Theoretical Velocities of Binary Mixtures of Di Methyl Malonate with Branched Alkanols at Different Temperatures

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Abstract

Ultrasonic velocities and densities of the binary liquid mixtures of di methyl malonate with branched alkanols like 2– methyl-1-propanol(2M1P), 2- propanol (2P), and 2- butanol (2B) have been measured in temperatures range 303.15 K to 318.15 K with an interval of 5K over the entire composition range of mole fractions. Using Nomoto's relation (U_{nm}), impedance relation (U_{im}), ideal mixing relation (U_{mx}), Junjie's relation (U_j), Rao's specific velocity relation (U_r) and Kudriavtsev relation (U_k), the theoretical values of ultrasonic velocity were evaluated. The computed estimations of ratio in velocity (U^2/U^2imx) from measured estimations of ultrasonic velocity (U) are graphically shown.From the values of experimental and theoretical velocities the molecular interaction parameter (α) has been evaluated and discussed its variation with the composition mixture has been conferred in terms of molecular interactions. The validity of the theories were checked by calculating standard deviation and chi square test.

Key Words: *Di Methyl Malonate, Ultrasonic velociets, Theoretical Velocities, Relative percenta ge of error, Chi-square test.*

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1. Introduction

Sound speed measurements have significance in science and technology since they provide valuable information about acoustic and thermodynamic parameters, the sign and magnitude of their excess functions being used to evaluate structure-making and /or structure-breaking effects arising due to mixing of two or more unlike liquids in varying proportions [1,2].

The ultrasonic sound velocities in liquid mixtures have been measured and compared with experimental values using different theories [3-8]. It is predicted that the essence of the interaction between constituent molecules in the mixture would be known by comparing ultrasonic velocities theoretically measured with those obtained experimentally in the current binary liquid mixtures. In discovering the detailed theoretical model for liquid mixtures, such theoretical analysis is helpful. These ultrasonic sound velocities of liquid mixtures are useful in evaluating different liquid state hypotheses. Theoretically, in binary liquid mixtures, the assessment of ultrasonic velocity and its connectio to the study of molecular interaction has been successfully carried out in recent years[9,10] using the theoretical relationships of Nomoto[3], Van Dael and Vangeel [4], the impedance relationship[5], Rao 's unique velocity[7], Junjie[6] and Kudriavtsev[8]. In binary liquid mixtures, several attempts have been made to theoretically determine the ultrasonic sound velocity, where all the physical properties in a given system gradually shift within well-defined limiting values, corresponding to that of the component liquids.

2. Experimental

Di methyl malonate (Loba >0.995 purity) was distilled at low pressure and over freshly activated 0.3 nm molecular sieves [11]. The branched alkanols referred to above in the study (Loba chemicals, India, with a purity of > 0.99) were purified using the methods mentioned in the literature[12, 13]. By calculating the densities and ultrasonic velocities, which are in good agreement with the values of the literature, the purity of the chemicals was further tested.

3. Apparatus and Procedure

The speed of sound is measured using an ultrasonic interferometer (Mittal Enterprises, New Delhi model F05) operating at 2 MHz. The experimentally measured speeds of sound have a precision of 0.8 m-sec^{-1} and an uncertainty less than ±0.1 m-sec^{-1}. The temperature stability was maintained within ±0.01 K, by circulating water bath around the measuring cell through a pump.

The pure liquids density and density of their mixtures are determined using a double-arm pycnometer, and the values from triplicate replication at each temperature are reproducible within kg - m^3 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.

4. Theory

4.1 *Nomoto* Equation

Rao's [14] found experimentally that, for pure liquids, the ratio of temperature coefficients of sound velocity U and molar volume V remains almost constant:

$$[\,(1/U)\,dU/dT]\,(dU/dT)/\,(1/V)\,(dV/dT)\,]\,=\,-3 \quad (1)$$

where T is the absolute temperature. Integrating this equation one obtains:

$$VU^{1/3} = const = M/pU^{1/3} = R \quad (2)$$

where M is molecular weight,ρ is density and R is constant which is called the molar sound velocity or Rao's constant. It was found to be additive

On assuming the additivity of molar sound velocity (R) and no volume change on mixing, Nomoto established the following relation [3] for a liquid mixture

$$R = M/pU^{1/3} \quad (3)$$

Here, the experimentally determined velocity and density are U and ρ respectively and M is the mean molecular weight in a binary liquid mixture.

$$M = (X_1M_1 + X_2M_2) \quad (4)$$

where M_1 and M_2 are molecular weights of constituent components. Simple manipulation yields the following relation4

$$U_{Nomoto} = [(X_1R_1) + X_2R_2)/(X_1V_1 + X_2V_2)]^3 \quad (5)$$

4.2 The *Van Dael*and *Vangeel* Equation

The ideal mixing theory advanced by Van Dael and Vangeel [4] in the light of assumptions made by Blandamer and Waddington[25], yield the following relation[26] for adiabatic compressibility $(\beta_{ad})_{imx}$

$$(\beta_{ad})_{imx} = \varphi_1\gamma_1/\gamma_{imx}(\beta_{ad})_1 + \varphi_2\gamma_2/\gamma_{imx}(\beta_{ad})_2 \quad (6)$$

whereφ_1, φ_2 are the volume fraction of species 1 and 2, γ_1 and γ_2 are ratios of specific heats of the respective species. This relation holds good if the mixture is ideal and if$\gamma_1 = \gamma_2 = \gamma_{imx.}$ Using the additional assumption that $V_1 = V_2$ the above equation can be transformed in to a linear combination of mole fraction X_1 and X_2.

$$(\beta_{ad})_{imx} = X_1(\beta_{ad})_1 + X_2(\beta_{ad})_2 \quad (7)$$

Basingon this equation, Van Dael obtained the relation for ultrasonic velocity in liquid mixtures as

$$1/(X_1M_1 + X_2M_2) * (1/U_{imx}^2) = X_1/M_1U_1^2 + X_2/M_2U_2^2 \quad (8)$$

where U_{imx} is the ideal mixing ultrasonic velocity in liquid mixture.U_1 and U_2 are ultrasonic velocity in species.

4.3 The Impedance relation

Impedance relation [5]

$$U = \sum X_iZ_i/\sum X_ip_i \quad (9)$$

where X_i mole fraction, $\rho_{t,}$ is the density of the mixture and Z_i is the acoustic impedance.

4.4 The *Rao's*specific velocity method relation

Rao's specific velocity method [7]

$$U = (\sum X_ir_id)^3 \quad (10)$$

where X_i mole fraction, U_i is the ultrasonic velocity, ρ_t is the density of the mixture, r_i is the Rao's specific sound velocity = $Ui^{1/3}/\rho_i$ and Z_i is the acoustic impedance.

4.5 The *Junjie* equation

Junjie equation [6] (U_J) =

$$(X_1M_1/\rho_1 + X_2M_2/\rho_2) \Big/ [\{X_1M_1 + X_2M_2\}^{1/2}\{X_1M_1/\rho_1U_1^2 + X_2M_2/\rho_2U_2^2)\}^{1/2}] \quad (11)$$

wher M_1, M_2 are molecular weights of constituent components. ρ_1 and ρ_2 are the densities of constituent components.

4.6. *Kudriavtsev* Equation

Kudriavtsev Relation [8] for the ultrasonic relation between experimental and theoretical values are calculated as

$$U_{KUD} = [X_1M_1U_1^2/M_{eff}] + [X_2M_2U_2^2/M_{eff}]^{1/2} \quad (12)$$

4.7 Chi-square test for goodness of fit

As indicated by Karl Pearson [15], Chi-square value is evaluated for the binary liquid mixtures under study utilizing the formula

$$\chi 2 = \sum_{i=1}^{n}((\mathrm{U(obs)} - \mathrm{U(cal)})2 / \mathrm{U(cal)} \quad (13)$$

where n is the number of data used,

and U (obs) = experimental values of ultrasonic velocities

U(cal) = computed values of ultrasonic velocities

4.8 Relative percentage of error (σ)

The Average percentage error is calculated by utilizing the relation

$$\sigma = 1/\mathrm{n}\sum((\mathrm{U_{(obs)}} - \mathrm{U_{(cal)}})/\mathrm{U_{(obs)}})\mathrm{X}100 \quad (14)$$

where n is the number of data used. U (obs) = experimental values of ultrasonic velocities

4.9 Molecular Association(α):

The degree of intermolecular interaction or molecular association is given by

$$\alpha = (\mathrm{U_{exp}^2/U_{imx}^2})^{-1} \quad (15)$$

5. Results and Discussion

In general, polar aprotic solvents solvate cat ions and anions efficiently, while aprotic solvents do not solvate anions to a large degree. Alkanols are protic solvents and because it has the group -C =O, DiMethyl Malonate is an aprotic solvent. Since oxygen is much more electro-negative than carbon, it has a strong tendency to draw the carbon-oxygen bond electron towards itself. One of the two pairs of electrons that make up a double bond of carbon-oxygen is much more readily drawn towards the oxygen that polarizes the carbon-oxygen bond. With a dipole moment of (μ), this polarity further attempts to pull hydrogen from self-associated alkanol molecules. This is the key phenomenon occurring between hetero molecules in a new hydrogen bond.

The experimental values, along with the values calculated theoretically using the relations of Nomoto, Van Dael ideal mixing, Impedance, Rao's specific velocity, Junjie and Kudrait for studied systems at the temperatures of 303.15, 308.15, 313.15 and 318.15K are given in Tables 1, 2 and 3. The percentage of deviation is calculated to check the validity of different theoretical formulae is checked by percentage deviation for all the mixtures at all the temperatures and these values are also incorporated in the tables 1, 2 and 3.

Tables 1 , 2 and 3 demonstrate that the theoretical ultrasonic velocity values calculated by different theories indicate differences from the experimental values. It is responsible for the constraints and approximations integrated into these theories. All of the molecules are thought to be spherical in shape, which is not always true. In Nomoto 's theory, when mixing, it is believed that the volume does not change. Therefore, no interaction has been taken into account between the components of liquid mixtures. The assumption for the development of the optimal mixing relationship is that the ratio of ideal mixtures' unique heats and volumes are also equal. Again, it does not take into account any molecular interaction. Similarly, as per the belief of the theory of the Collision Factor, the molecules are handled, which is not really the case, as real non-elastic substances. But the interaction between the molecules of the two liquids happens when two liquids are combined due to the presence of different kinds of forces, such as dispersion forces, charge transfer, hydrogen bonding, dipole-dipole and dipole-induced dipole interactions. Therefore, the variations found in the velocity values measured using different models from the experimental values suggest that there is a molecular interaction between the different molecules in the liquid mixture.

The computed estimations of ratio in velocity (U^2/U^2imx) from measured estimations of ultrasonic velocity (U) are graphically shown in Fig 1, 2 and 3. The ratio (U^2/U^2imx) is used as an important tool to measure the non-ideality in liquid mixtures, especially in these cases where the properties other than sound velocity are not known. The values of the (U^2/U^2imx) are positive[16] for the studied binary mixtures at all the different temperatures and over the entire composition range of DMM, which indicates dominance of associations over dispersion forces among the molecules of liquid mixture.

Fig 1, 2 and 3 represent the variation of (U^2/U^2imx) with mole fraction of DMM with branched alkanols. It is observed at 0.5 mole fraction systems show maximum positive deviation at all the temperatures, which infers the maximum hetero molecular associations at this mole fraction of DMM. The deviation of the ratio (U^2/U^2imx) from unity is a direct measure of non ideality of the system as a consequence of association or dissociation.

6. Conclusion

From the values of experimental and evaluated velocity values, it may be concluded that, the Impedance Relation has provided good results. Thus, the linearity of molar sound velocity and additive of molar volumes, as suggested by Impedance Relation has been truly observed in the above mentioned binary liquid mixtures. The success of these relations in predicting the experimental ultrasonic velocities for polar-polar liquid mixtures has also been emphasized by others.

Table 1: Experimental and theoretical values of velocities with their percentage of deviations for the system DMM +2M1P at 303.15, 308.15,313.15 and 318.15K

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	U_{KUD}	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	$\%U_{KUD}$	U^2/U^2_{imx}	α
303.15K															
0.0000	1111.0	1111.0	1111.0	1111.0	1111.0	1111.0	1111.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1125.2	1135.5	1140.1	1104.2	1118.2	1192.7	1149.4	0.9157	1.3280	-1.8594	-0.6221	6.0053	2.1572	1.0383	0.0383
0.1680	1140.8	1160.1	1168.3	1101.4	1128.3	1265.3	1183.6	1.6966	2.4099	-3.4488	-1.0960	10.9171	3.7559	1.0727	0.0727
0.2572	1158.1	1185.0	1195.6	1103.0	1141.6	1328.1	1214.3	2.3238	3.2339	-4.7578	-1.4298	14.6756	4.8524	1.1024	0.1024
0.3500	1177.5	1210.1	1222.0	1109.6	1158.3	1379.7	1242.0	2.7751	3.7851	-5.7634	-1.6291	17.1749	5.4837	1.1261	0.1261
0.4469	1199.2	1235.5	1247.7	1122.1	1178.8	1419.1	1267.2	3.0252	4.0452	-6.4256	-1.6975	18.3415	5.6725	1.1421	0.1421
0.5479	1223.7	1261.0	1272.6	1142.0	1203.7	1443.7	1290.2	3.0442	3.9919	-6.6789	-1.6361	17.9734	5.4298	1.1483	0.1483
0.6534	1251.7	1286.7	1296.8	1171.4	1233.7	1451.1	1311.3	2.7970	3.5977	-6.4172	-1.4433	15.9311	4.7561	1.1418	0.1418
0.7637	1283.9	1312.7	1320.2	1213.7	1269.6	1441.3	1330.7	2.2419	2.8296	-5.4649	-1.1141	12.2571	3.6418	1.1190	0.1190
0.8791	1321.3	1338.8	1343.0	1274.8	1312.8	1412.3	1348.6	1.3294	1.6468	-3.5169	-0.6388	6.8865	2.0668	1.0742	0.0742
1.0000	1365..2	1365.2	1365.2	1365.2	1365.2	1365.2	1365.2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	6.0445	0.2601	-0.4688	-0.1146	1.0480	-3.4380								
	χ^2	6.0445	10.6778	29.3118	1.8769	214.5263	1.3002								
308.15K															
0.0000	1104.7	1104.7	1104.7	1104.7	1104.7	1104.7	1104.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1118.9	1128.7	1133.4	1097.9	1111.5	1189.5	1142.4	0.8776	1.2971	-1.8738	-0.6575	6.3099	2.1073	1.0386	0.0386
0.1680	1134.3	1152.9	1161.1	1095.0	1121.3	1262.5	1176.0	1.6385	2.3643	-3.4624	-1.1494	11.3019	3.6782	1.0730	0.0730
0.2572	1151.3	1177.3	1188.0	1096.5	1134.2	1325.8	1206.2	2.2598	3.1862	-4.7604	-1.4883	15.1582	4.7657	1.1025	0.1025
0.3500	1170.1	1202.0	1214.0	1102.9	1150.5	1377.4	1233.4	2.7225	3.7508	-5.7433	-1.6773	17.7150	5.4085	1.1256	0.1256
0.4469	1191.4	1226.8	1239.2	1115.2	1170.6	1416.9	1258.1	2.9741	4.0129	-6.3960	-1.7454	18.9228	5.6009	1.1413	0.1413
0.5479	1215.5	1251.9	1263.7	1134.8	1195.1	1440.4	1280.7	2.9978	3.9632	-6.6417	-1.6812	18.5039	5.3664	1.1473	0.1473
0.6534	1243.0	1277.3	1287.4	1163.7	1224.5	1447.3	1301.5	2.7583	3.5743	-6.3757	-1.4826	16.4416	4.7048	1.1408	0.1408
0.7637	1274.1	1302.8	1310.4	1205.4	1260.0	1435.2	1320.5	2.2520	2.8513	-5.3891	-1.1075	12.6421	3.6442	1.1172	0.1172
0.8791	1311.2	1328.5	1332.8	1265.6	1302.7	1404.2	1338.2	1.3224	1.6461	-3.4795	-0.6483	7.0958	2.0560	1.0734	0.0734
1.0000	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	0.1933	0.2581	-0.4665	-0.1180	1.0780	-3.3941								
	χ^2	5.8133	10.4440	28.7975	1.9735	226.9631	1.2672								
313.15K															
0.0000	1096.0	1096.0	1096.0	1096.0	1096.0	1096.0	1096.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1108.9	1118.3	1122.8	1088.8	1101.8	1180.6	1130.9	0.8468	1.2509	-1.8083	-0.6356	6.4638	1.9819	1.0372	0.0372
0.1680	1123.2	1140.8	1148.6	1085.5	1110.6	1254.7	1162.0	1.5652	2.2649	-3.3541	-1.1250	11.7049	3.4544	1.0706	0.0706
0.2572	1138.6	1163.5	1173.7	1086.4	1122.3	1316.8	1190.0	2.1840	3.0779	-4.5839	-1.4311	15.6505	4.5115	1.0984	0.0984
0.3500	1155.8	1186.4	1197.9	1092.1	1137.4	1368.0	1215.3	2.6478	3.6412	-5.5095	-1.5936	18.3602	5.1487	1.1200	0.1200
0.4469	1175.2	1209.5	1221.3	1103.5	1156.1	1406.0	1238.3	2.9211	3.9258	-6.1028	-1.6267	19.6369	5.3727	1.1342	0.1342
0.5479	1197.6	1232.9	1244.1	1121.8	1178.9	1427.6	1259.4	2.9444	3.8790	-6.3292	-1.5608	19.2074	5.1595	1.1397	0.1397
0.6534	1222.8	1256.4	1266.1	1149.1	1206.5	1431.0	1278.7	2.7479	3.5390	-6.0300	-1.3333	17.0251	4.5724	1.1325	0.1325
0.7637	1252.0	1280.1	1287.4	1188.4	1239.7	1416.7	1296.5	2.2481	2.8297	-5.0802	-0.9812	13.1550	3.5556	1.1099	0.1099
0.8791	1287.3	1304.1	1308.1	1245.0	1279.7	1383.6	1313.0	1.3087	1.6231	-3.2823	-0.5827	7.4862	1.9987	1.0690	0.0690
1.0000	1328.3	1328.3	1328.3	1328.3	1328.3	1328.3	1328.3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	0.1896	0.2523	-0.4437	-0.1102	1.1126	-3.2505								
	χ^2	5.5257	9.8471	25.7656	1.6980	240.6945	1.1622								

318.15K															
0.0000	1089.5	1089.5	1089.5	1089.5	1089.5	1089.5	1089.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1101.7	1110.6	1115.0	1082.1	1094.6	1174.9	1122.4	0.8067	1.2044	-1.7796	-0.6439	6.6429	1.8816	1.0366	0.0366
0.1680	1115.2	1131.9	1139.6	1078.5	1102.5	1249.2	1151.9	1.5010	2.1899	-3.2892	-1.1307	12.0165	3.2931	1.0692	0.0692
0.2572	1129.4	1153.4	1163.3	1079.0	1113.5	1312.0	1178.4	2.1244	3.0051	-4.4650	-1.4120	16.1716	4.3362	1.0957	0.0957
0.3500	1145.6	1175.1	1186.3	1084.2	1127.6	1362.1	1202.4	2.5752	3.5545	-5.3633	-1.5726	18.9004	4.9556	1.1166	0.1166
0.4469	1163.8	1197.0	1208.6	1094.9	1145.3	1399.4	1224.2	2.8541	3.8453	-5.9238	-1.5925	20.2461	5.1914	1.1299	0.1299
0.5479	1185.0	1219.1	1230.1	1112.3	1167.0	1421.1	1244.2	2.8806	3.8033	-6.1340	-1.5231	19.9224	4.9957	1.1350	0.1350
0.6534	1209.0	1241.5	1250.9	1138.4	1193.2	1423.7	1262.6	2.6848	3.4663	-5.8395	-1.3030	17.7623	4.4294	1.1279	0.1279
0.7637	1236.8	1264.0	1271.1	1176.1	1225.0	1407.0	1279.5	2.1981	2.7731	-4.9092	-0.9561	13.7651	3.4501	1.1059	0.1059
0.8791	1270.4	1286.7	1290.7	1230.3	1263.3	1369.4	1295.1	1.2884	1.5995	-3.1562	-0.5584	7.7984	1.9501	1.0662	0.0662
1.0000	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ		0.0485	-0.0107	-0.2491	-0.0569	0.0280	-3.1348							
	χ^2		0.3653	0.0178	9.1423	0.4964	0.1234	1.0810							

Table 2: Experimental andtheoretical values of velocities with their percentage of deviations for the system DMM +2-Propanol at 303.15,308.15,313.15 and 318.15K

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	U_{KUD}	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	$\%U_{KUD}$	U^2/U^2_{imx}	α
303.15K															
0.0000	1110.0	1110.0	1110.0	1110.0	1110.0	1110.0	1110.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1127.7	1130.3	1135.2	1104.1	1114.8	1211.1	1149.3	0.2309	0.6658	-2.0924	-1.1417	7.4025	1.9129	1.0432	0.0432
0.1680	1146.6	1151.5	1160.4	1100.9	1122.1	1304.5	1184.0	0.4287	1.2071	-3.9870	-2.1390	13.7691	3.2637	1.0848	0.0848
0.2572	1166.9	1173.8	1185.8	1101	1132.2	1385.6	1215.0	0.5881	1.6163	-5.6495	-2.9730	18.7471	4.1244	1.1233	0.1233
0.3500	1188.7	1197.1	1211.2	1105.2	1145.7	1452.2	1242.9	0.7031	1.8852	-7.0309	-3.6177	22.1616	4.5587	1.1570	0.1570
0.4469	1212.3	1221.6	1236.6	1114.6	1163.4	1502.5	1268.1	0.7669	2.0048	-8.0587	-4.0379	23.9329	4.6014	1.1830	0.1830
0.5479	1237.9	1247.4	1262.2	1131.1	1186.1	1530.5	1291.0	0.7717	1.9656	-8.6232	-4.1841	23.6407	4.2883	1.1976	0.1976
0.6534	1265.6	1274.6	1287.8	1157.4	1215.1	1533.6	1311.9	0.7085	1.7573	-8.5498	-3.9865	21.1748	3.6588	1.1957	0.1957
0.7637	1295.8	1303.2	1313.5	1198	1252.5	1507.7	1331.1	0.5670	1.3685	-7.5444	-3.3425	16.3510	2.7241	1.1699	0.1699
0.8791	1328.9	1333.3	1339.3	1261.5	1301	1451.4	1348.8	0.3354	0.7872	-5.0672	-2.0965	9.2179	1.4955	1.1096	0.1096
1.0000	1365.2	1365.2	1365.2	1365.2	1365.2	1365.2	1365.1	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0066	1.0000	0.0000
	σ		0.3913	0.1305	-0.6089	-0.2848	1.3132	-2.78425							
	χ^2		0.3913	2.6258	49.0337	11.4455	368.6141	0.85272							
308.15K															
0.0000	1105.0	1105.0	1105.0	1105.0	1105.0	1105.0	1105.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1122.3	1124.8	1129.7	1099.0	1109.4	1209.1	1143.4	0.2212	0.6632	-2.0736	-1.1476	7.7367	1.8757	1.0428	0.0428
0.1680	1140.8	1145.5	1154.5	1095.7	1116.2	1303.9	1177.3	0.4109	1.2022	-3.9505	-2.1503	14.2995	3.2001	1.0840	0.0840
0.2572	1160.6	1167.2	1179.3	1095.7	1125.9	1385.6	1207.6	0.5640	1.6095	-5.5969	-2.9890	19.3857	4.0512	1.1221	0.1221
0.3500	1182.0	1190.0	1204.2	1099.7	1139.0	1452.9	1234.9	0.6747	1.8770	-6.9638	-3.6378	22.9224	4.4726	1.1553	0.1553
0.4469	1205.0	1213.9	1229.1	1108.9	1156.1	1504.4	1259.5	0.7364	1.9958	-7.9797	-4.0610	24.8392	4.5239	1.1810	0.1810
0.5479	1230.0	1239.1	1254.1	1125.0	1178.2	1531.5	1281.9	0.7415	1.9566	-8.5356	-4.2089	24.5142	4.2215	1.1954	0.1954
0.6534	1257.1	1265.7	1279.1	1150.8	1206.7	1531.4	1302.4	0.6813	1.7490	-8.4590	-4.0110	21.8163	3.6037	1.1934	0.1934
0.7637	1286.7	1293.7	1304.2	1190.7	1243.4	1503.8	1321.2	0.5457	1.3619	-7.4592	-3.3640	16.8734	2.6807	1.1677	0.1677
0.8791	1319.0	1323.2	1329.3	1253.0	1291.1	1444.6	1338.5	0.3230	0.7833	-5.0051	-2.1107	9.5232	1.4785	1.1082	0.1082
1.0000	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ		0.0487	0.1299	-0.6022	-0.2866	1.352	-2.7376							
	χ^2		0.3589	2.5863	47.7236	11.5086	392.4588	0.8244							

313.15K															
0.0000	1097.0	1097.0	1097.0	1097.0	1097.0	1097.0	1097.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1113.0	1115.3	1120.0	1090.7	1100.6	1203.0	1132.4	0.2068	0.6284	-2.0066	-1.1147	8.0857	1.7422	1.0414	0.0414
0.1680	1130.2	1134.5	1143.1	1087.0	1106.6	1298.3	1163.8	0.3845	1.1399	-3.8208	-2.0872	14.8751	2.9722	1.0810	0.0810
0.2572	1148.6	1154.7	1166.1	1086.5	1115.3	1379.0	1191.9	0.5282	1.5271	-5.4096	-2.8988	20.0554	3.7674	1.1177	0.1177
0.3500	1168.4	1175.8	1189.3	1089.8	1127.2	1446.2	1217.2	0.6324	1.7821	-6.7255	-3.5246	23.7730	4.1726	1.1494	0.1494
0.4469	1189.8	1198.0	1212.4	1098.2	1143.1	1495.5	1240.0	0.6909	1.8963	-7.6988	-3.9301	25.6902	4.2230	1.1738	0.1738
0.5479	1213.0	1221.4	1235.6	1113.2	1163.6	1518.9	1260.9	0.6964	1.8605	-8.2243	-4.0680	25.2189	3.9477	1.1873	0.1873
0.6534	1238.1	1246.1	1258.7	1137.4	1190.2	1517.6	1279.9	0.6405	1.6645	-8.1361	-3.8708	22.5687	3.3797	1.1850	0.1850
0.7637	1265.5	1272.0	1282.0	1175.0	1224.5	1486.4	1297.4	0.5136	1.2973	-7.1569	-3.2403	17.4535	2.5244	1.1601	0.1601
0.8791	1295.5	1299.5	1305.2	1233.6	1269.3	1425.6	1313.6	0.3044	0.7469	-4.7849	-2.0284	10.0356	1.3955	1.1030	0.1030
1.0000	1328.5	1328.5	1328.5	1328.5	1328.5	1328.5	1328.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
σ		0.0457	0.1235	-0.5784	-0.2767	1.3931	-2.5553								
χ^2		0.3121	2.3058	43.6455	10.6094	414.8536	0.7183								
318.15K															
0.0000	1090.0	1090.0	1090.0	1090.0	1090.0	1090.0	1090.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0824	1105.2	1107.4	1111.9	1083.5	1093	1197.5	1123.5	0.1952	0.6083	-1.9639	-1.1009	8.3481	1.6530	1.0405	0.0405
0.1680	1121.5	1125.6	1133.9	1079.6	1098.4	1292.9	1153.2	0.3631	1.1036	-3.7382	-2.0606	15.2871	2.8270	1.0792	0.0792
0.2572	1139.0	1144.7	1155.8	1078.7	1106.4	1375.4	1179.8	0.4992	1.4789	-5.2902	-2.8607	20.7608	3.5844	1.1148	0.1148
0.3500	1157.8	1164.7	1177.8	1081.7	1117.5	1441.5	1203.8	0.5982	1.7264	-6.5734	-3.4766	24.5093	3.9744	1.1457	0.1457
0.4469	1178.1	1185.8	1199.7	1089.5	1132.4	1489.3	1225.6	0.6541	1.8376	-7.5195	-3.8746	26.4209	4.0282	1.1692	0.1692
0.5479	1200.0	1208.0	1221.7	1103.7	1151.9	1512.8	1245.4	0.6598	1.8036	-8.0256	-4.0081	26.0599	3.7801	1.1821	0.1821
0.6534	1223.9	1231.3	1243.7	1126.9	1177.3	1508.5	1263.5	0.6074	1.6142	-7.9302	-3.8110	23.2548	3.2343	1.1797	0.1797
0.7637	1249.9	1256.0	1265.7	1162.9	1210.1	1477.0	1280.1	0.4875	1.2587	-6.9645	-3.1875	18.1698	2.4190	1.1553	0.1553
0.8791	1278.4	1282.1	1287.6	1219.0	1252.9	1411.3	1295.5	0.2892	0.7250	-4.6453	-1.9932	10.3997	1.3369	1.0998	0.0998
1.0000	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
σ		0.0485	-0.0107	-0.2491	-0.0569	0.0280	-2.4404								
χ^2		0.3653	0.0178	9.1423	0.4964	0.1234	0.6551								

Table 3: Experimental and theoretical values of velocities with their percentage of deviations for the system DMM +2-Butanol at 303.15,308.15,313.15 and318.15K

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	U_K	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	$\%U_K$	U^2/U^2_{imx}	α
303.15K															
0.0000	1150.0	1150.0	1150.0	1150.0	1150.0	1150.0	1150.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0819	1167.6	1170.9	1174.4	1141.7	1155.7	1229.6	1181.8	0.2832	0.5765	-2.2158	-1.0235	5.3096	1.2176	1.0458	0.0458
0.1671	1186.0	1192.0	1198.0	1137.4	1164.1	1300.1	1210.4	0.5080	1.0149	-4.0984	-1.8452	9.6240	2.0611	1.0873	0.0873
0.2560	1205.1	1213.2	1221.0	1137.2	1175.4	1360.3	1236.2	0.6728	1.3194	-5.6334	-2.4656	12.8765	2.5837	1.1230	0.1230
0.3486	1225.0	1234.5	1243.3	1141.8	1189.7	1409.7	1259.7	0.7759	1.4939	-6.7924	-2.8801	15.0741	2.8278	1.1511	0.1511
0.4453	1245.8	1256.0	1265.0	1152.0	1207.5	1445.4	1281.0	0.8155	1.5421	-7.5282	-3.0795	16.0202	2.8276	1.1694	0.1694
0.5463	1267.6	1277.6	1286.2	1169.1	1228.9	1464.8	1300.7	0.7900	1.4673	-7.7667	-3.0483	15.5641	2.6115	1.1755	0.1755
0.6519	1290.3	1299.3	1306.7	1194.9	1254.6	1467.6	1318.7	0.6974	1.2728	-7.3916	-2.7638	13.7427	2.2026	1.1660	0.1660
0.7625	1314.1	1321.1	1326.7	1232.4	1285.3	1451.8	1335.4	0.5361	0.9616	-6.2180	-2.1938	10.4817	1.6205	1.1370	0.1370
0.8784	1339.0	1343.1	1346.2	1286.3	1321.7	1416.6	1350.8	0.3043	0.5364	-3.9373	-1.2935	5.7944	0.8816	1.0837	0.0837
1.0000	1365.2	1365.2	1365.2	1365.2	1365.2	1365.2	1365.2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
σ		0.4432	0.1006	-0.5507	-0.2112	0.9265	-1.7122								
χ^2		0.4432	1.5823	40.9543	6.4761	168.0739	0.3225								

308.15K															
0.0000	1141.0	1141.0	1141.0	1141.0	1141.0	1141.0	1141.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0819	1158.5	1161.7	1165.3	1132.8	1146.4	1222.7	1172.6	0.2760	0.5847	-2.2157	-1.0450	5.5413	1.2175	1.0458	0.0458
0.1671	1176.7	1182.5	1188.8	1128.5	1154.5	1295.0	1200.9	0.4953	1.0289	-4.0983	-1.8851	10.0547	2.0610	1.0873	0.0873
0.2560	1195.6	1203.5	1211.6	1128.3	1165.5	1356.3	1226.5	0.6563	1.3369	-5.6332	-2.5204	13.4370	2.5835	1.1230	0.1230
0.3486	1215.4	1224.6	1233.8	1132.9	1179.6	1405.5	1249.8	0.7572	1.5130	-6.7922	-2.9462	15.6365	2.8276	1.1511	0.1511
0.4453	1236.1	1245.9	1255.4	1143.0	1197.1	1442.1	1271.0	0.7962	1.5611	-7.5280	-3.1525	16.6679	2.8274	1.1694	0.1694
0.5463	1257.6	1267.3	1276.3	1160.0	1218.4	1461.2	1290.5	0.7717	1.4847	-7.7664	-3.1231	16.1902	2.6113	1.1755	0.1755
0.6519	1280.2	1288.9	1296.7	1185.6	1243.9	1462.1	1308.4	0.6816	1.2874	-7.3914	-2.8342	14.2136	2.2024	1.1660	0.1660
0.7625	1303.8	1310.6	1316.5	1222.7	1274.4	1445.1	1324.9	0.5242	0.9722	-6.2177	-2.2521	10.8415	1.6203	1.1370	0.1370
0.8784	1328.5	1332.5	1335.7	1276.2	1310.9	1408.7	1340.3	0.2977	0.5421	-3.9371	-1.3294	6.0318	0.8815	1.0836	0.0836
1.0000	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	1354.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	0.0522	0.1018	-0.5507	-0.2165	0.9589	-1.7120								
	χ^2	0.4192	1.6090	40.6305	6.7387	180.0848	0.3224								
313.15K															
0.0000	1137.5	1137.5	1137.5	1137.5	1137.5	1137.5	1137.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0819	1153.1	1156.0	1159.3	1128.7	1141.6	1220.2	1165.5	0.2498	0.5321	-2.1173	-2.1173	0.2498	1.0750	1.0437	0.0437
0.1671	1169.4	1174.6	1180.3	1123.6	1148.4	1292.9	1190.7	0.4488	0.9373	-3.9120	-3.9120	0.4488	1.8254	1.0831	0.0831
0.2560	1186.3	1193.4	1200.8	1122.6	1157.9	1352.5	1213.6	0.5954	1.2193	-5.3705	-5.3705	0.5954	2.2949	1.1167	0.1167
0.3486	1204.0	1212.3	1220.6	1126.2	1170.3	1401.1	1234.3	0.6878	1.3816	-6.4657	-6.4657	0.6878	2.5185	1.1430	0.1430
0.4453	1222.5	1231.3	1239.9	1135.0	1186.0	1435.2	1253.3	0.7242	1.4272	-7.1533	-7.1533	0.7242	2.5250	1.1600	0.1600
0.5463	1241.7	1250.5	1258.6	1150.3	1205.1	1450.4	1270.8	0.7028	1.3591	-7.3637	-7.3637	0.7028	2.3379	1.1653	0.1653
0.6519	1261.9	1269.7	1276.8	1173.7	1228.2	1448.8	1286.8	0.6216	1.1799	-6.9889	-6.9889	0.6216	1.9767	1.1559	0.1559
0.7625	1283.0	1289.1	1294.4	1207.8	1255.9	1428.0	1301.7	0.4787	0.8922	-5.8583	-5.8583	0.4787	1.4578	1.1283	0.1283
0.8784	1305.1	1308.7	1311.6	1256.9	1288.9	1389.6	1315.5	0.2722	0.4982	-3.6919	-3.6919	0.2722	0.7950	1.0781	0.0781
1.0000	1328.3	1328.3	1328.3	1328.3	1328.3	1328.3	1328.3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	0.0475	0.0932	-0.5205	-0.2045	0.9975	-1.5279								
	χ^2	0.3431	1.3301	36.0957	5.9633	194.1327	0.2568								
318K															
0.0000	1132.4	1132.4	1132.4	1132.4	1132.4	1132.4	1132.4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0819	1146.9	1149.6	1152.7	1123.3	1135.7	1216.8	1158.3	0.2321	0.5037	-2.0617	-0.9801	5.8508	0.9946	1.0425	0.0425
0.1671	1162.0	1166.9	1172.3	1117.8	1141.5	1289.2	1181.7	0.4175	0.8877	-3.8067	-1.7633	10.4857	1.6919	1.0807	0.0807
0.2560	1177.8	1184.3	1191.4	1116.3	1150.1	1350.1	1202.9	0.5543	1.1553	-5.2217	-2.3507	13.9964	2.1305	1.1132	0.1132
0.3486	1194.2	1201.9	1209.8	1119.2	1161.5	1396.8	1222.2	0.6410	1.3097	-6.2808	-2.7392	16.2165	2.3419	1.1385	0.1385
0.4453	1211.3	1219.5	1227.7	1127.3	1176.0	1429.4	1239.8	0.6755	1.3536	-6.9411	-2.9210	17.2077	2.3515	1.1547	0.1547
0.5463	1229.3	1237.3	1245.1	1141.5	1193.8	1444.5	1256.1	0.6562	1.2897	-7.1357	-2.8829	16.7433	2.1804	1.1596	0.1596
0.6519	1248.0	1255.2	1262.0	1163.6	1215.5	1440.5	1271.0	0.5809	1.1204	-6.7614	-2.6055	14.7600	1.8462	1.1503	0.1503
0.7625	1267.6	1273.3	1278.3	1195.9	1241.5	1418.8	1284.9	0.4479	0.8477	-5.6557	-2.0608	11.4290	1.3635	1.1235	0.1235
0.8784	1288.1	1291.4	1294.2	1242.4	1272.6	1375.7	1297.7	0.2549	0.4736	-3.5543	-1.2102	6.5294	0.7446	1.0751	0.0751
1.0000	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	1309.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	0.0485	-0.0107	-0.2491	-0.0569	0.0280	-1.4223								
	χ^2	0.3653	0.0178	9.1423	0.4964	0.1234	0.2225								

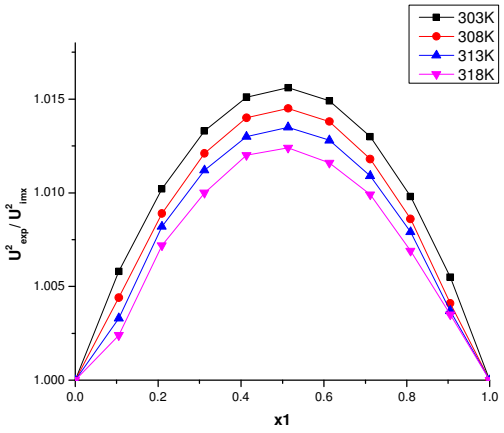

Fig 1:Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DMM for the system DMM + 2-Methyl-1-Propanol

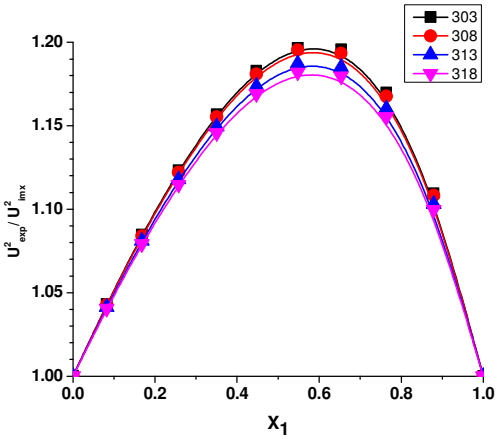

Fig 2:Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DEM for the system DMM + 2- Propanol

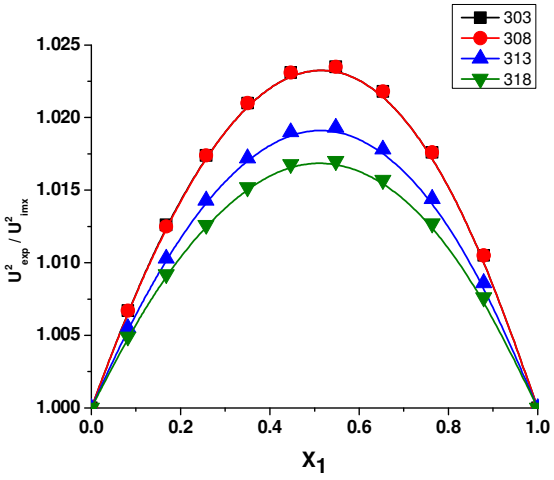

Fig 3:Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DMM for the system DMM + 2-Butanol

References

1. AklimaJahan,Md. AshrafulAlam, Md. RabiulAwual, ShamimAkhtar, *American Journal of Chemistry,* **2019**, 9(1), 1-12 **doi:10.5923/j.chemistry.20190901.01**
2. V. Vanathi, S. Mullainathan, S. Nithiyanatham,, V. Ramasamy, and L. Palaniappan, *J.Heliyon*, 5(8), **2019**, doi: 10.1016/j.heliyon.2019.e02203
3. O. Nomoto, *J. Phys. Soc. Jpn*. 4 **(1949)** 280.
4. W. Van Dael, E. Vangeel, *Pro. Int. Conf. on Cal. &Thermdyn.Warsa***(1955)** 555.
5. S. Baluja, P.H. Parsania, *Asian J. Chem*. **(1995)** 7,417.
6. Z. Junjie, *J. China Univ. Sci. Techn*. 14 (1984) 298.
7. V.D. Gokhale, N.N. Bhagavat, *J. Pure Appl. Ultrason.***(1989)** 11, 21
8.] S.G.M. Hussain, R. Kumar, V. Kannappan, *IJ of Innovative Research in Sc. Eng. & Tech.***(2016)** 5**,** 22.
9. Radha SirijaMaganti,Gayatri Devi Nanduri, Raghu Sai SarathDittakavi, Ramachandran Dittakavi, *Karbala International Journal of Modern Science,* **March 2018**, Volume 4, Issue 1,Pages 126-133. https://doi.org/10.1016/j.kijoms.2017.12.003
10. Ch. Udayalakshmi , K. A. K. Raj Kumar , V. N. S. R. Venkateswararao , P. B. Sandhyasri , G. R. Satyanarayana and C. Rambabu, *Der PharmaChemica*, **2016**, 8(5):209-218
11. A. Pal and Y. P. Singh, *Journal of Chemical & Engineering Data*, **1995** vol. 40, no. 4, pp. 818–822,.View at: Google Scholar
12. J. A. Reddick, W. B. Bungar, and T .Sakano, *Organic Solvents: Physical Properties and Methods of Purification, Wiley-Interscience,* New York, NY, USA, 4th edition, **1986**.
13. Weissberger, Proskaner ES, Riddick EE and Toops Jr. Organic Solvents.New York:Wiley Interscience;1955
14. R. Rao, *J. Chem. Phys*. **(1941)** 9 (682). https://doi.org/10.1063/1.1750976
15. K.Pearson; Fundamentals of Mathematical Statistics, S.G.Gupta, V.K.Kapoor, S.Chand, Company, (Eds.); New Delhi, India, 903 (1973).
16. Sk. FakruddinBabavali.P.Shakira,ChSrinivasu,K.Narendra, *Karbala International Journal of Modern Science*, **November 2015**, Volume 1, Issue 3, Pages 172-177https://doi.org/10.1016/j.kijoms.2015.11.003