | 0.4003 | 0.3633 | 0.3564 | 0.3553 |
| 1 | 1284 | 1284 | 1284 | 1284 | 1284 | 1284 | 0.0167 | 0.0167 | 0.0167 | 0.0167 | 0.0167 |
| | **Hexanol + Benzene** | | | | | | | | | | |
| 0 | 1288 | 1288 | 1288 | 1288 | 1288 | 1288 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1291 | 1289.6 | 1284.8 | 1289.2 | 1289 | 1289 | 0.1282 | 0.4951 | 0.1583 | 0.1418 | 0.1481 |
| 0.2 | 1293 | 1291 | 1282.6 | 1290.4 | 1291 | 1291 | 0.1583 | 0.8082 | 0.2096 | 0.1818 | 0.193 |
| 0.3 | 1298 | 1292.5 | 1281.4 | 1291.6 | 1292 | 1292 | 0.3972 | 1.2464 | 0.4617 | 0.4271 | 0.4417 |
| 0.4 | 1303 | 1293.8 | 1281.2 | 1292.9 | 1293 | 1293 | 0.741 | 1.7072 | 0.8115 | 0.7741 | 0.7905 |
| 0.5 | 1303 | 1295.1 | 1282 | 1294.2 | 1295 | 1295 | 0.6131 | 1.6211 | 0.6839 | 0.6467 | 0.6637 |
| 0.6 | 1302 | 1296.4 | 1283.8 | 1295.6 | 1296 | 1296 | 0.4664 | 1.4369 | 0.5319 | 0.4978 | 0.5141 |
| 0.7 | 1302 | 1297.6 | 1286.5 | 1296.9 | 1297 | 1297 | 0.3664 | 1.2187 | 0.4217 | 0.3932 | 0.4073 |
| 0.8 | 1301 | 1298.8 | 1290.3 | 1298.3 | 1299 | 1298 | 0.171 | 0.8242 | 0.2117 | 0.191 | 0.2017 |
| 0.9 | 1302 | 1299.9 | 1295.1 | 1299.6 | 1300 | 1300 | 0.1278 | 0.4972 | 0.1499 | 0.1388 | 0.1447 |
| 1 | 1301 | 1301 | 1301 | 1301 | 1301 | 1301 | -0.0282 | -0.0282 | -0.0282 | -0.028 | -0.028 |
| | **Heptanol + Toluene** | | | | | | | | | | |
| 0 | 1207 | 1207 | 1207 | 1207 | 1207 | 1207 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1231 | 1214.6 | 1209 | 1213.8 | 1214 | 1213 | 1.3567 | 1.8134 | 1.4194 | 1.4243 | 1.4528 |
| 0.2 | 1245 | 1221.9 | 1211.8 | 1220.5 | 1220 | 1220 | 1.8257 | 2.6332 | 1.9332 | 1.9419 | 1.9919 |
| 0.3 | 1259 | 1228.9 | 1215.7 | 1227.2 | 1227 | 1226 | 2.3735 | 3.4282 | 2.5095 | 2.5211 | 2.5858 |
| 0.4 | 1263 | 1235.7 | 1220.4 | 1233.8 | 1234 | 1233 | 2.15 | 3.3606 | 2.3011 | 2.3144 | 2.388 |
| 0.5 | 1268 | 1242.3 | 1226.2 | 1240.4 | 1240 | 1239 | 2.0183 | 3.2854 | 2.1712 | 2.1853 | 2.2614 |
| 0.6 | 1262 | 1248.6 | 1233.1 | 1246.8 | 1247 | 1246 | 1.078 | 2.312 | 1.2219 | 1.2357 | 1.3088 |
| 0.7 | 1263 | 1254.8 | 1241 | 1253.2 | 1253 | 1252 | 0.6803 | 1.7712 | 0.8031 | 0.8153 | 0.8791 |
| 0.8 | 1261 | 1260.7 | 1250.1 | 1259.5 | 1259 | 1259 | 0.0348 | 0.8779 | 0.1263 | 0.1357 | 0.1843 |
| 0.9 | 1267 | 1266.4 | 1260.4 | 1265.8 | 1266 | 1265 | 0.0556 | 0.5341 | 0.1056 | 0.111 | 0.1381 |
| 1 | 1272 | 1272 | 1272 | 1272 | 1272 | 1272 | -0.0368 | -0.0368 | -0.0368 | -0.036 | -0.036 |
| | **Heptanol + Carbontetra chloride** | | | | | | | | | | |
| 0 | 1207 | 1207 | 1207 | 1207 | 1207 | 1207 | 0 | 0 | 0 | 0 | 0 |
| 0.1 | 1183 | 1192 | 1144.2 | 1185.6 | 1154 | 1173 | -0.7417 | 3.303 | -0.2005 | 2.5037 | 0.8803 |
| 0.2 | 1160 | 1175.2 | 1093.3 | 1162.8 | 1108 | 1139 | -1.2991 | 5.7646 | -0.2248 | 4.4932 | 1.7939 |
| 0.3 | 1133 | 1156.2 | 1051.3 | 1138.2 | 1069 | 1107 | -2.048 | 7.2095 | -0.4598 | 5.6843 | 2.3398 |
| 0.4 | 1107 | 1134.5 | 1016.3 | 1111.8 | 1034 | 1074 | -2.4837 | 8.1955 | -0.4292 | 6.5795 | 2.9566 |
| 0.5 | 1064 | 1109.5 | 986.8 | 1083.1 | 1004 | 1043 | -4.2761 | 7.2602 | -1.7989 | 5.6543 | 2.0035 |
| 0.6 | 1033 | 1080.4 | 961.7 | 1052.1 | 976.9 | 1012 | -4.5898 | 6.8999 | -1.8458 | 5.4283 | 2.0599 |
| 0.7 | 994 | 1046.2 | 940.4 | 1018.2 | 952.9 | 981.4 | -5.2471 | 5.3882 | -2.4302 | 4.1367 | 1.2699 |
| 0.8 | 984 | 1005.2 | 922.3 | 980.9 | 931.3 | 951.6 | -2.1584 | 6.267 | 0.3112 | 5.3589 | 3.2879 |
| 0.9 | 941 | 955.5 | 907 | 939.8 | 911.7 | 922.5 | -1.5459 | 3.6169 | 0.1261 | 3.1098 | 1.9635 |
| 1 | 894 | 894 | 894 | 894 | 894 | 894 | 0 | 0 | 0 | 0 | 0 |

## CONCLUSION

An analysis of these values suggests the presence of strong intermolecular interaction in all the binary mixtures which may be due to hydrogen bond, dipole-dipole, hyperconjugation and charge transfer. It is found that the intermolecular interaction is very strong in alcohol + non-polar solvents and this strong interaction may be attributed to the fact that the interaction due to negative inductive effect dominates over the resonance effect in the mixture. Theoretical ultrasonic velocities of the binary mixtures were estimated using various empirical, semi empirical,

models given by eqns and are presented with experimental values in Table 3. The percentage of deviation of the theoretical ultrasonic velocity values from experimental values are also shown in Table 3. On the whole, all the theoretical models fairly predicted ultrasonic velocities, are reasonably close to the experimental values for these binary mixtures reported in this work, thus showing the validity of these theoretical models for binary mixtures.

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