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Theoretical Velocities and Viscosities of Binary Mixtures of Diethyl Malonate with Alkoxy Alkanols

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ABSTRACT

Experimental and theoretical ultrasonic velocity and viscosity of the binary mixtures of di ethyl malonate + methoxy ethanol, di ethyl malonate + ethoxy ethanol and di ethyl malonate + butoxy ethanol have been reported at 303.15, 308.15, 313.15 and 318.15K, The following theoretical methods such as Nomotos relation, Van Dael relation , Impedance relation , Junjies relation , Impedance relation , Rao relation are used to calculate the theoretical ultrasonic velocity . Theoretical values are compared with experimental values to find the merits of the relations and check the validity of theses theoretical models by using percentage error and average percentage deviations. The results are discussed in terms of inter molecular interactions occurring in the systems. The theoretical viscosity data are evaluated with some of the semi - empirical viscosity models such as Grunberg and Nissan, Katti Chaudhri, Heric and Brewer and Hind and the results are compared with the experimental results.

INTRODUCTION

Ultrasonic velocity gives the information about the molecular interactions of the pure liquid and liquid mixtures [1-3].Various theoretical models are employed by many authors [4-6] for the ultrasonic velocity of pure, binary, ternary mixtures. Many workers checked the validity of the theoretical ultrasonic velocity for liquid mixtures by different models like Nomoto [7], Van Dael and Vangel [8], impedance relation [9], Rao's specific velocity [10] and Junjie [11]. Theoretical evaluation of ultrasonic velocity in binary liquid mixtures and its comparison with the experimental values reflects the molecular interaction in liquid mixtures, which is very useful to build comprehensive theoretical models for liquids. The viscosity data are correlated with some of the semi - empirical viscosity models such as Grunberg and Nissan[12], Katti and Chaudhri [13], Heric and Brewer[14] and Hind[15], and the results are compared with the experimental results.

In the present investigation, experimentally determined ultrasonic sound velocities are compared with the theoretical relations like Nomoto, Van Dael and Vangael, Impedance Relation, Rao ís specific velocity and Junji's relation at various temperatures. Diethyl malonate is mixed with alkoxy alkanols such as methoxy ethanol (MOE), ethoxy ethanol (EOE) and butoxy ethanol (BOE) at different mole fractions to study the interactions between the component 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_{exp}/U^2_{imx}, average percentage deviation and chi square test for goodness of fit from unity have been calculated for further support.

MATERIALS AND METHODS

Di ethyl malonate and alkoxy alkanols from Merk were purified as described in the literature [16,17]. The pure chemicals were stored over activated molecular sieves to reduce water content before use.All the binary liquid mixtures are prepared by weighing an amount of pure liquids in an electric balance (Afoset, ER-120A, and India)

with a precision of ±0.1 mg by syringing each component into air-tight stopper bottles to minimize evaporation losses. 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 are reproducible within 2 x 10^{-1} 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

Temperature control for the measurement of viscosity and density is achieved by using a microprocessor assisted circulating water bath, (supplied by Mac, New Delhi) regulated to ±0.01 K, using a proportional temperature controller. Adequate precautions were taken to minimize evaporation losses during the actual measurements.

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 $m.sec^{-1}$. The temperature stability was maintained within ±0.01K.by circulating water bath around the measuring cell through a pump.

THEORETICAL CONIDERATIONS

Nomoto Equation

The ratio of temperature coefficients of sound velocity U and molar volume V remains almost constant for pure liquids [7].

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

where T is the absolute temperature.

Integration the above equation, we get

$$VU^{1/3} = \text{const} = M/\rho U^{1/3} = R \quad [2]$$

Where U and ρ are determined experimentally and M is the mean molecular weight in a binary liquid mixture

$$M=(X_1M_1+X_2M_2 \quad [3]$$

where M_1 and M_2 are molecular weights of constituent components.

Simple manipulation yields the following relation

$$U_{Nomoto} = [(X_1R_1+X_2R_2) / (X_1V_1+X_2V_2)]^3 \quad [4]$$

The Van Dael and Vangeel Equation

Van Dael [8] obtained the relation for ultrasonic velocity in liquid mixtures as

$$1/(X_1M_1+X_2M_2)*1/U^2_{imx} = X_1/M_1U_1^2 +X_2/M_2U_2^2 \quad [5]$$

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

The Impedance Relation

Impedance relation $U = \Sigma X_i Z_i / \Sigma X_i\rho_I$ [6]

where X_i mole fraction, ρ_t, is the density of the mixture and Z_i is the acoustic impedance.

The Rao's Specific Velocity Method Relation [13]

$$U = (\Sigma X_i r_i \rho)^3 \quad [7]$$

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.

The Junjie Equation [11]

$$U_J = (X_1M_1/\rho_1+X_2M_2/\rho_2)/[\{X_1M_1+X_2M_2\}^{1/2}\{X_1M_1/\rho_1U_1^2+X_2M_2/\rho_2U_2^2)\}^{1/2}] \quad [8]$$

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

Chi-Square Test for Goodness of Fit

According to Karl Pearson [18] Chi-square value is evaluated for the binary liquid mixtures under study using the formula

$$\chi^2 = \sum_{i=1}^{N} (U_{mix(obs)} - U_{mix(cal)})^2 / U_{mix(cal)}) \quad [9]$$

where n is the number of data used.

Average Percentage Error (APE)

The Average percentage error is calculated using the relation

$$APE = 1/n \sum (Umix(obs) - Umix(cal)) / Umix(obs)) \ X100\% \quad [10]$$

where n is the number of data used.

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

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

The dynamic viscosities of the liquid mixtures have been calculated using empirical relations given by Grunberg-Nissan, Katti-Chaudari, Heric-Brewer and Hind *et al* Mc. Allister four body model. Grunberg and Nissan [12] proposed the following equation for the measurement of viscosity of liquid mixtures:

$$\ln \eta = X_1 \ln \eta_1 + X_2 \ln \eta_2 + X_1 X_2 G_{12} \quad [11]$$

where G_{12} is an interaction parameter, which is a function of viscosity of component liquids 1and 2 and temperature. Katti and Chaudhri [13] equation for the dynamic viscosity of the liquid mixture is

$$\ln[\eta V] = X_1 \ln [\eta_1 V_1] + X_2 \ln [\eta_2 V_2] + X_1 X_2 W_{vis}/RT \quad [12]$$

where W_{vis} is an interaction term.

Heric and Brewer [14] derived the following equation to calculate the viscosity of the binary liquid mixtures:

$$\ln\eta = X_1 \ln\eta_1 + X_2 \ln\eta_2 + X_1 \ln M_1 + X_2 \ln M_2 - \ln(X_1 M_1 + X_2 M_2) + X_1X_2 \Delta_{12} \quad [13]$$

Δ_{12} is the interaction term and other symbols have their usual meaning.

The expression to determine the viscosity of the binary liquid mixtures proposed by Hind et.al [15] is given by

$$\eta = X_1^2 \eta_1 + X_2^2\eta_2 + 2X_1X_2 H_{12} \quad [14]$$

where H_{12} is an interaction term.

RESULTS AND DISCUSSION

Generally, polar aprotic solvents effectively solvate cations and anions, whereas aprotic solvents do not solvate anions to appreciable extent. Alkoxy ethanols are protic solvents and di ethyl malonate is aprotic solvent since it has the group –C=O. Since oxygen is far more electro negative than carbon, it has a strong tendency to pull electron in carbon – oxygen bond towards itself. One of the two pairs of electrons that make up a carbon – oxygen double bond is even more easily pulled towards the oxygen which makes the carbon – oxygen bond polar. This polarity with a dipole moment of (μ) further tries to pull hydrogen from alkoxy alkanol molecule which are self associated. This is the main phenomenon occurring in a new hydrogen bond between hetero molecules. As the carbon chain length

increases from MOE to BOE, the strength of hydrogen bond decreases owing to stearic hindrance of long carbon chain, and hence, weakening of association between dissimilar molecules is expected.

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

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K													
0.0000	1357.0	1357.0	1357.0	1357.0	1357.0	1357.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0547	1353.5	1351.5	1352.2	1350.1	1351.2	1395.4	-0.1486	-0.0988	-0.2494	-0.1677	3.0975	1.0050	0.0050
0.1153	1349.3	1345.6	1346.9	1342.9	1345.1	1420.2	-0.2764	-0.1798	-0.4735	-0.3127	5.2573	1.0095	0.0095
0.1825	1344.5	1339.2	1341.1	1335.4	1338.5	1436.8	-0.3941	-0.2556	-0.6805	-0.4454	6.8682	1.0137	0.0137
0.2578	1338.8	1332.3	1334.7	1327.4	1331.5	1446.3	-0.4837	-0.3098	-0.8481	-0.5470	8.0319	1.0172	0.0172
0.3426	1332.2	1324.9	1327.5	1319.2	1323.9	1446.2	-0.5496	-0.3496	-0.9753	-0.6210	8.5579	1.0198	0.0198
0.4387	1324.6	1316.8	1319.6	1310.7	1315.8	1435.7	-0.5896	-0.3766	-1.0517	-0.6642	8.3860	1.0214	0.0214
0.5487	1315.5	1308.0	1310.7	1301.9	1307.0	1414.9	-0.5723	-0.3641	-1.0338	-0.6436	7.5566	1.0210	0.0210
0.6758	1304.7	1298.3	1300.6	1293.0	1297.5	1382.8	-0.4890	-0.3105	-0.8949	-0.5486	5.9861	1.0181	0.0181
0.8242	1291.8	1287.7	1289.2	1284.3	1287.2	1337.0	-0.3164	-0.2025	-0.5836	-0.3534	3.4975	1.0118	0.0118
1.0000	1276.0	1276.0	1276.0	1276.0	1276.0	1276.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	-0.0384	-0.0245	-0.0685	-0.0433	0.5353							
	χ^2	0.2390	0.0977	0.7595	0.3034	52.8462							
308.15K													
0.0000	1346.0	1346.0	1346.0	1346.0	1346.0	1346.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0547	1342.3	1340.6	1341.3	1339.3	1340.4	1385.5	-0.1253	-0.0735	-0.2268	-0.1431	3.2195	1.0046	0.0046
0.1153	1338.1	1334.8	1336.2	1332.2	1334.4	1410.8	-0.2433	-0.1431	-0.4421	-0.2774	5.4308	1.0089	0.0089
0.1825	1333.4	1328.6	1330.5	1324.8	1328.0	1426.8	-0.3576	-0.2138	-0.6465	-0.4058	7.0072	1.0131	0.0131
0.2578	1328.0	1321.9	1324.3	1317.0	1321.1	1436.1	-0.4571	-0.2766	-0.8249	-0.5165	8.1400	1.0167	0.0167
0.3426	1321.6	1314.7	1317.4	1309.0	1313.8	1436.6	-0.5238	-0.3163	-0.9536	-0.5908	8.7012	1.0193	0.0193
0.4387	1314.2	1306.8	1309.7	1300.7	1305.9	1425.6	-0.5627	-0.3416	-1.0295	-0.6326	8.4758	1.0209	0.0209
0.5487	1305.3	1298.2	1301.1	1292.1	1297.4	1405.2	-0.5416	-0.3255	-1.0082	-0.6084	7.6557	1.0205	0.0205
0.6758	1294.8	1288.9	1291.3	1283.5	1288.1	1374.2	-0.4593	-0.2741	-0.8700	-0.5151	6.1287	1.0176	0.0176
0.8242	1282.3	1278.6	1280.1	1275.1	1278.1	1328.3	-0.2919	-0.1737	-0.5625	-0.3265	3.5882	1.0113	0.0113
1.0000	1267.2	1267.2	1267.2	1267.2	1267.2	1267.2	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	-0.0358	-0.0214	-0.0662	-0.0404	0.5451							
	χ^2	0.2092	0.0757	0.7099	0.2655	54.2961							
313.15K													
0.0000	1336.0	1336.0	1336.0	1336.0	1336.0	1336.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0547	1332.1	1330.5	1331.2	1329.2	1330.3	1379.0	-0.1172	-0.0647	-0.2163	-0.1357	3.5170	1.0043	0.0043
0.1153	1327.7	1324.7	1326.0	1322.1	1324.2	1403.3	-0.2276	-0.1259	-0.4216	-0.2629	5.6939	1.0085	0.0085
0.1825	1322.8	1318.4	1320.3	1314.6	1317.7	1420.1	-0.3347	-0.1887	-0.6165	-0.3846	7.3581	1.0124	0.0124
0.2578	1317.2	1311.6	1314.0	1306.8	1310.8	1429.1	-0.4275	-0.2442	-0.7862	-0.4890	8.4935	1.0159	0.0159
0.3426	1310.8	1304.2	1307.0	1298.7	1303.3	1428.8	-0.5029	-0.2922	-0.9221	-0.5723	9.0045	1.0187	0.0187
0.4387	1303.3	1296.2	1299.1	1290.3	1295.3	1419.0	-0.5436	-0.3190	-0.9987	-0.6159	8.8749	1.0203	0.0203
0.5487	1294.3	1287.5	1290.3	1281.6	1286.6	1397.5	-0.5246	-0.3052	-0.9795	-0.5938	7.9701	1.0199	0.0199
0.6758	1283.6	1278.0	1280.4	1272.9	1277.2	1365.4	-0.4371	-0.2490	-0.8374	-0.4949	6.3738	1.0170	0.0170
0.8242	1270.9	1267.5	1269.1	1264.2	1267.1	1319.5	-0.2649	-0.1449	-0.5285	-0.3007	3.8270	1.0107	0.0107
1.0000	1256.0	1256.0	1256.0	1256.0	1256.0	1256.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	-0.0339	-0.0194	-0.0636	-0.0387	0.5694							
	χ^2	0.1883	0.0624	0.6527	0.2436	58.8075							
0.0000	1313.0	1313.0	1313.0	1313.0	1313.0	1313.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0547	1309.6	1308.3	1308.9	1306.8	1308.1	1360.6	-0.0990	-0.0542	-0.2138	-0.1154	3.8964	1.0043	0.0043
0.1153	1305.7	1303.3	1304.4	1300.3	1302.9	1384.4	-0.1867	-0.1000	-0.4117	-0.2180	6.0307	1.0083	0.0083
0.1825	1301.6	1297.8	1299.5	1293.6	1297.3	1402.5	-0.2892	-0.1649	-0.6162	-0.3335	7.7514	1.0124	0.0124
0.2578	1296.7	1292.0	1294.0	1286.6	1291.3	1411.8	-0.3642	-0.2082	-0.7807	-0.4188	8.8770	1.0158	0.0158
0.3426	1291.2	1285.6	1287.9	1279.3	1284.8	1412.5	-0.4311	-0.2517	-0.9180	-0.4926	9.3959	1.0186	0.0186
0.4387	1284.7	1278.7	1281.2	1271.9	1277.9	1403.1	-0.4636	-0.2727	-0.9927	-0.5279	9.2175	1.0202	0.0202
0.5487	1277.0	1271.2	1273.6	1264.5	1270.4	1383.9	-0.4517	-0.2651	-0.9807	-0.5130	8.3721	1.0199	0.0199
0.6758	1267.8	1263.0	1265.0	1257.1	1262.4	1352.0	-0.3777	-0.2179	-0.8436	-0.4289	6.6450	1.0171	0.0171
0.8242	1256.7	1254.0	1255.3	1250.1	1253.6	1307.2	-0.2167	-0.1149	-0.5239	-0.2485	4.0200	1.0106	0.0106
1.0000	1244.0	1244.0	1244.0	1244.0	1244.0	1244.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	-0.0289	-0.0165	-0.0633	-0.0331	0.5963							
	χ^2	0.1356	0.0452	0.6395	0.1770	63.6694							

The experimental values along with the values calculated theoretically using the relations of Nomoto, Van Dael ideal mixing, impedance, Rao's specific velocity and Junjie for studied systems at the temperatures of 303.15, 308.15, 313.15 and 318.15K are given in Tables 1 - 3 for the mixtures. The validity of different theoretical formulae is checked by percentage deviation for all the mixtures at all the temperatures and is given in the same tables along with chi square test values and interaction parameter α.

It can be seen from Tables 1-3, that the theoretical values of ultrasonic velocity computed by various theories show deviations from experimental values. The limitations and approximations incorporated in these theories are responsible for it. It is assumed that all the molecules are spherical in shape, which is not true every time. In Nomoto's theory, it is supposed that the volume does not change on mixing. Therefore, no interaction between the components of liquid mixtures has been taken into account. The assumption for the formation of ideal mixing relation is that the ratio of specific heats of ideal mixtures and the volumes are also equal. Again, no molecular interaction is taken into account. Similarly, as per the assumption for the Collision Factor theory, the molecules are treated as real non- elastic substances which is not really the case. But on mixing two liquids, the interaction between the molecules of the two liquids takes place because of presence of various types of forces such as dispersion forces, charge transfer, hydrogen bonding, dipole - dipole and dipole – induced dipole interactions. Thus

the observed deviation of theoretical values of velocity from the experimental values shows that strong molecular interactions exist between the unlike molecules in the liquid mixture [19, 20].

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

303.15K													
X_1	**U_{EXP}**	**U_{NOM}**	**U_{IMP}**	**U_{VDV}**	**U_{JUN}**	**U_{RAO}**	**$\%U_N$**	**$\%U_{imp}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2/U^2_{imx}**	**α**
0.0000	1306.1	1306.1	1306.1	1306.1	1306.1	1306.1	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0701	1304.5	1302.9	1303.7	1290.6	1302.2	1331.8	-0.1225	-0.0592	-1.0642	-0.1776	2.0911	1.0216	0.0216
0.1450	1303.1	1299.7	1301.2	1276.8	1298.5	1349.2	-0.2572	-0.1427	-2.0204	-0.3533	3.5378	1.0417	0.0417
0.2252	1301.7	1296.6	1298.6	1264.8	1295.0	1360.8	-0.3889	-0.2358	-2.8370	-0.5128	4.5414	1.0592	0.0592
0.3113	1300.1	1293.6	1295.9	1254.9	1291.8	1368.6	-0.5023	-0.3239	-3.4771	-0.6414	5.2652	1.0733	0.0733
0.4041	1297.8	1290.5	1293.0	1247.5	1288.7	1370.5	-0.5592	-0.3695	-3.8745	-0.7016	5.5989	1.0822	0.0822
0.5043	1295.1	1287.6	1290.0	1243.2	1285.8	1366.1	-0.5825	-0.3963	-4.0110	-0.7170	5.4859	1.0853	0.0853
0.6128	1291.4	1284.6	1286.8	1242.5	1283.1	1355.8	-0.5258	-0.3591	-3.7851	-0.6417	4.9882	1.0802	0.0802
0.7307	1286.9	1281.7	1283.4	1246.6	1280.6	1337.0	-0.4039	-0.2738	-3.1286	-0.4910	3.8955	1.0656	0.0656
0.8592	1282.0	1278.8	1279.8	1257.0	1278.2	1310.7	-0.2471	-0.1720	-1.9483	-0.2954	2.2363	1.0401	0.0401
1.0000	1276.0	1276.0	1276.0	1276.0	1276.0	1276.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0361**	**-0.0234**	**-0.2702**	**-0.0456**	**0.3600**							
	χ2	**0.2121**	**0.0921**	**10.9275**	**0.3339**	**22.2634**							
308.15K													
0.0000	1290.4	1290.4	1290.4	1290.4	1290.4	1290.4	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0701	1289.1	1287.9	1288.6	1275.4	1287.2	1318.0	-0.0906	-0.0406	-1.0641	-0.1463	2.2447	1.0216	0.0216
0.1450	1288.0	1285.5	1286.7	1262.0	1284.2	1336.0	-0.1942	-0.1037	-2.0175	-0.2914	3.7253	1.0416	0.0416
0.2252	1286.8	1283.1	1284.7	1250.5	1281.5	1348.8	-0.2875	-0.1665	-2.8202	-0.4130	4.8218	1.0589	0.0589
0.3113	1285.6	1280.7	1282.5	1241.2	1278.9	1356.8	-0.3785	-0.2375	-3.4572	-0.5194	5.5369	1.0729	0.0729
0.4041	1283.9	1278.4	1280.3	1234.3	1276.5	1359.5	-0.4283	-0.2785	-3.8604	-0.5726	5.8846	1.0819	0.0819
0.5043	1281.7	1276.1	1278.0	1230.6	1274.4	1356.0	-0.4370	-0.2900	-3.9880	-0.5733	5.7950	1.0848	0.0848
0.6128	1279.1	1273.8	1275.5	1230.6	1272.3	1345.7	-0.4121	-0.2805	-3.7883	-0.5296	5.2103	1.0803	0.0803
0.7307	1275.7	1271.6	1272.9	1235.6	1270.5	1328.4	-0.3222	-0.2195	-3.1456	-0.4104	4.1334	1.0660	0.0660
0.8592	1271.8	1269.4	1270.1	1246.9	1268.8	1302.3	-0.1903	-0.1310	-1.9544	-0.2392	2.4015	1.0403	0.0403
1.0000	1267.2	1267.2	1267.2	1267.2	1267.2	1267.2	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0275**	**-0.0175**	**-0.2697**	**-0.0371**	**0.3794**							
	χ2	**0.1226**	**0.0515**	**10.7658**	**0.2192**	**24.5057**							
313.15K													
0.0000	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0701	1276.4	1275.3	1275.9	1262.8	1274.6	1308.2	-0.0857	-0.0392	-1.0663	-0.1437	2.4915	1.0217	0.0217
0.1450	1275.2	1273.0	1274.1	1249.6	1271.8	1326.4	-0.1691	-0.0849	-2.0061	-0.2704	4.0152	1.0414	0.0414
0.2252	1274.0	1270.8	1272.2	1238.3	1269.1	1338.7	-0.2502	-0.1376	-2.8021	-0.3809	5.0788	1.0585	0.0585
0.3113	1272.7	1268.6	1270.3	1229.1	1266.7	1347.1	-0.3213	-0.1901	-3.4240	-0.4682	5.8484	1.0722	0.0722
0.4041	1271.1	1266.4	1268.2	1222.5	1264.5	1350.1	-0.3668	-0.2272	-3.8258	-0.5173	6.2188	1.0811	0.0811
0.5043	1269.2	1264.3	1266.0	1218.9	1262.5	1346.4	-0.3865	-0.2496	-3.9652	-0.5288	6.0830	1.0843	0.0843
0.6128	1266.5	1262.2	1263.7	1219.1	1260.6	1335.9	-0.3411	-0.2186	-3.7446	-0.4638	5.4805	1.0793	0.0793
0.7307	1263.4	1260.1	1261.3	1224.1	1258.9	1318.4	-0.2618	-0.1662	-3.1080	-0.3539	4.3520	1.0652	0.0652
0.8592	1259.9	1258.0	1258.7	1235.6	1257.4	1292.2	-0.1482	-0.0930	-1.9266	-0.1993	2.5616	1.0397	0.0397
1.0000	1256.0	1256.0	1256.0	1256.0	1256.0	1256.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0234**	**-0.0141**	**-0.2672**	**-0.0334**	**0.4010**							
	χ2	**0.0879**	**0.0332**	**10.4707**	**0.1759**	**27.1235**							
318.15K													
0.0000	1258.4	1258.4	1258.4	1258.4	1258.4	1258.4	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0701	1257.6	1256.9	1257.3	1244.1	1256.1	1292.8	-0.0576	-0.0266	-1.0734	-0.1219	2.8018	1.0218	0.0218
0.1450	1256.8	1255.4	1256.1	1231.4	1254.0	1310.1	-0.1137	-0.0577	-2.0171	-0.2263	4.2405	1.0416	0.0416
0.2252	1256.0	1253.9	1254.8	1220.7	1252.1	1324.0	-0.1684	-0.0934	-2.8132	-0.3138	5.4151	1.0587	0.0587
0.3113	1255.3	1252.4	1253.5	1212.0	1250.4	1332.4	-0.2295	-0.1422	-3.4459	-0.3933	6.1442	1.0727	0.0727
0.4041	1254.4	1251.0	1252.1	1206.0	1248.9	1336.1	-0.2733	-0.1805	-3.8599	-0.4414	6.5158	1.0819	0.0819
0.5043	1253.2	1249.5	1250.7	1203.0	1247.5	1333.1	-0.2919	-0.2009	-4.0037	-0.4510	6.3732	1.0852	0.0852
0.6128	1251.2	1248.1	1249.1	1203.9	1246.4	1324.0	-0.2453	-0.1639	-3.7772	-0.3827	5.8204	1.0801	0.0801
0.7307	1249.0	1246.7	1247.5	1209.8	1245.4	1306.9	-0.1812	-0.1177	-3.1364	-0.2845	4.6354	1.0658	0.0658
0.8592	1246.6	1245.4	1245.8	1222.3	1244.6	1281.1	-0.0995	-0.0629	-1.9472	-0.1569	2.7679	1.0401	0.0401
1.0000	1244.0	1244.0	1244.0	1244.0	1244.0	1244.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0166**	**-0.0105**	**-0.2694**	**-0.0278**	**0.4245**							
	χ2	**0.0451**	**0.0189**	**10.5050**	**0.1215**	**29.9624**							

The percentage of deviation i.e %U shows either positive or negative at intermediate concentration for the three binary mixtures. Tables 1 and 2 show that in the DEM + MOE and DEM +EOE systems, there is good agreement between experimental and theoretical values calculated by impedance relation. Here impedance relation provides the best result than the result of Nomoto at all the temperatures. However, higher deviations are observed in ideal mixing relation. From Table 3, it is observed that in the system of DEM + BOE, Nomoto's relation holds well followed by impedance relation. Higher deviations are observed in Rao's theory.

The ratio U^2/U^2_{imx} is an important tool for to measure non ideality in the mixtures, especially in the cases where the properties other than sound velocity are not known. Figs 1,2 and 3 represent the variation of U^2/U^2_{imx} with the mole fraction of DEM. It can be seen from Figs 1,2 and 3 U^2/U^2_{imx} is maximum at 0.43 and 0.50 mole fractions for DEM + MOE and DEM + EOE respectively. For DEM + NOE system it is maximum at 0.48 mole fraction.

The deviation of U^2/U^2_{imx} from unity and its variation as a function of mole fraction is a direct measure of non ideality of the system as a consequence of association or other type interactions. The positive values of α in all the systems clearly indicate that there exist a strong interaction between the consecutive molecule though hydrogen

bonding. Further the decrease in the value of α from DEM + MOE to DEM + BOE indicates that strength of interaction decreases from MOE to BOE.

Table 3: Experimental theoretical values of velocities with their percentage of deviations for the system DEM + BOE at 303.15,308.15,313.15 and 318.15K

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	$\%U_N$	$\%U_{imp}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2/U^2_{imx}	α
303.15K													
0.0000	1325.0	1325.0	1325.0	1325.0	1325.0	1325.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0923	1321.4	1319.8	1319.8	1316.3	1318.7	1336.8	-0.1227	-0.1221	-0.3885	-0.2013	1.1690	1.0078	0.0078
0.1863	1317.6	1314.6	1314.6	1308.4	1312.8	1344.6	-0.2253	-0.2242	-0.7008	-0.3620	2.0465	1.0142	0.0142
0.2818	1313.8	1309.6	1309.6	1301.3	1307.3	1348.4	-0.3228	-0.3214	-0.9515	-0.4985	2.6304	1.0193	0.0193
0.3790	1309.6	1304.6	1304.6	1295.1	1302.0	1348.5	-0.3849	-0.3833	-1.1099	-0.5818	2.9710	1.0226	0.0226
0.4780	1305.0	1299.6	1299.7	1289.7	1297.0	1345.7	-0.4114	-0.4098	-1.1745	-0.6128	3.1156	1.0239	0.0239
0.5787	1299.8	1294.8	1294.8	1285.1	1292.3	1339.3	-0.3869	-0.3853	-1.1283	-0.5767	3.0371	1.0230	0.0230
0.6812	1294.2	1290.0	1290.0	1281.5	1287.9	1328.7	-0.3261	-0.3247	-0.9837	-0.4893	2.6634	1.0200	0.0200
0.7855	1288.4	1285.3	1285.3	1278.7	1283.7	1314.8	-0.2441	-0.2431	-0.7527	-0.3664	2.0460	1.0152	0.0152
0.8918	1282.4	1280.6	1280.6	1276.9	1279.7	1297.6	-0.1407	-0.1401	-0.4315	-0.2084	1.1838	1.0087	0.0087
1.0000	1276.0	1276.0	1276.0	1276.0	1276.0	1276.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0257**	**-0.0256**	**-0.0769**	**-0.0392**	**0.2035**							
	χ2	**0.1073**	**0.1064**	**0.9325**	**0.2457**	**6.9002**							
308.15K													
0.0000	1274.5	1274.5	1274.5	1274.5	1274.5	1274.5	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0923	1274.2	1273.7	1273.7	1269.0	1272.3	1293.3	-0.0370	-0.0374	-0.4048	-0.1455	1.5008	1.0081	0.0081
0.1863	1274.0	1273.0	1273.0	1264.5	1270.5	1306.7	-0.0810	-0.0818	-0.7424	-0.2711	2.5701	1.0150	0.0150
0.2818	1273.7	1272.2	1272.2	1261.0	1269.1	1314.6	-0.1165	-0.1175	-0.9956	-0.3624	3.2134	1.0202	0.0202
0.3790	1273.4	1271.5	1271.5	1258.5	1267.9	1320.1	-0.1513	-0.1524	-1.1702	-0.4285	3.6681	1.0238	0.0238
0.4780	1272.9	1270.7	1270.7	1257.0	1267.1	1321.1	-0.1698	-0.1709	-1.2477	-0.4546	3.7850	1.0254	0.0254
0.5787	1272.0	1270.0	1270.0	1256.6	1266.6	1319.0	-0.1561	-0.1572	-1.2090	-0.4262	3.6979	1.0246	0.0246
0.6812	1270.9	1269.3	1269.3	1257.4	1266.3	1312.6	-0.1261	-0.1270	-1.0650	-0.3596	3.2834	1.0216	0.0216
0.7855	1269.7	1268.6	1268.6	1259.3	1266.4	1302.2	-0.0874	-0.0881	-0.8178	-0.2633	2.5570	1.0166	0.0166
0.8918	1268.5	1267.9	1267.9	1262.6	1266.6	1287.1	-0.0480	-0.0484	-0.4682	-0.1459	1.4682	1.0094	0.0094
1.0000	1267.2	1267.2	1267.2	1267.2	1267.2	1267.2	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0097**	**-0.0098**	**-0.0820**	**-0.0287**	**0.2497**							
	χ2	**0.0157**	**0.0159**	**1.0327**	**0.1295**	**10.1938**							
313.15K													
0.0000	1264.0	1264.0	1264.0	1264.0	1264.0	1264.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0923	1263.5	1263.2	1263.1	1258.5	1261.8	1285.3	-0.0273	-0.0278	-0.3931	-0.1360	1.7280	1.0079	0.0079
0.1863	1263.0	1262.3	1262.3	1254.0	1259.9	1297.6	-0.0537	-0.0547	-0.7115	-0.2443	2.7381	1.0144	0.0144
0.2818	1262.7	1261.5	1261.5	1250.5	1258.4	1305.7	-0.0952	-0.0965	-0.9695	-0.3417	3.4030	1.0197	0.0197
0.3790	1262.3	1260.7	1260.7	1247.9	1257.2	1310.8	-0.1281	-0.1295	-1.1412	-0.4059	3.8392	1.0232	0.0232
0.4780	1261.7	1259.9	1259.9	1246.4	1256.3	1312.0	-0.1443	-0.1458	-1.2162	-0.4299	3.9906	1.0248	0.0248
0.5787	1260.7	1259.1	1259.1	1245.9	1255.7	1309.9	-0.1281	-0.1295	-1.1750	-0.3989	3.9027	1.0239	0.0239
0.6812	1259.5	1258.3	1258.3	1246.5	1255.4	1303.4	-0.0953	-0.0965	-1.0288	-0.3294	3.4832	1.0209	0.0209
0.7855	1258.3	1257.5	1257.5	1248.4	1255.3	1292.5	-0.0617	-0.0626	-0.7877	-0.2380	2.7192	1.0159	0.0159
0.8918	1257.2	1256.8	1256.8	1251.5	1255.5	1277.0	-0.0352	-0.0357	-0.4527	-0.1333	1.5721	1.0091	0.0091
1.0000	1256.0	1256.0	1256.0	1256.0	1256.0	1256.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0077**	**-0.0078**	**-0.0795**	**-0.0267**	**0.2651**							
	χ2	**0.0101**	**0.0104**	**0.9644**	**0.1118**	**11.3457**							
318.15K													
0.0000	1252.0	1252.0	1252.0	1252.0	1252.0	1252.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.0923	1251.4	1251.2	1251.1	1246.6	1249.8	1276.0	-0.0194	-0.0202	-0.3852	-0.1307	1.9664	1.0077	0.0077
0.1863	1250.8	1250.3	1250.3	1242.1	1247.9	1287.4	-0.0381	-0.0394	-0.6958	-0.2330	2.9230	1.0141	0.0141
0.2818	1250.4	1249.5	1249.5	1238.6	1246.3	1295.6	-0.0719	-0.0737	-0.9461	-0.3242	3.6163	1.0192	0.0192
0.3790	1250.0	1248.7	1248.7	1236.0	1245.1	1300.5	-0.1050	-0.1070	-1.1181	-0.3895	4.0440	1.0227	0.0227
0.4780	1249.5	1247.9	1247.9	1234.5	1244.2	1302.1	-0.1294	-0.1315	-1.2011	-0.4220	4.2095	1.0245	0.0245
0.5787	1248.5	1247.1	1247.1	1234.0	1243.6	1299.8	-0.1131	-0.1150	-1.1598	-0.3905	4.1058	1.0236	0.0236
0.6812	1247.4	1246.3	1246.3	1234.7	1243.3	1293.5	-0.0879	-0.0896	-1.0212	-0.3279	3.6932	1.0207	0.0207
0.7855	1246.2	1245.5	1245.5	1236.5	1243.3	1283.0	-0.0540	-0.0553	-0.7799	-0.2349	2.9494	1.0158	0.0158
0.8918	1245.1	1244.8	1244.8	1239.6	1243.5	1266.9	-0.0274	-0.0281	-0.4448	-0.1280	1.7473	1.0090	0.0090
1.0000	1244.0	1244.0	1244.0	1244.0	1244.0	1244.0	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
	σ	**-0.0065**	**-0.0066**	**-0.0783**	**-0.0259**	**0.2827**							
	χ2	**0.0074**	**0.0077**	**0.9260**	**0.1047**	**12.7163**							

Several workers have carried out extensive work on the viscosity and transport phenomena of binary and ternary mixtures. They have utilised the experimental data of viscosity data to test the applicability of empirical relations of Gruenberg and Nissan, Katti -Chaudhri, Heric and Brewer and Hind et.al for the systems studies. The computed viscosity values are presented in the Table 3. Figures 4, 5 and 6 show the average relative percentage errors in estimating the viscosity. From them, it can be seen that the viscosities calculated using Hind et.al are best suited for the tree systems followed by Gruenberg and Nissan. The interaction parameter is also calculated and presented in the Table 4 from which it can be observed that the interaction parameter is positive and the IP value is decreased from MOE to BOE. This indicates that there exists strong interactions [21] between the hetero molecules and the strength of interaction is decreasing from MOE to BOE which supports the results drawn from α calculations.

Table 4: Experimental and calculated values of viscosity(η) for the binary mixtures of di ethyl malonate and studied alkoxy alkanols(+MOE, +EOE, +BOE) at the temperatures 303.15, 308.15, 313.15 and 318.15K

X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
					DEM + MOE					
			303.15K					**308.15K**		
0.0000	1.547	1.547	1.547	1.547	1.547	1.489	1.489	1.489	1.489	1.489
0.0740	1.657	1.637	1.634	1.630	1.643	1.583	1.565	1.563	1.559	1.569
0.1525	1.725	1.723	1.718	1.714	1.730	1.640	1.638	1.633	1.629	1.642
0.2357	1.789	1.803	1.797	1.795	1.807	1.689	1.703	1.698	1.695	1.705
0.3242	1.852	1.872	1.868	1.867	1.870	1.738	1.758	1.755	1.754	1.756
0.4185	1.912	1.924	1.924	1.926	1.916	1.789	1.799	1.798	1.800	1.792
0.5191	1.954	1.955	1.958	1.963	1.942	1.808	1.819	1.822	1.827	1.810
0.6267	1.942	1.957	1.964	1.971	1.943	1.801	1.815	1.821	1.828	1.806
0.7422	1.912	1.924	1.933	1.940	1.914	1.779	1.781	1.788	1.795	1.774
0.8662	1.845	1.851	1.857	1.862	1.846	1.708	1.711	1.717	1.721	1.709
1.0000	1.732	1.732	1.732	1.732	1.732	1.602	1.602	1.602	1.602	1.602
			313.15K					**318.15K**		
0.0000	1.214	1.214	1.214	1.214	1.214	1.123	1.123	1.123	1.123	1.123
0.0740	1.297	1.284	1.283	1.279	1.289	1.205	1.191	1.191	1.186	1.196
0.1525	1.354	1.352	1.348	1.345	1.359	1.265	1.258	1.255	1.252	1.265
0.2357	1.409	1.416	1.412	1.410	1.421	1.324	1.323	1.319	1.317	1.328
0.3242	1.460	1.475	1.471	1.471	1.475	1.365	1.383	1.379	1.380	1.384
0.4185	1.513	1.523	1.522	1.524	1.518	1.423	1.435	1.433	1.436	1.430
0.5191	1.545	1.557	1.559	1.564	1.548	1.460	1.476	1.476	1.482	1.465
0.6267	1.558	1.573	1.577	1.584	1.561	1.481	1.500	1.503	1.510	1.486
0.7422	1.560	1.565	1.571	1.578	1.554	1.492	1.503	1.508	1.515	1.489
0.8662	1.529	1.528	1.533	1.538	1.522	1.475	1.479	1.484	1.489	1.471
1.0000	1.458	1.458	1.458	1.458	1.458	1.425	1.425	1.425	1.425	1.425
					DEM + MOE					
			303.15K					**308.15K**		
0.0000	1.613	1.613	1.613	1.613	1.613	1.481	1.481	1.481	1.481	1.481
0.0664	1.668	1.662	1.662	1.659	1.664	1.529	1.525	1.526	1.523	1.527
0.1379	1.718	1.709	1.709	1.706	1.712	1.571	1.568	1.568	1.565	1.571
0.2152	1.762	1.754	1.753	1.750	1.755	1.617	1.609	1.608	1.606	1.611
0.2990	1.794	1.794	1.792	1.792	1.793	1.647	1.646	1.644	1.644	1.646
0.3901	1.817	1.826	1.825	1.827	1.824	1.671	1.676	1.674	1.676	1.674
0.4897	1.835	1.848	1.848	1.852	1.844	1.689	1.697	1.696	1.700	1.693
0.5988	1.842	1.856	1.856	1.862	1.850	1.697	1.705	1.705	1.711	1.701
0.7190	1.835	1.843	1.844	1.850	1.838	1.692	1.696	1.697	1.703	1.692
0.8520	1.795	1.804	1.805	1.810	1.802	1.657	1.663	1.664	1.669	1.661
1.0000	1.732	1.732	1.732	1.732	1.732	1.602	1.602	1.602	1.602	1.602
			313.15K					**318.15K**		
0.0000	1.344	1.344	1.344	1.344	1.344	1.254	1.254	1.254	1.254	1.254
0.0664	1.386	1.384	1.385	1.381	1.385	1.298	1.295	1.297	1.293	1.297
0.1379	1.423	1.422	1.422	1.419	1.424	1.336	1.335	1.336	1.332	1.338
0.2152	1.466	1.459	1.457	1.456	1.460	1.381	1.375	1.373	1.372	1.377
0.2990	1.494	1.492	1.490	1.490	1.492	1.413	1.411	1.409	1.409	1.412
0.3901	1.514	1.519	1.517	1.519	1.517	1.438	1.443	1.441	1.443	1.442
0.4897	1.533	1.538	1.537	1.541	1.535	1.462	1.468	1.466	1.471	1.465
0.5988	1.541	1.546	1.545	1.551	1.542	1.478	1.483	1.482	1.488	1.479
0.7190	1.537	1.539	1.539	1.545	1.535	1.482	1.485	1.484	1.491	1.480
0.8520	1.506	1.511	1.512	1.516	1.509	1.462	1.467	1.467	1.472	1.464
1.0000	1.458	1.458	1.458	1.458	1.458	1.425	1.425	1.425	1.425	1.425
					DEM + MOE					
			303.15K					**308.15K**		
0.0000	2.408	2.408	2.408	2.408	2.408	2.282	2.282	2.282	2.282	2.282
0.0876	2.388	2.400	2.401	2.399	2.394	2.254	2.268	2.269	2.267	2.262
0.1776	2.373	2.380	2.381	2.379	2.370	2.234	2.243	2.244	2.242	2.233
0.2701	2.342	2.347	2.347	2.346	2.337	2.201	2.205	2.205	2.204	2.196
0.3654	2.296	2.300	2.299	2.299	2.292	2.156	2.156	2.155	2.155	2.148
0.4634	2.238	2.239	2.238	2.239	2.235	2.098	2.093	2.092	2.093	2.090
0.5644	2.167	2.163	2.163	2.164	2.165	2.027	2.018	2.017	2.018	2.020
0.6683	2.084	2.074	2.074	2.075	2.081	1.944	1.930	1.930	1.931	1.937
0.7755	1.986	1.972	1.972	1.973	1.982	1.844	1.831	1.831	1.832	1.841
0.8860	1.862	1.858	1.858	1.858	1.866	1.721	1.721	1.721	1.722	1.729
1.0000	1.732	1.732	1.732	1.732	1.732	1.602	1.602	1.602	1.602	1.602
			313.15K					**318.15K**		
0.0000	2.126	2.126	2.126	2.126	2.126	1.935	1.935	1.935	1.935	1.935
0.0876	2.092	2.107	2.109	2.106	2.101	1.909	1.923	1.926	1.922	1.919
0.1776	2.066	2.078	2.079	2.077	2.068	1.889	1.902	1.903	1.901	1.896
0.2701	2.034	2.037	2.037	2.036	2.028	1.871	1.874	1.873	1.873	1.867
0.3654	1.989	1.986	1.985	1.986	1.979	1.842	1.836	1.835	1.835	1.831
0.4634	1.932	1.924	1.923	1.924	1.920	1.801	1.790	1.788	1.789	1.787
0.5644	1.862	1.850	1.849	1.851	1.852	1.748	1.734	1.733	1.734	1.734
0.6683	1.780	1.766	1.766	1.767	1.772	1.683	1.669	1.668	1.670	1.673
0.7755	1.683	1.672	1.672	1.673	1.681	1.605	1.596	1.596	1.596	1.601
0.8860	1.568	1.569	1.569	1.570	1.576	1.510	1.514	1.514	1.515	1.519
1.0000	1.458	1.458	1.458	1.458	1.458	1.425	1.425	1.425	1.425	1.425

Table 5: Interaction Parameters calculated from Eqns. And the corresponding standard deviations(σ) for the binary mixtures di ethyl malonate and studied alkoxy alkanols(+MOE, +EOE, +BOE) at the temperatures 303.15, 308.15, 313.15 and 318.15K

	SD				IP			
	DEM +MOE							
	303.15K	**308.15K**	**313.15K**	**318.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**
$GN(G_{12})$	0.0125	0.0117	0.0098	0.0120	0.0662	0.0617	0.0572	0.0692
$KC(W_{vis}/RT)$	0.0144	0.0127	0.0107	0.0131	0.0764	0.0688	0.0634	0.0743
$HB(\Delta_{12})$	0.0181	0.0163	0.0145	0.0175	0.0925	0.0864	0.0827	0.0989
$H(H_{12})$	0.0100	0.0091	0.0077	0.0076	2.2389	2.0709	1.7512	1.6456
	DEM +EOE							
	303.15K	**308.15K**	**313.15K**	**318.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**
$GN(G_{12})$	0.0087	0.0054	0.0042	0.0042	0.0336	0.0227	0.0189	0.0208
$KC(W_{vis}/RT)$	0.0089	0.0056	0.0042	0.0038	0.0319	0.0197	0.0147	0.0141
$HB(\Delta_{12})$	0.0125	0.0090	0.0073	0.0072	0.0494	0.0384	0.0341	0.0360
$H(H_{12})$	0.0059	0.0033	0.0028	0.0024	2.0181	1.8480	1.6720	1.5938
	DEM + BOE							
	303.15K	**308.15K**	**313.15K**	**318.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**
$GN(G_{12})$	0.0074	0.0087	0.0094	0.0102	0.0285	0.0334	0.0381	0.0415
$KC(W_{vis}/RT)$	0.0077	0.0093	0.0103	0.0113	0.0000	0.0000	0.0000	0.0000
$HB(\Delta_{12})$	0.0068	0.0082	0.0090	0.0099	0.0263	0.0315	0.0363	0.0400
$H(H_{12})$	0.0037	0.0064	0.0077	0.0094	2.3524	2.1889	2.0012	1.8569

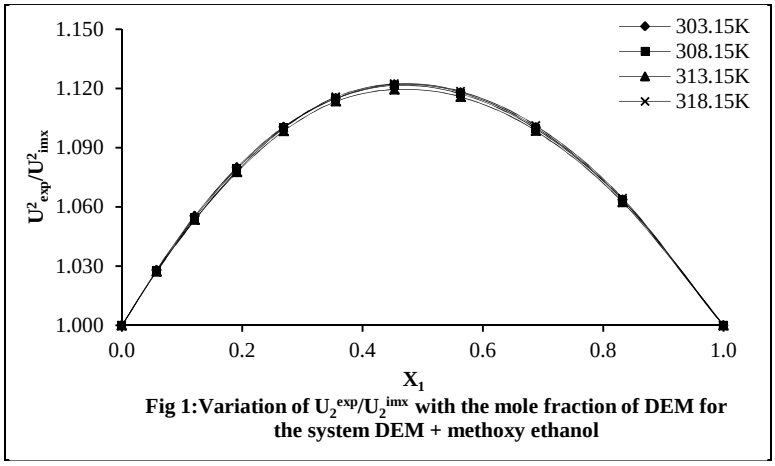

Fig 1:Variation of U_2^{exp}/U_2^{imx} with the mole fraction of DEM for the system DEM + methoxy ethanol

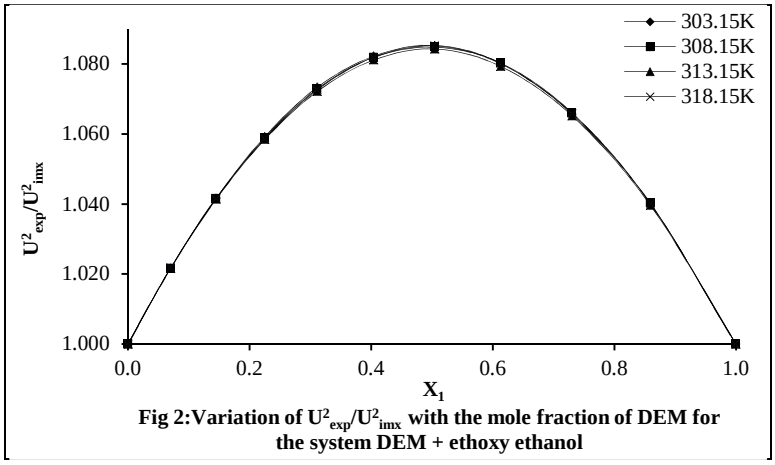

Fig 2:Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DEM for the system DEM + ethoxy ethanol

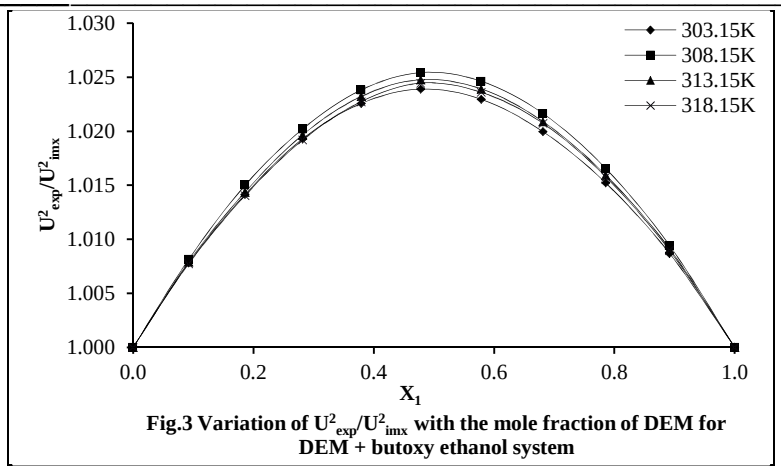

Fig.3 Variation of U^2_{exp}/U^2_{imx} with the mole fraction of DEM for DEM + butoxy ethanol system

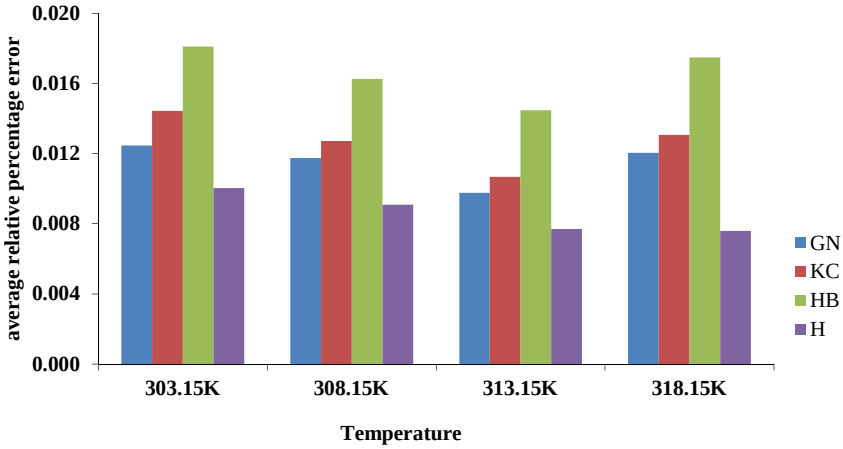

Fig4: Average relative percentage errors in estimating viscosity by the adopted theory for DEM + MOE system

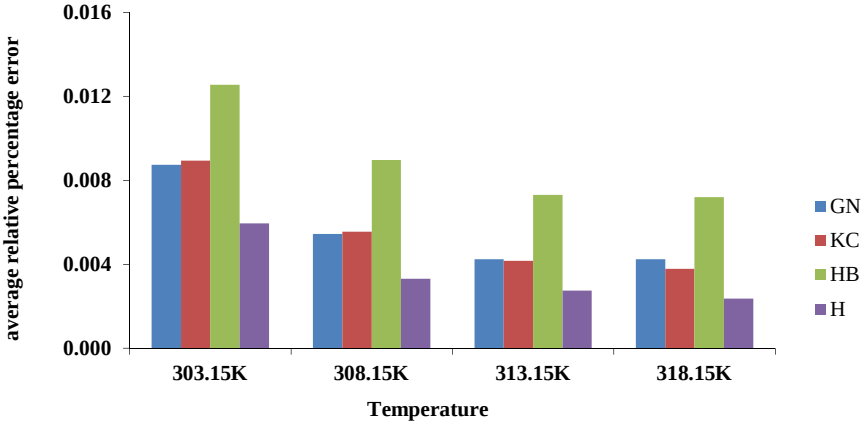

Fig 5:Average relative percentage errors in estimating viscosity by the adopted theory for DEM +EOE system

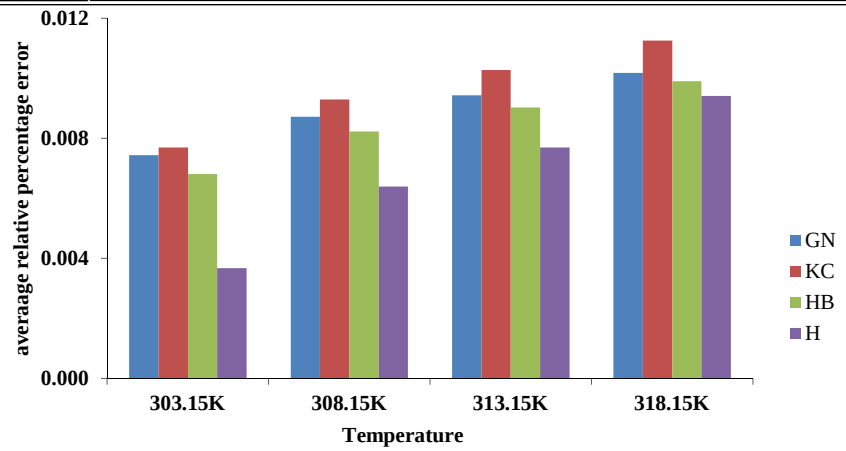

Fig6: Average relative percentage errors in estimating viscosity by the adopted for DEM + BOE

CONCLUSION

It may be concluded that the ultrasonic velocities calculated from impedance relation are best suited for DEM+MOE and DEM + EOE and Nomoto's relation for DEM + BOE. The positive values of α indicates that there exists a strong interaction exist through hydrogen bonding between DEM and alkoxy alkanol molecules. The viscosities computed from relation Hind et.al provided good results for the three systems.

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