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Research Article

A Comparative Analysis of Ultra Sound Velocity in Binary Mixtures of Diethyl Malonate with Branched Alkanols by Theoretical and Experimental Methods

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ABSTRACT
Ultrasonic velocities are measured for the binary mixtures of diethyl malonate with 3- methyl -1-butanol, 2- methyl -1- propanol, 2-propanol and 2-butanol at (303.15, 308.15, 313.15 and 318.15) K. Ultrasonic velocities calculated using various theories, such as Nomotos relation, Van Dael relation, Impedance relation, Junjie's relation , Rao relation are reported and compared with the experimental values to find the merits of the relations and check the validity of these theoretical models by using percentage error and average percentage deviations. The results are discussed in terms of inter molecular interactions occurring in the systems.

Keyword: Ultrasonic velocity; diethyl malonate; Chi-Square test; molecular interaction parameter

INTRODUCTION

The thermodynamic properties of liquids and liquid mixtures [1] have been utilized to recognize the molecular associations involving the components of a mixture and also for engineering applications relating to the heat transfer, mass transfer and fluid flow. The binary mixtures containing diethylmalonate and alcohols were preferred in the present analysis on the origin of their industrial significance. Diethyl malonate (DEM) is the diethyl ester of malonic acid. DEM is a colourless fluid. The odour of DEM is like that of apple juice. It is utilized in perfumes, preparation of the compounds such as barbiturates, vitamin B_1, Vitamin B_6 and synthetic flavorings. Alcohols are employed as hydraulic fluids in pharmaceutical and cosmetics, in medications for animals, in manufacturing perfumes, paint removers, flavors and dyestuffs, as defrosting and as antibacterial agents [2].

Ultrasonic sound velocity of liquid mixtures containing polar as well as non-polar groups are of extensive significance in understanding intermolecular interaction involving constituent molecules [3-8]. Comparative studies on the investigational theoretical estimations of ultrasonic velocities for different organic liquid mixtures utilizing various models like Nomoto [9-10], Impedance relation [11], Van Dael and Vangael [12], Junjie [13] and Rao's specific velocity [14] have been carried out by various

researchers. The current study is an extension of our research programme on application of theoretical models of ultrasonic velocities of liquid binaries at various temperatures [15-19]. In the present examination, diethyl malonate is mixed with alcohols at various mole fractions to study the interactions among the constituent molecules. The results are explained and discussed in terms of molecular interactions present in the investigated systems. The deviation in the variation of U^2/U^2_{imx}, average percentage error, (APE), Chi-square test for goodness of fit, from unity have also been evaluated to further explain the non-ideality of the system. The ratio of U^2/U^2_{imx} gives a suggestion of scope of interaction taking place among molecules of the mixtures, positive values of which support strong interactions among the components.

MATERIALS AND METHODS

Diethyl malonate, 3- methyl -1- butanol, 2-methyl -1- propanol, 2-propanol and 2-butanol acquired from Merck Company were purified as described in the literature [20, 21]**.** The pure chemicals were stored over activated molecular sieves to reduce water content before use. All the binary liquid mixtures are prepared gravimetrically using an electronic balance (Shimadzu AY 120) with an uncertainty of ± $1x10^{-7}$ kg and stored in airtight bottles. The uncertainty on mole fraction is estimated to be $1x10^{-4}$. It is ensured that the mixtures are properly mixed and the measurement of the required parameters was done within one day of preparation.

The densities (ρ) of pure liquids and their mixtures are determined using a 10^{-5} m^3 double-arm pycnometer and the values from triplicate replication at each temperature and the uncertainty in the measurement of density is found to be 2 parts in 10^4 parts. The reproducibility in mole fractions was within ±0.0002. The ultrasonic velocity of sound (U) is measured using an ultrasonic interferometer (Mittal Enterprises, New Delhi model F05) operating at 2 MHz The measured speeds of sound have a precision of 0.8 $m.sec^{-1}$ and an uncertainty less than ± 0.1 $m.sec^{-1}$.

Temperature control for the measurement of velocity and density is achieved by using a microprocessor assisted circulating water bath regulated to ±0.01 K, using a proportional temperature controller. Adequate precautions were taken to minimize evaporation losses during the actual measurements. The temperature stability was maintained within ± 0.01K. by circulating water bath around the measuring cell through a pump.

The ultrasonic velocities measured by ultrasonic interferometer for all the systems at different temperatures have been compared with the theoretical velocities evaluated by using five semi empirical models. The extent of deviation observed between the theoretical and experimental methods have been explained in terms of various forces operative between the components.

Theoretical Considerations

1. Nomoto theory: Nomoto's empirical formula depends on the assumption of the linear dependence of the molecular sound velocity on concentration and the additive of the molar volume in the liquid mixture. The sound velocity U is given by

$$U = \left[\frac{\sum_{i=1}^{n} x_i R_i}{\sum_{i=1}^{n} x_i V_i}\right]^3$$

where the molar sound velocity $R = x_1R_1+x_2R_2$.

Hence, ultrasonic velocity (U) is given by

$$U = \left[\frac{x_1R_1 + x_2R_2}{x_1V_1 + x_2V_2}\right]^3 \quad \text{..... (1)}$$

In the above equation $R_i = (M_i/\rho_i)\ U_i^{1/3} = V_i\ (U_i)^{1/3}$

2.Impedance relation: The specific acoustic impedance of the unadulterated liquids is utilized for assessing the ultrasonic velocity in the liquid mixtures by the following relation:

$$U = \sum x_i Z_i / \sum x_{ii} \quad \text{..... (2)}$$

where Z_i is acoustic impedance and ρ_i is the density of the mixture.

3. Van Dael and Vangeel relation: Van Dael and Vangeel got the formula for ultrasonic velocity in the liquid mixtures adopting the adiabatic compressibilities of the unadulterated liquids based on ideal mixing of the liquids. Van Dael and Vangeel expected that the adiabatic compressibility (β_{ad}) of the mixture is given by

$\beta_{ad} = \phi_A (\beta_{ad})_A + \phi_B (\beta_{ad})_B$

and recommended the accompanying relation for sound velocity in homogeneous liquid mixtures as

$$\beta_{ad}^{im} = \phi_A \frac{\gamma_A}{\gamma^{im}} (\beta_{ad})_A + \phi_B \frac{\gamma_B}{\gamma^{im}} (\beta_{ad})_B$$

where ϕ and γ refer the volume function and principal specific ratio.

It holds true if the mixture is an ideal one and also $\gamma_A = \gamma_B = \gamma_{im}$. It can be transformed into a linear combination of the mole fractions if the additional assumption $v_A = v_B$ is made.

$\beta_{ad}{}^{im} = x_A (\beta_{ad})_A + x_B (\beta_{ad})_B$

The sound velocities appropriate to the above equations are given by

$$\frac{x_A v_A + x_B v_B}{x_A M_A + x_B M_B} \frac{1}{\left(U^{im}\right)^2} = \varphi_A \frac{v_A}{M_A U_A^2} + \varphi_B \frac{v_B}{M_B U_B^2}$$

and

$$\frac{1}{x_A M_A + x_B M_B} \frac{1}{\left(U^{im}\right)^2} = \frac{x_A}{M_A U_A^2} + \frac{x_B}{M_B U_B^2}$$

..... (3)

4. Junjie's relation: This relation developed by Junjie for the ultrasonic velocity of the mixture in terms of the mole fraction, molecular weight and density of the mixture is given as

$$U = \frac{\sum_{i=1}^{n} x_i V_i}{(\sum_{i=1}^{n} x_i M_i)^{1/2} (\sum_{i=1}^{n} x_i V_i / \rho_i u_i^2)^{1/2}} \quad \text{..... (4)}$$

where the symbols have their usual meanings.

5. Rao's relation: Using the ratio of the temperature coefficient of velocity and expansion coefficient, Rao obtained a formula for ultrasonic velocity (U)

$$U = \left(\frac{R}{V}\right)^3 \quad \text{..... (5)}$$

where V is the molar volume and R is called Rao's constant or molar sound velocity, which is constant for a liquid at a temperature.

Chi-square test for goodness of fit:

As indicated by Karl Pearson [22], Chi-square value is evaluated for the binary liquid mixtures under study utilizing the formula

$$\chi^2 = \sum_{i=1}^{n} ((U_{(obs)} - U_{(cal)})^2 / U_{(cal)}) \quad \text{..... (6)}$$

where n is the number of data used,

and 'U $_{(obs)}$ = experimental values of ultrasonic velocities

$U_{(cal)}$ = computed values of ultrasonic velocities

Relative percentage of error (σ):

The Average percentage error is calculated by utilizing the relation

$\sigma = 1/n\sum((U_{(obs)} - U_{(cal)}) / U_{(obs)})$ X 100% ..... (7)

where n is the number of data used.

$U_{(obs)}$ = experimental values of ultrasonic velocities

Molecular associations:

The degree of intermolecular interaction or molecular association is given by

$\boldsymbol{\alpha} = [U^2_{exp}/U^2_{imx}] - 1$ ..... (8)

RESULTS & DISCUSSION

Experimental values of ultrasonic velocities along with the calculated values using various theories for all the three binary mixtures at the temperatures (303.15, 308.15, 313.15 and 318.15) K are presented in the Table 1(a)-Table 4(a). Percentage deviations and interaction parameters for all the four systems at different temperatures are represented in the Table 1(b) – Table 4(b). The standard deviation and $\boldsymbol{\chi^2}$ test values for all the four systems have been included in Table 5. A comparative study has been made between the experimental velocities and velocities evaluated from five different theoretical modes. The extent of deviations between experimental velocity and theoretical velocity has been viewed in terms of assumptions made in deriving the theoretical relations and nature of forces operative between the component molecules. From the tables, it is observed that Nomoto's theory exhibits more satisfactory results for all four systems studied followed by Impedance relation.

Alkanols are self-associated liquids with hydrogen bond between them. As the chain length increases the self-association decreases in their pure form. When diethyl malonate is added to alkanols, there will be an interaction between OH group of alkanols and C=O group of diethyl malonate through the formation of hydrogen bonding.

The deviation in experimental values and calculated values from different theories confirms the existence of molecular interactions between molecules of the constituent liquids. Large variations are observed at intermediate concentration range suggesting the existence strong tendency of association between component molecules as a result of hydrogen bonding.

Nomoto's theory is based the principle of additivity of molar sound velocity under which volume does not change even after mixing of components by taking into account that there are no interactions between the component molecules. But the positive deviation of the experimental values from the theoretical velocities using Nomoto's relation indicates that the sound velocity is not additive and volume of the mixture dos not remains constant. This is attributed due to the existence of strong hydrogen bonding interactions between the components. Positive deviations of the experimental velocities from the theoretical values observed in the case of Van Dael and Vangeel ideal mixing relation might be due to the existence of chemical forces such as hydrogen bonding and dipole-dipole interactions between the component molecules. Large positive deviations of the calculated velocities from that of experimental values using Rao's relation and Impedance relations indicate the non additivity of acoustic impedance and sound velocity in the liquid mixtures [23]. The large deviations of experimental values from the values obtained Junjie's relation also confirm the same argument.

The values of U^2_{exp}/U^2_{imx} and its deviation from unity (α), its variation with mole fraction of diethyl malonate are also represented in table 1, as this is the direct measure of non ideality of the system as a result of association or other type of interactions, in particular, in the cases where the properties other than sound velocity are not known [24]. The value of U^2_{exp}/U^2_{imx} is high at 0.47, 0.54, 0.58 and 0.51 mole fractions for 3- methyl -1- butanol, 2- methyl -1- propanol, 2-propanol and 2-butanol respectively at all temperatures over the entire mole fraction of diethyl malonate. The value of U^2_{exp}/U^2_{imx} is positive for all the four systems at all studied temperatures indicating the existence of strong interactions between the component molecules [25]. The variation of U^2_{exp}/U^2_{imx} with the mole fraction of diethyl malonate at four temperatures is shown in Figures 1-4. Deviation of U^2_{exp}/U^2_{imx} from unity (α) is also positive which supports the existence of strong interaction between the molecules of component liquids. The negative values indicate the dominance of dispersive forces arising from the breakage of hydrogen bonds in the associates. The percentage of deviation in velocities shows positive as well as negative in magnitude indicating non ideal behavior of liquid mixtures.

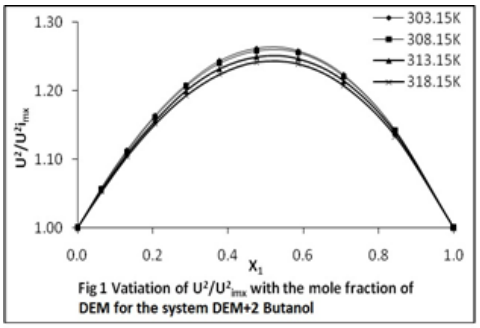

Fig 1 Vatiation of U^2/U^2_{imx} with the mole fraction of DEM for the system DEM+2 Butanol

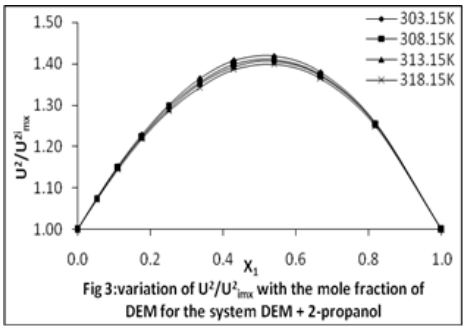

Fig 3:variation of U^2/U^2_{imx} with the mole fraction of DEM for the system DEM + 2-propanol

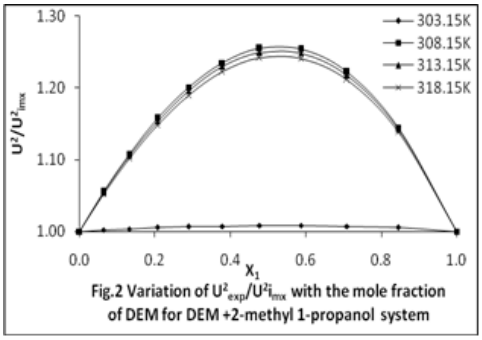

Fig.2 Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DEM for DEM +2-methyl 1-propanol system

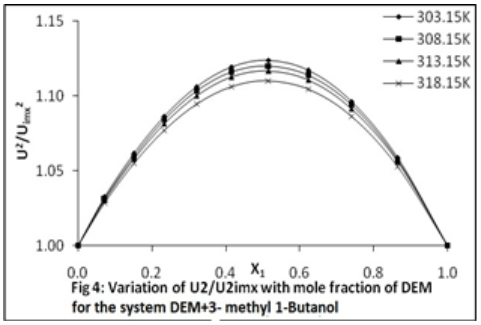

Fig 4: Variation of U2/U2imx with mole fraction of DEM for the system DEM+3- methyl 1-Butanol

Table1(a) : Experimental and theoretical velocities with their percentage of deviations for the systems Diethyl malonate+ 2- butanol

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15K						
0.0000	1151.0	1151.0	1151.0	1151.0	1151.0	1151.0
0.0630	1166.0	1163.0	1161.0	1133.5	1155.7	1212.0
0.1314	1180.6	1175.1	1171.5	1118.9	1161.8	1270.8
0.2060	1194.9	1187.3	1182.4	1107.5	1169.3	1325.9
0.2875	1209.6	1199.6	1193.8	1100.0	1178.5	1375.5
0.3771	1223.7	1211.9	1205.8	1097.4	1189.4	1413.5
0.4759	1237.3	1224.4	1218.3	1101.3	1202.1	1437.4
0.5855	1250.0	1236.9	1231.5	1114.2	1216.8	1441.3
0.7077	1261.1	1249.5	1245.2	1140.4	1233.6	1419.6
0.8449	1269.9	1262.2	1259.7	1188.2	1252.9	1365.1
1.0000	1275.0	1275.0	1275.0	1275.0	1275.0	1275.0
308.15K						
0.0000	1140.5	1140.5	1140.5	1140.5	1140.5	1140.5
0.0630	1155.0	1152.8	1150.8	1123.3	1145.3	1203.8
0.1314	1169.2	1165.1	1161.5	1108.9	1151.5	1263.9
0.2060	1183.2	1177.6	1172.7	1097.7	1159.3	1322.3
0.2875	1197.4	1190.1	1184.3	1090.4	1168.7	1373.8
0.3771	1211.4	1202.7	1196.6	1088.0	1179.8	1413.9
0.4759	1225.1	1215.5	1209.4	1092.1	1192.7	1438.6
0.5855	1238.4	1228.3	1222.8	1105.2	1207.7	1442.9
0.7077	1250.3	1241.2	1236.9	1131.7	1224.9	1418.9
0.8449	1260.9	1254.2	1251.7	1179.8	1244.7	1360.6
1.0000	1267.3	1267.3	1267.3	1267.3	1267.3	1267.3
313.15K						
0.0000	1138.5	1138.5	1138.5	1138.5	1138.5	1138.5
0.0630	1151.7	1149.9	1148.0	1121.1	1142.8	1202.9
0.1314	1164.7	1161.4	1158.0	1106.5	1148.5	1264.2
0.2060	1177.7	1173.0	1168.3	1095.1	1155.6	1323.5
0.2875	1190.9	1184.6	1179.2	1087.5	1164.3	1375.0
0.3771	1203.8	1196.4	1190.5	1084.7	1174.6	1415.1
0.4759	1216.4	1208.2	1202.4	1088.2	1186.7	1439.9
0.5855	1228.9	1220.1	1214.9	1100.6	1200.6	1442.7
0.7077	1240.5	1232.0	1228.0	1125.9	1216.7	1414.8
0.8449	1250.3	1244.1	1241.7	1172.2	1235.2	1353.6
1.0000	1256.2	1256.2	1256.2	1256.2	1256.2	1256.2
318.15K						
0.0000	1133.8	1133.8	1133.8	1133.8	1133.8	1133.8
0.0630	1145.7	1144.5	1142.8	1116.3	1137.5	1200.7
0.1314	1157.5	1155.2	1152.1	1101.6	1142.6	1264.7
0.2060	1169.8	1166.1	1161.8	1090.0	1149.1	1324.5
0.2875	1182.0	1177.0	1172.0	1082.2	1157.1	1377.3
0.3771	1193.9	1188.0	1182.7	1079.1	1166.7	1418.4
0.4759	1205.9	1199.0	1193.8	1082.2	1178.0	1442.2
0.5855	1217.6	1210.2	1205.5	1093.9	1191.2	1443.8
0.7077	1228.7	1221.4	1217.7	1118.3	1206.5	1412.7
0.8449	1238.0	1232.7	1230.6	1163.0	1224.0	1347.9
1.0000	1244.1	1244.1	1244.1	1244.1	1244.1	1244.1

Table 1(b) : **Percentage Deviations and Interaction Parameters (α), for the System Diethyl malonate+ 2- butanol**

X_1	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0630	-0.2532	-0.4243	-2.7813	-0.8841	3.9476	1.0580	0.0580
0.1314	-0.4647	-0.7728	-5.2284	-1.5970	7.6420	1.1134	0.1134
0.2060	-0.6380	-1.0480	-7.3196	-2.1415	10.9639	1.1642	0.1642
0.2875	-0.8264	-1.3016	-9.0616	-2.5680	13.7139	1.2092	0.2092
0.3771	-0.9590	-1.4616	-10.3198	-2.8026	15.5088	1.2434	0.2434
0.4759	-1.0455	-1.5359	-10.9934	-2.8488	16.1673	1.2623	0.2623
0.5855	-1.0488	-1.4855	-10.8660	-2.6615	15.3014	1.2587	0.2587
0.7077	-0.9177	-1.2571	-9.5684	-2.1784	12.5700	1.2228	0.2228
0.8449	-0.6067	-0.8019	-6.4375	-1.3375	7.4956	1.1423	0.1423
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0630	-0.1933	-0.3668	-2.7455	-0.8396	4.2221	1.0573	0.0573
0.1314	-0.3449	-0.6574	-5.1571	-1.5062	8.1013	1.1117	0.1117
0.2060	-0.4779	-0.8939	-7.2308	-2.0216	11.7538	1.1620	0.1620
0.2875	-0.6082	-1.0906	-8.9371	-2.3985	14.7321	1.2059	0.2059
0.3771	-0.7110	-1.2212	-10.1826	-2.6080	16.7223	1.2396	0.2396
0.4759	-0.7856	-1.2833	-10.8550	-2.6428	17.4315	1.2584	0.2584
0.5855	-0.8191	-1.2622	-10.7567	-2.4810	16.5082	1.2556	0.2556
0.7077	-0.7316	-1.0757	-9.4893	-2.0313	13.4774	1.2207	0.2207
0.8449	-0.5340	-0.7316	-6.4352	-1.2873	7.9054	1.1423	0.1423
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0630	-0.1526	-0.3171	-2.6527	-0.7711	4.4447	1.0552	0.0552
0.1314	-0.2854	-0.5819	-5.0001	-1.3957	8.5438	1.1080	0.1080
0.2060	-0.3974	-0.7923	-7.0143	-1.8721	12.3856	1.1566	0.1566
0.2875	-0.5249	-0.9830	-8.6847	-2.2335	15.4623	1.1993	0.1993
0.3771	-0.6215	-1.1063	-9.8986	-2.4299	17.5441	1.2318	0.2318
0.4759	-0.6763	-1.1497	-10.5360	-2.4449	18.3739	1.2494	0.2494
0.5855	-0.7170	-1.1385	-10.4396	-2.2972	17.3992	1.2467	0.2467
0.7077	-0.6808	-1.0080	-9.2345	-1.9141	14.0502	1.2138	0.2138
0.8449	-0.4973	-0.6853	-6.2494	-1.2109	8.2667	1.1378	0.1378
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0630	-0.1111	-0.2608	-2.5666	-0.7203	4.7926	1.0534	0.0534
0.1314	-0.1974	-0.4676	-4.8308	-1.2917	9.2629	1.1041	0.1041
0.2060	-0.3199	-0.6799	-6.8224	-1.7733	13.2227	1.1518	0.1518
0.2875	-0.4238	-0.8417	-8.4442	-2.1081	16.5242	1.1930	0.1930
0.3771	-0.5007	-0.9431	-9.6199	-2.2837	18.8007	1.2242	0.2242
0.4759	-0.5699	-1.0019	-10.2577	-2.3132	19.5930	1.2417	0.2417
0.5855	-0.6082	-0.9930	-10.1568	-2.1658	18.5797	1.2389	0.2389
0.7077	-0.5955	-0.8943	-8.9873	-1.8108	14.9763	1.2072	0.2072
0.8449	-0.4301	-0.6018	-6.0644	-1.1330	8.8711	1.1333	0.1333
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table2(a) : Experimental and theoretical velocities for the systems Diethyl malonate+ 2-propanol

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15K						
0.0000	1111.0	1111.0	1111.0	1111.0	1111.0	1111.0
0.0531	1126.5	1126.7	1122.5	1085.7	1116.9	1188.0
0.1120	1142.1	1142.6	1134.8	1063.4	1124.6	1264.2
0.1778	1158.4	1158.6	1148.0	1044.5	1134.3	1336.9
0.2518	1175.0	1174.8	1162.1	1029.9	1146.0	1403.5
0.3354	1191.9	1191.1	1177.3	1020.7	1160.1	1456.6
0.4309	1208.9	1207.6	1193.7	1019.2	1176.6	1491.5
0.5408	1225.9	1224.2	1211.5	1029.1	1195.9	1499.3
0.6687	1242.8	1241.0	1230.9	1058.0	1218.4	1471.7
0.8196	1259.5	1257.9	1251.9	1123.0	1244.6	1399.1
1.0000	1275.0	1275.0	1275.0	1275.0	1275.0	1275.0
308.15K						
0.0000	1106.0	1106.0	1106.0	1106.0	1106.0	1106.0
0.0531	1120.7	1121.5	1117.3	1080.8	1111.7	1185.3
0.1120	1135.9	1137.1	1129.4	1058.6	1119.3	1262.4
0.1778	1151.1	1152.8	1142.4	1039.8	1128.8	1338.8
0.2518	1167.0	1168.7	1156.3	1025.1	1140.3	1407.5
0.3354	1183.1	1184.8	1171.3	1015.9	1154.1	1463.0
0.4309	1199.6	1201.0	1187.4	1014.3	1170.3	1498.2
0.5408	1216.5	1217.3	1204.9	1024.1	1189.3	1505.2
0.6687	1233.9	1233.8	1223.9	1052.6	1211.5	1473.3
0.8196	1251.4	1250.5	1244.6	1116.9	1237.3	1395.4
1.0000	1267.3	1267.3	1267.3	1267.3	1267.3	1267.3
313.15K						
0.0000	1097.5	1097.5	1097.5	1097.5	1097.5	1097.5
0.0531	1111.6	1112.7	1108.6	1072.5	1103.1	1178.2
0.1120	1125.9	1128.1	1120.5	1050.4	1110.5	1257.9
0.1778	1140.6	1143.6	1133.3	1031.7	1119.8	1335.5
0.2518	1155.9	1159.2	1147.0	1017.2	1131.2	1406.1
0.3354	1171.6	1175.0	1161.7	1008.0	1144.7	1462.2
0.4309	1187.6	1191.0	1177.6	1006.3	1160.7	1497.0
0.5408	1204.7	1207.1	1194.8	1015.9	1179.4	1502.9
0.6687	1222.2	1223.3	1213.5	1044.1	1201.3	1468.8
0.8196	1239.8	1239.7	1233.9	1107.7	1226.7	1388.2
1.0000	1256.2	1256.2	1256.2	1256.2	1256.2	1256.2
318.15K						
0.0000	1090.6	1090.6	1090.6	1090.6	1090.6	1090.6
0.0531	1103.6	1105.3	1101.4	1065.7	1095.8	1174.4
0.1120	1116.9	1120.1	1113.0	1043.7	1102.7	1256.9
0.1778	1131.0	1135.1	1125.3	1025.0	1111.5	1336.2
0.2518	1145.6	1150.2	1138.6	1010.5	1122.4	1408.4
0.3354	1160.5	1165.5	1152.9	1001.2	1135.4	1466.1
0.4309	1176.3	1180.9	1168.3	999.4	1150.9	1499.5
0.5408	1192.8	1196.4	1184.9	1008.7	1169.1	1504.6
0.6687	1210.0	1212.2	1203.0	1036.2	1190.4	1467.6
0.8196	1227.4	1228.1	1222.6	1098.6	1215.2	1382.6
1.0000	1244.1	1244.1	1244.1	1244.1	1244.1	1244.1

Table 2(b) : **Percentage Deviations and Interaction Parameters (α), for the System Diethyl malonate+ 2- propanol**

X_1	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0531	0.0201	-0.3549	-3.6189	-0.8517	5.4626	1.0765	0.0765
0.1120	0.0439	-0.6396	-6.8891	-1.5293	10.6907	1.1534	0.1534
0.1778	0.0194	-0.9012	-9.8283	-2.0807	15.4123	1.2299	0.2299
0.2518	-0.0173	-1.0982	-12.3490	-2.4644	19.4478	1.3016	0.3016
0.3354	-0.0655	-1.2238	-14.3605	-2.6717	22.2104	1.3635	0.3635
0.4309	-0.1082	-1.2538	-15.6923	-2.6739	23.3738	1.4069	0.4069
0.5408	-0.1374	-1.1720	-16.0540	-2.4475	22.2986	1.4191	0.4191
0.6687	-0.1456	-0.9608	-14.8733	-1.9634	18.4206	1.3800	0.3800
0.8196	-0.1256	-0.6008	-10.8399	-1.1861	11.0813	1.2579	0.2579
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0531	0.0682	-0.3015	-3.5585	-0.7993	5.7646	1.0752	0.0752
0.1120	0.1035	-0.5706	-6.8072	-1.4620	11.1370	1.1514	0.1514
0.1778	0.1505	-0.7581	-9.6730	-1.9406	16.3042	1.2256	0.2256
0.2518	0.1489	-0.9185	-12.1572	-2.2886	20.6121	1.2959	0.2959
0.3354	0.1428	-1.0015	-14.1285	-2.4538	23.6545	1.3561	0.3561
0.4309	0.1160	-1.0161	-15.4443	-2.4406	24.8906	1.3987	0.3987
0.5408	0.0693	-0.9531	-15.8188	-2.2319	23.7288	1.4111	0.4111
0.6687	-0.0046	-0.8096	-14.6934	-1.8140	19.4052	1.3742	0.3742
0.8196	-0.0722	-0.5412	-10.7446	-1.1268	11.5076	1.2553	0.2553
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0531	0.1005	-0.2662	-3.5179	-0.7631	5.9942	1.0743	0.0743
0.1120	0.1934	-0.4756	-6.7055	-1.3659	11.7279	1.1489	0.1489
0.1778	0.2614	-0.6406	-9.5477	-1.8217	17.0908	1.2223	0.2223
0.2518	0.2881	-0.7718	-12.0036	-2.1404	21.6454	1.2914	0.2914
0.3354	0.2923	-0.8442	-13.9638	-2.2949	24.8054	1.3509	0.3509
0.4309	0.2833	-0.8413	-15.2627	-2.2640	26.0496	1.3927	0.3927
0.5408	0.1952	-0.8200	-15.6706	-2.0964	24.7568	1.4062	0.4062
0.6687	0.0889	-0.7104	-14.5725	-1.7122	20.1782	1.3703	0.3703
0.8196	-0.0106	-0.4761	-10.6566	-1.0598	11.9694	1.2528	0.2528
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0531	0.1517	-0.1974	-3.4346	-0.7103	6.4153	1.0724	0.0724
0.1120	0.2860	-0.3513	-6.5561	-1.2713	12.5369	1.1452	0.1452
0.1778	0.3594	-0.5002	-9.3714	-1.7220	18.1412	1.2175	0.2175
0.2518	0.4001	-0.6104	-11.7969	-2.0276	22.9412	1.2854	0.2854
0.3354	0.4268	-0.6572	-13.7238	-2.1610	26.3359	1.3434	0.3434
0.4309	0.3889	-0.6837	-15.0377	-2.1594	27.4740	1.3853	0.3853
0.5408	0.3060	-0.6626	-15.4369	-1.9876	26.1403	1.3984	0.3984
0.6687	0.1800	-0.5824	-14.3597	-1.6231	21.2854	1.3635	0.3635
0.8196	0.0538	-0.3901	-10.4924	-0.9968	12.6467	1.2482	0.2482
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table 3(a) : Experimental and theoretical velocities for the systems Diethyl malonate+ 2-methyl -1- propanol

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15K						
0.0000	1112.5	1112.5	1112.5	1112.5	1112.5	1112.5
0.0634	1126.9	1128.1	1125.8	1096.4	1119.2	1175.5
0.1322	1141.6	1143.8	1139.6	1083.3	1127.5	1236.9
0.2070	1157.0	1159.7	1154.1	1073.5	1137.6	1294.3
0.2888	1172.7	1175.7	1169.1	1067.8	1149.6	1345.6
0.3786	1189.1	1191.9	1184.8	1067.3	1163.6	1387.2
0.4775	1205.9	1208.2	1201.2	1073.7	1180.0	1415.0
0.5870	1223.1	1224.7	1218.4	1089.7	1199.0	1423.9
0.7090	1240.6	1241.3	1236.4	1120.4	1220.8	1407.9
0.8457	1258.4	1258.1	1255.2	1175.1	1246.0	1360.8
1.0000	1275.0	1275.0	1275.0	1275.0	1275.0	1275.0
308.15K						
0.0000	1105.0	1105.0	1105.0	1105.0	1105.0	1105.0
0.0634	1118.6	1120.6	1118.3	1089.1	1111.7	1170.2
0.1322	1132.7	1136.3	1132.1	1076.0	1120.0	1233.6
0.2070	1147.0	1152.2	1146.5	1066.3	1130.1	1293.0
0.2888	1162.4	1168.2	1161.5	1060.7	1142.1	1345.9
0.3786	1178.2	1184.3	1177.2	1060.2	1156.2	1388.7
0.4775	1194.7	1200.6	1193.6	1066.6	1172.6	1417.0
0.5870	1212.1	1217.1	1210.7	1082.7	1191.5	1425.3
0.7090	1230.5	1233.7	1228.7	1113.2	1213.3	1407.7
0.8457	1249.5	1250.4	1247.5	1167.7	1238.4	1357.2
1.0000	1267.3	1267.3	1267.3	1267.3	1267.3	1267.3
313.15K						
0.0000	1097.0	1097.0	1097.0	1097.0	1097.0	1097.0
0.0634	1109.8	1112.3	1110.0	1081.1	1103.5	1163.7
0.1322	1123.1	1127.7	1123.6	1068.1	1111.7	1228.7
0.2070	1136.7	1143.3	1137.7	1058.4	1121.6	1289.4
0.2888	1151.4	1159.0	1152.4	1052.8	1133.4	1343.3
0.3786	1166.7	1174.8	1167.8	1052.3	1147.2	1386.8
0.4775	1182.7	1190.8	1183.9	1058.5	1163.2	1415.0
0.5870	1200.1	1206.9	1200.7	1074.3	1181.8	1422.6
0.7090	1218.3	1223.2	1218.3	1104.4	1203.2	1403.3
0.8457	1237.7	1239.6	1236.8	1158.1	1227.8	1350.0
1.0000	1256.2	1256.2	1256.2	1256.2	1256.2	1256.2
318.15K						
0.0000	1090.0	1090.0	1090.0	1090.0	1090.0	1090.0
0.0634	1101.6	1104.7	1102.7	1074.2	1096.1	1159.4
0.1322	1113.7	1119.6	1115.8	1061.1	1103.7	1227.2
0.2070	1126.7	1134.7	1129.5	1051.4	1113.2	1290.1
0.2888	1140.6	1149.9	1143.8	1045.6	1124.4	1345.7
0.3786	1155.1	1165.2	1158.7	1044.9	1137.7	1390.4
0.4775	1170.8	1180.7	1174.3	1050.9	1153.3	1417.5
0.5870	1187.5	1196.3	1190.6	1066.2	1171.3	1424.7
0.7090	1205.8	1212.1	1207.6	1095.7	1192.2	1401.7
0.8457	1225.0	1228.0	1225.4	1148.2	1216.3	1344.4
1.0000	1244.1	1244.1	1244.1	1244.1	1244.1	1244.1

Table 3(b) : **Percentage Deviations and Interaction Parameters (α), for the System Diethyl malonate+ 2-methyl 1-propanol**

X_1	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0634	0.1024	-0.1013	-2.7065	-0.6904	4.3131	1.0020	0.0020
0.1322	0.1991	-0.1676	-5.1058	-1.2331	8.3502	1.0034	0.0034
0.2070	0.2342	-0.2534	-7.2189	-1.6794	11.8695	1.0051	0.0051
0.2888	0.2609	-0.3037	-8.9448	-1.9704	14.7447	1.0061	0.0061
0.3786	0.2364	-0.3595	-10.2447	-2.1399	16.6638	1.0072	0.0072
0.4775	0.1908	-0.3891	-10.9675	-2.1475	17.3397	1.0078	0.0078
0.5870	0.1311	-0.3834	-10.9022	-1.9719	16.4156	1.0077	0.0077
0.7090	0.0559	-0.3418	-9.6889	-1.5960	13.4848	1.0069	0.0069
0.8457	-0.0232	-0.2502	-6.6156	-0.9845	8.1419	1.0050	0.0050
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0634	0.1764	-0.0301	-2.6410	-0.6180	4.6112	1.0550	0.0550
0.1322	0.3221	-0.0498	-5.0015	-1.1137	8.9141	1.1081	0.1081
0.2070	0.4474	-0.0474	-7.0384	-1.4725	12.7268	1.1572	0.1572
0.2888	0.4984	-0.0747	-8.7498	-1.7407	15.7872	1.2010	0.2010
0.3786	0.5226	-0.0825	-10.0121	-1.8631	17.8704	1.2349	0.2349
0.4775	0.4928	-0.0961	-10.7245	-1.8549	18.6001	1.2547	0.2547
0.5870	0.4099	-0.1125	-10.6798	-1.7010	17.5907	1.2534	0.2534
0.7090	0.2549	-0.1486	-9.5329	-1.4019	14.3991	1.2219	0.2219
0.8457	0.0762	-0.1539	-6.5398	-0.8869	8.6224	1.1448	0.1448
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0634	0.2198	0.0154	-2.5866	-0.5685	4.8559	1.0538	0.0538
0.1322	0.4147	0.0461	-4.8907	-1.0108	9.4039	1.1055	0.1055
0.2070	0.5767	0.0861	-6.8863	-1.3299	13.4304	1.1534	0.1534
0.2888	0.6589	0.0905	-8.5637	-1.5649	16.6693	1.1961	0.1961
0.3786	0.6986	0.0983	-9.8080	-1.6707	18.8657	1.2293	0.2293
0.4775	0.6837	0.0993	-10.5043	-1.6478	19.6410	1.2485	0.2485
0.5870	0.5696	0.0514	-10.4859	-1.5255	18.5426	1.2480	0.2480
0.7090	0.4008	0.0006	-9.3530	-1.2429	15.1832	1.2170	0.2170
0.8457	0.1544	-0.0737	-6.4315	-0.8002	9.0749	1.1422	0.1422
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0634	0.2815	0.0921	-2.4949	-0.5068	5.2383	1.0518	0.0518
0.1322	0.5361	0.1945	-4.7167	-0.8906	10.1910	1.1015	0.1015
0.2070	0.7087	0.2538	-6.6821	-1.2005	14.5059	1.1483	0.1483
0.2888	0.8137	0.2864	-8.3228	-1.4149	17.9855	1.1898	0.1898
0.3786	0.8773	0.3200	-9.5340	-1.4989	20.3738	1.2219	0.2219
0.4775	0.8394	0.2970	-10.2439	-1.4995	21.0668	1.2413	0.2413
0.5870	0.7373	0.2561	-10.2141	-1.3660	19.9672	1.2405	0.2405
0.7090	0.5241	0.1526	-9.1298	-1.1263	16.2524	1.2110	0.2110
0.8457	0.2442	0.0325	-6.2672	-0.7147	9.7462	1.1382	0.1382
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table4 (a): **Experimental and theoretical velocities for the systems Diethyl malonate+ 3- methyl 1-butanol**

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15K						
0.0000	1222.0	1222.0	1222.0	1222.0	1222.0	1222.0
0.0733	1228.5	1227.2	1226.9	1209.1	1222.3	1271.5
0.1510	1234.9	1232.5	1231.9	1198.6	1223.7	1317.6
0.2337	1241.2	1237.7	1237.0	1190.7	1226.1	1358.6
0.3217	1247.3	1243.0	1242.1	1185.8	1229.5	1393.0
0.4157	1253.3	1248.3	1247.4	1184.5	1234.1	1418.1
0.5163	1258.8	1253.6	1252.7	1187.6	1239.8	1431.0
0.6241	1264.0	1258.9	1258.2	1196.0	1246.7	1427.9
0.7400	1268.5	1264.3	1263.7	1211.5	1254.8	1404.5
0.8649	1272.3	1269.6	1269.3	1236.4	1264.2	1355.5
1.0000	1275.0	1275.0	1275.0	1275.0	1275.0	1275.0
308.15K						
0.0000	1211.2	1211.2	1211.2	1211.2	1211.2	1211.2
0.0733	1217.2	1216.7	1216.4	1198.5	1211.8	1262.7
0.1510	1223.2	1222.3	1221.7	1188.2	1213.5	1310.9
0.2337	1229.2	1227.9	1227.0	1180.6	1216.2	1353.8
0.3217	1235.2	1233.5	1232.5	1176.0	1219.9	1390.4
0.4157	1241.1	1239.1	1238.1	1174.9	1224.8	1416.6
0.5163	1247.0	1244.7	1243.7	1178.2	1230.8	1430.3
0.6241	1252.6	1250.3	1249.5	1186.9	1238.0	1427.3
0.7400	1257.9	1256.0	1255.3	1202.7	1246.4	1402.7
0.8649	1262.9	1261.6	1261.2	1228.2	1256.1	1351.3
1.0000	1267.3	1267.3	1267.3	1267.3	1267.3	1267.3
313.15K						
0.0000	1198.3	1198.3	1198.3	1198.3	1198.3	1198.3
0.0733	1203.8	1204.0	1203.7	1185.9	1199.1	1251.1
0.1510	1209.3	1209.8	1209.1	1175.8	1201.0	1300.6
0.2337	1215.0	1215.5	1214.6	1168.3	1203.9	1345.1
0.3217	1220.8	1221.3	1220.3	1163.9	1207.8	1382.2
0.4157	1226.7	1227.1	1226.0	1163.0	1212.9	1409.8
0.5163	1232.7	1232.9	1231.8	1166.4	1219.0	1425.6
0.6241	1238.6	1238.7	1237.8	1175.3	1226.4	1421.4
0.7400	1244.6	1244.5	1243.8	1191.3	1235.0	1395.6
0.8649	1250.5	1250.3	1249.9	1216.8	1244.9	1342.8
1.0000	1256.2	1256.2	1256.2	1256.2	1256.2	1256.2
318.15K						
0.0000	1191.0	1191.0	1191.0	1191.0	1191.0	1191.0
0.0733	1195.3	1196.2	1195.9	1178.5	1191.5	1245.9
0.1510	1199.9	1201.5	1200.9	1168.3	1192.9	1297.3
0.2337	1204.6	1206.8	1206.0	1160.6	1195.4	1343.5
0.3217	1209.5	1212.1	1211.2	1156.0	1198.9	1381.9
0.4157	1214.7	1217.4	1216.4	1154.8	1203.5	1410.2
0.5163	1220.1	1222.7	1221.8	1157.9	1209.2	1425.8
0.6241	1225.7	1228.0	1227.2	1166.3	1216.1	1420.4
0.7400	1231.6	1233.4	1232.7	1181.5	1224.1	1392.2
0.8649	1237.7	1238.7	1238.4	1206.1	1233.4	1335.6
1.0000	1244.1	1244.1	1244.1	1244.1	1244.1	1244.1

Table 4(b): **Percentage Deviations and Interaction Parameters (α), for the System Diethyl malonate+ 3-methyl 1- butanol**

X_1	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0733	-0.1000	-0.1259	-1.5766	-0.5003	3.4996	1.0323	0.0323
0.1510	-0.1933	-0.2396	-2.9403	-0.9069	6.6982	1.0615	0.0615
0.2337	-0.2771	-0.3381	-4.0696	-1.2176	9.4621	1.0866	0.0866
0.3217	-0.3456	-0.4157	-4.9319	-1.4264	11.6814	1.1064	0.1064
0.4157	-0.3940	-0.4674	-5.4840	-1.5277	13.1568	1.1194	0.1194
0.5163	-0.4148	-0.4857	-5.6632	-1.5127	13.6742	1.1237	0.1237
0.6241	-0.3989	-0.4613	-5.3794	-1.3696	12.9668	1.1169	0.1169
0.7400	-0.3347	-0.3825	-4.4990	-1.0834	10.7203	1.0964	0.0964
0.8649	-0.2079	-0.2350	-2.8170	-0.6351	6.5378	1.0588	0.0588
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0733	-0.0346	-0.0630	-1.5302	-0.4397	3.7416	1.0313	0.0313
0.1510	-0.0702	-0.1210	-2.8545	-0.7930	7.1704	1.0596	0.0596
0.2337	-0.1068	-0.1739	-3.9532	-1.0600	10.1391	1.0840	0.0840
0.3217	-0.1399	-0.2170	-4.7937	-1.2359	12.5635	1.1032	0.1032
0.4157	-0.1668	-0.2475	-5.3340	-1.3170	14.1379	1.1159	0.1159
0.5163	-0.1830	-0.2609	-5.5128	-1.2971	14.6998	1.1201	0.1201
0.6241	-0.1825	-0.2510	-5.2412	-1.1676	13.9439	1.1137	0.1137
0.7400	-0.1583	-0.2108	-4.3885	-0.9181	11.5072	1.0939	0.0939
0.8649	-0.1010	-0.1308	-2.7513	-0.5344	6.9968	1.0574	0.0574
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0733	0.0215	-0.0091	-1.4875	-0.3860	3.9348	1.0304	0.0304
0.1510	0.0345	-0.0203	-2.7762	-0.6928	7.5444	1.0579	0.0579
0.2337	0.0386	-0.0337	-3.8461	-0.9210	10.7051	1.0816	0.0816
0.3217	0.0365	-0.0466	-4.6657	-1.0673	13.2186	1.1003	0.1003
0.4157	0.0275	-0.0594	-5.1950	-1.1311	14.9231	1.1126	0.1126
0.5163	0.0153	-0.0687	-5.3728	-1.1071	15.6534	1.1168	0.1168
0.6241	0.0025	-0.0714	-5.1122	-0.9899	14.7561	1.1107	0.1107
0.7400	-0.0078	-0.0643	-4.2846	-0.7729	12.1304	1.0915	0.0915
0.8649	-0.0105	-0.0425	-2.6896	-0.4468	7.3856	1.0560	0.0560
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0733	0.0755	0.0479	-1.4115	-0.3255	4.2260	1.0288	0.0288
0.1510	0.1368	0.0874	-2.6338	-0.5790	8.1185	1.0548	0.0548
0.2337	0.1816	0.1163	-3.6486	-0.7630	11.5320	1.0772	0.0772
0.3217	0.2100	0.1350	-4.4266	-0.8764	14.2476	1.0948	0.0948
0.4157	0.2212	0.1426	-4.9282	-0.9191	16.0916	1.1064	0.1064
0.5163	0.2148	0.1389	-5.0961	-0.8894	16.8647	1.1103	0.1103
0.6241	0.1899	0.1232	-4.8486	-0.7859	15.8886	1.1045	0.1045
0.7400	0.1457	0.0946	-4.0634	-0.6061	13.0386	1.0865	0.0865
0.8649	0.0827	0.0538	-2.5501	-0.3455	7.9128	1.0530	0.0530
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table 5: Standard deviations and chi – square test values for four studied systems at 303.15, 30815, 313.15 and 318.15K

	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
	DEM + 2-butanol									
	303.15K					**308.15K**				
σ	-0.0682	-0.1022	-0.7975	-0.1947	0.9159	-0.0524	-0.0867	-0.7880	-0.1821	0.9745
χ^2	0.7024	1.5378	80.0168	5.4143	163.9257	0.4124	1.0949	77.5360	4.6858	187.5072
	313.15K					**318.15K**				
σ	-0.0458	-0.0784	-0.7630	-0.1691	1.0176	-0.0377	-0.0674	-0.7396	-0.1590	1.0796
χ^2	0.3173	0.8922	72.6511	4.0264	205.6688	0.2197	0.6613	68.1045	3.5465	233.1178
DEM + 2-propanol										
	303.15K					**308.15K**				
σ	-0.0052	-0.0829	-1.2028	-0.1827	1.2536	0.0072	-0.0693	-1.1831	-0.1690	1.3139
χ^2	0.0092	0.9938	164.2399	4.6697	331.8063	0.0122	0.6823	158.4586	3.9569	370.0430
	313.15K					**318.15K**				
σ	0.0169	-0.0589	-1.1684	-0.1582	1.3641	0.0254	-0.0466	-1.1464	-0.1493	1.4308
χ^2	0.0478	0.4874	153.6178	3.4356	400.9923	0.0990	0.3063	147.3224	3.0450	444.8480
DEM + 2- methyl -1- propanol										
	303.15K					**308.15K**				
σ	0.0138	-0.0256	-0.7955	-0.1467	0.9787	0.0319	-0.0080	-0.7777	-0.1285	1.0385
χ^2	0.0336	0.0966	77.8898	3.0231	184.9877	0.1573	0.0104	74.0981	2.2950	210.1960
	313.15K					**318.15K**				
σ	0.0435	0.0041	-0.7608	-0.1152	1.0879	0.0552	0.0188	-0.7381	-0.1035	1.1597
χ^2	0.2861	0.0053	70.5099	1.8272	231.7377	0.4492	0.0546	66.1314	1.4672	265.9308
DEM +3- butyl 1-butanol										
	303.15K					**308.15K**				
σ	-0.0268	-0.0316	-0.3916	-0.1031	0.7972	-0.0114	-0.0168	-0.3806	-0.0886	0.8496
χ^2	0.1112	0.1543	21.5038	1.5879	121.6788	0.0208	0.0435	20.1813	1.1652	139.0721
	313.15K					**318.15K**				
σ	0.0016	-0.0042	-0.3705	-0.0758	0.8922	0.0146	0.0094	-0.3506	-0.0614	0.9524
χ^2	0.0007	0.0029	18.9491	0.8468	153.6313	0.0317	0.0132	16.8826	0.5508	176.3989

CONCLUSION

Ultrasonic velocities of binary mixtures of DEM with 2-alkanols were evaluated using various theories at different temperatures over the whole composition range and compared with the experimental values. The positive deviations of the experimental velocities from the theoretical values using various theoretical models indicate the existence of chemical forces such as hydrogen bonding and dipole-dipole interactions between the component molecules.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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