Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Chemistry

Elixir Appl. Chem. 99 (2016) 43175-43186

ISSN: 2229-712X

Theoretical approach of ultrasonic velocity and viscosity in binary liquid mixtures of dimethyl carbonate and isomeric cresols in the assessment of molecular interactions

SK.Beebi [1,2], Ch.Udaya Lakshmi [1,2],K.Pavan Krishna[2] and C.Rambabu[2]

[1] Department of Chemistry, Y.V.N.R.Govt. Degree College, Kaikaluru, India.

[2] Department of Chemistry, Acharya Nagarjuna University, Nagarjunanagar-522510, India.

ARTICLE INFO

Article history:

Received: 23 August 2016;

Received in revised form:

3 October 2016;

Accepted: 13 October 2016;

Keywords

Ultrasonic velocity,
Density,
Viscosity,
Interaction parameter,
Molecular interaction.

ABSTRACT

Ultrasonic velocities, viscosities and densities of binary liquid mixtures containing dimethyl carbonate and isomeric cresols (ortho, meta and para) have been measured at temperatures T= (303.15, 308.15, 313.15 and 318.15) K over the entire mole fraction range of dimethyl carbonate. The theoretical values of ultrasonic velocity were evaluated using Nomoto's relation (U_{NR}), impedance relation (U_{IR}), ideal mixing relation (U_{IMR}), Jungie's relation (U_{JR}), and Rao's specific velocity relation(U_R).The molecular interaction parameter (α) has been evaluated from the values of experimental and theoretical velocities. The experimental data of viscosity is used to test the applicability of semi empirical relations of various viscosity models like Grunberg–Nissan, Katti–Chaudhri, Heric–Brewer and Hind et al. for the systems studied. On the basis of the values of interaction parameters (d) of these viscosity models and interaction parameter (α) obtained from various velocity models ,the nature of molecular interactions between the components of mixtures have been explained.

Introduction

Binary and multi component liquid mixtures have been extensively used as media for many chemical, biological and industrial processes as they provide information regarding wide range of physicochemical properties. Due to its non-destructive nature, ultrasonic study of liquid mixtures has gained much importance in assessing the nature of molecular interactions present in the mixtures. Several researchers [1-5] carried out many investigations in ultrasonic studies and correlated the experimental results of ultrasonic velocity with the theoretical relations of Nomoto [6, 7], van Deal and Vangeel ideal mixing relation [8] impedance relation [9], Junjie [10] and Rao's Specific velocity [11] and interpreted the results in terms of molecular interactions. Comparison of theoretical velocities with those obtained experimentally is expected to assess the nature of interaction between the components of liquid mixture. The variation of U^2_{exp} / U^2_{imix} from unity has also been used for explaining the non-ideality in the liquid mixtures.

Viscosity is a transport property, arising from collisions between neighboring particles in a fluid that are moving at different velocities. The knowledge of physicochemical properties such as viscosity or surface tension are required to know the mass and heat transfer operations, determination of flow in pipelines and capillaries, developing separation methods like HPLC and capillary electrophoresis. The experimental data of viscosity is used to test the applicability of semi empirical relations of Grunberg–Nissan, Katti–Chaudhri, Heric-Brewer and Hind et al. for the systems studied. Viscosity deviations reflect the degree of intermolecular association.

The solvents used in our work are of importance due to their various industrial applications. Dimethyl carbonate (DMC) is a nontoxic substance and is widely used as a replacement for dimethyl sulphate, methyl halide, and phosgene in methylation and carbonisation reactions, because it is considered to be an "environmentally benign building block" [12]. DMC has about 3 times the oxygen content as methyl tert-butyl ether. DMC is a strong contender for meeting the Clean Air Act specifications for oxygen in gasoline [13]. Cresols (alkyl phenols) are extensively used in phonograph records, wood preservatives and selective weed killing. The authors report the theoretical velocities and viscosities by using various theoretical models for DMC with isomeric cresols.

2. Materials and methods

DMC was obtained from Aldrich Chemical Co., stated purity 99 mol %.The chemicals o-,m- and p-cresol (S.D. Fine chemicals Ltd. India, mass fraction purity >0.99) are used in this study. Before measurements, all the liquids were kept in dark bottles, dried over molecular sieves (Union Carbide, type 4A), and degassed it ultrasonically. All the chemicals were purified by method described in literature [14, 15]. The chemicals after purification were 99.8% pure and their purity was ascertained by GLC and also by comparing experimental values of density, viscosity, and ultrasound velocity at 303.15 K with those reported in the literature ,as presented in Table 1.

Tele: 9949838299
E-mail address: rbchintala@gmail.com

Table 1 Comparison of density (ρ) ultrasonic velocity (u) and viscosity (η) of the pure liquids with literature data at 303.15 K.

compound	ρ (10^{-3} kg m^{-3})		u ($m \cdot s^{-1}$)		η/m·pa s	
	Expt.	Lit.	Expt.	Lit.	Expt.	Lit.
Dimethyl carbonate	1.05671	1.05671 [a]	1176.0	1177[c]	0.549	0.549[e]
o-cresol	1.03621	1.0365 [b]	1485.3	1487[d]	7.479	-
m-cresol	1.02570	1.0264[b]	1464.1	1465[d]	8.929	-
p-cresol	1.02646	1.0262[b]	1468.4	1471[d]	9.539	10.070[f]

a - [16] ; b- [17] ; c -[18] ; d- [19] ; e- [20] ; f -[21].

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 2×10^{-1} kg m^3.The pycnometer was calibrated with deionised double -distilled water .The position of the liquid levels, in the two arms of the pycnometer (which should be air bubble-free), is recorded with the help of a travelling microscope. 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.

Viscosities (η) were determined using a modified Ubbelohode viscometer. At each temperature the viscometer was calibrated against the known viscosities of benzene and carbon tetrachloride. After the mixture had attained bath temperature, flow time has been measured. The flow measurements were made with an electronic stopwatch with a precision of 0.01 s.

Ultrasonic velocities were measured with a single-crystal ultrasonic interferometer at a frequency of 2MHz and these are accurate to ± 0.02. The temperature was maintained by circulating water around the liquid cell from a U10 thermostat controlled to ± 0.01 K

3. Theory

Various theories used for evaluating ultrasonic velocities in binary liquid mixtures and their equations are as follows.

Nomoto

Established an empirical relation for ultrasonic velocity in binary liquid mixtures as:

$$U_{Nomoto}=[(X_1R_1+X_2R_2)/(X_1V_1+X_2V_2)]^3 \quad (1)$$

where, X_1 and X_2 are the mole fractions of 1st and 2nd components of the liquid mixture, R is molar sound velocity and V is molar volume

Impedance dependent relation

$$U_{IMP} = \Sigma X_i Z_i / \Sigma X_i\rho_i \quad (2)$$

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

Van Dael and Vangeel

Obtained the relation for ultrasonic velocity in liquid mixtures as

$$1/(X_1M_1+X_2M_2)*1/U^2_{imx}=X_1/M_1U_1^2+X_2/M_2U_2^2 \quad (3)$$

where M_1, M_2 are molecular weights of constituent components. U_1 and U_2 are ultrasonic velocities of individual compounds.

Junjie Equation

$$U_J = (X_1M_1/\rho_1+X_2M_2/\rho_2)/ [\{X_1M_1+X_2M_2\}^{1/2}\{X_1M_1/\rho_1U_1^2+X_2M_2/\rho_2U_2^2)\}^{1/2}] \quad (4)$$

where ρ_1 and ρ_2 are the densities of constituent components.

Rao's specific velocity

$$U_{Rao} = (\Sigma X_i r_i \rho_i)^3 \quad (5)$$

where X_i is mole fraction, ρ_i is the density of the mixture, r_i is the Rao's specific sound velocity.

The degree of intermolecular interaction or molecular association is given by

$$\alpha = (U^2_{exp} / U^2_{imix}) - 1 \quad (6)$$

There are several semi-empirical relations used to correlate the viscosity of binary liquid mixtures, which help us to know the strength of molecular interactions. The dynamic viscosities have been calculated by the following empirical relations.

The Grunberg–Nissan proposed the empirical relation as

$$\ln\eta = x_1 \ln\eta_1 + x_2 \ln\eta_2 + x_1 x_2 G_{12} \quad (7)$$

Katti and Choudhri derived the following equation

$$\ln(\eta V) = x_1 \ln(\eta_1 V_1) + x_2 \ln(\eta_2 V_2) + x_1 x_2 W_{vis}/RT \quad (8)$$

here W_{vis} is an interaction term Heric and Brewer equation is

$$\ln\eta = x_1 \ln\eta_1 + x_2 \ln\eta_2 + x_1 \ln M_1 + x_2 \ln M_2 - \ln(x_1M_1 + x_2M_2)x_1 x_2 \Delta_{12} \quad (9)$$

where Δ_{12} is the interaction term and M_1 and M_2 are molecular weights of components 1 and 2.

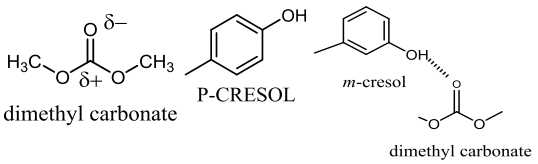
Hind et al. suggested following equation for determination of the viscosity of the liquid mixtures as

$$\eta = x_1^2\eta_1 + x_2^2\eta_2 + 2x_1x_2H_{12} \quad (10)$$

Where x_1 and x_2 are the mole fraction, η_1 and η_2 are the viscosities of liquid component 1 and 2 respectively. η is viscosity of binary mixture and H_{12} is Hind interaction parameter.

4. Results and Discussions

Dimethyl carbonate is a polar aprotic solvent (do not have a hydrogen atom that's attached to an atom of an electronegative element). Because of the electro-negativity difference of carbon and oxygen atom of *C=O* group of *DMC*, it is expected to have dipole-dipole interaction in its pure form. Cresols are methyl phenols, methyl group (CH_3) is an e^- directing in ortho and para positions, which increases e^-density in the *–O--H* bond thereby increasing basic nature of oxygen atom. Being strongly polarized O-*H* bond in cresols as $O^{\delta-}\cdots H^{\delta+}$, cresol[s] is able to form strong hydrogen bonds in their pure state. In binary mixtures of *DMC*+cresols (o, m, p) there is a possibility of intermolecular interaction between $O^{\delta-}$of *C=O* of ester (*DMC*) and $H^{\delta+}$ of *–OH* of cresols. Along with the hydrogen bonding ,dipole-dipole interactions are also assumed to be exist among the components of binary liquid mixture of *DMC*+ o-cresol(OC),+m-cresol(MC),+p-cresol(PC).



4.1 Theoretical velocities

Theoretical ultrasonic studies play an important role, in some cases where there is no possibility for the calculation of acoustical and excess acoustical parameters. The experimental values of ultrasonic velocity along with theoretical values derived from Nomoto's Relation (U_{NR}), Vandeal Vangael Ideal Mixing Relation (U_{Imix}), Impedance Dependence Relation (U_{IR}), Rao's specific velocity method (U_R), and Junjie's relation (U_J) are compared for all the three binaries (DMC+OC,MC,PC) at temperatures T=(303.15,308.15,313.15 and 318.15) K are given in Table 2 -4 and the percentage deviations in experimental and theoretical ultrasonic velocity values along with the U^2_{exp}/U^2_{Imix} and interaction parameter (α) for all the three systems are given in Table 5-7.

It is observed from the Table 2-4 that the experimental values show deviation with the theoretical values of ultrasonic velocities which confirms the existence of molecular interactions. These variations between experimental and theoretical velocity values are mainly due to the limitations and approximations incorporated in these theoretical relations. Nomoto's theory assumes 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 equal. Again, no molecular interactions are taken into account [22].

Table 2 Experimental and Theoretical values of ultrasonic velocities (m/s) in binary liquid mixtures containing dimethyl carbonate and o-cresol over the entire mole fraction range of DMC at four different temperatures T= (303.15, 308.15, 313.15, 318.15) K.

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15 K						
0.0000	1485.30	1485.30	1485.30	1485.30	1485.30	1485.30
0.1197	1448.60	1452.18	1447.62	1424.38	1443.66	1446.53
0.2343	1413.40	1419.56	1411.73	1374.99	1405.20	1409.66
0.3441	1379.60	1387.43	1377.49	1334.21	1369.53	1375.14
0.4494	1347.20	1355.79	1344.80	1300.05	1336.32	1342.62
0.5504	1315.90	1324.64	1313.56	1271.11	1305.30	1311.06
0.6474	1285.80	1293.96	1283.67	1246.33	1276.25	1280.96
0.7407	1256.80	1263.77	1255.04	1224.97	1248.95	1251.91
0.8304	1228.90	1234.04	1227.60	1206.41	1223.24	1224.75
0.9168	1202.00	1204.79	1201.28	1190.21	1198.97	1199.57
1.0000	1176.00	1176.00	1176.00	1176.00	1176.00	1176.00
			308.15 K			
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1466.70	1466.70	1466.70	1466.70	1466.70	1466.70
0.1197	1429.60	1433.24	1428.77	1404.96	1424.35	1428.01
0.2343	1394.10	1400.29	1392.63	1355.04	1385.34	1391.86
0.3441	1360.00	1367.87	1358.14	1313.92	1349.25	1357.64
0.4494	1327.30	1335.96	1325.21	1279.53	1315.74	1324.85
0.5504	1295.80	1304.55	1293.73	1250.42	1284.51	1292.87
0.6474	1265.50	1273.65	1263.59	1225.54	1255.31	1262.51
0.7407	1236.30	1243.25	1234.73	1204.10	1227.93	1233.45
0.8304	1208.20	1213.34	1207.06	1185.48	1202.19	1205.94
0.9168	1181.10	1183.93	1180.50	1169.24	1177.92	1179.88
1.0000	1155.00	1155.00	1155.00	1155.00	1155.00	1155.00
313.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1452.30	1452.30	1452.30	1452.30	1452.30	1452.30
0.1197	1414.40	1418.12	1413.74	1388.95	1408.64	1413.74
0.2343	1378.20	1384.49	1376.98	1337.93	1368.58	1377.15
0.3441	1343.50	1351.42	1341.90	1296.03	1331.67	1342.37
0.4494	1310.20	1318.90	1308.39	1261.07	1297.50	1308.93
0.5504	1278.10	1286.92	1276.34	1231.53	1265.74	1276.38
0.6474	1247.20	1255.48	1245.65	1206.32	1236.14	1245.27
0.7407	1217.50	1224.57	1216.26	1184.61	1208.45	1215.64
0.8304	1189.00	1194.19	1188.06	1165.80	1182.47	1187.57
0.9168	1161.50	1164.34	1161.00	1149.38	1158.04	1160.79
1.0000	1135.00	1135.00	1135.00	1135.00	1135.00	1135.00
318.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1437.30	1437.30	1437.30	1437.30	1437.30	1437.30
0.1197	1398.90	1402.58	1398.30	1372.71	1392.61	1398.86
0.2343	1362.20	1368.45	1361.11	1320.87	1351.75	1362.23
0.3441	1327.00	1334.91	1325.60	1278.40	1314.22	1326.94
0.4494	1293.30	1301.95	1291.67	1243.04	1279.57	1292.93
0.5504	1260.80	1269.56	1259.22	1213.22	1247.45	1260.00
0.6474	1229.50	1237.74	1228.14	1187.79	1217.58	1228.50
0.7407	1199.50	1206.47	1198.36	1165.92	1189.69	1198.44
0.8304	1170.60	1175.77	1169.79	1146.98	1163.59	1169.98
0.9168	1142.80	1145.61	1142.36	1130.47	1139.07	1142.59
1.0000	1116.00	1116.00	1116.00	1116.00	1116.00	1116.00

Table 3 Experimental and Theoretical values of ultrasonic velocities in binary liquid mixtures containing dimethyl carbonate and m-cresol over the entire mole fraction range of DMC at four different temperatures T= (303.15, 308.15, 313.15, 318.15) K.

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15 K						
0.0000	1464.10	1464.10	1464.10	1464.10	1464.10	1464.10
0.1208	1429.70	1433.38	1428.37	1407.71	1426.35	1430.34
0.2362	1396.80	1403.09	1394.50	1361.84	1391.19	1398.26
0.3464	1365.20	1373.23	1362.34	1323.87	1358.33	1367.73
0.4519	1334.90	1343.80	1331.78	1292.00	1327.53	1337.03
0.5529	1305.70	1314.79	1302.68	1264.96	1298.58	1307.16
0.6498	1277.70	1286.21	1274.96	1241.80	1271.29	1278.36
0.7427	1250.80	1258.04	1248.51	1221.82	1245.52	1250.62
0.8319	1224.90	1230.28	1223.26	1204.46	1221.12	1224.04
0.9176	1199.90	1202.94	1199.11	1189.30	1197.99	1199.61
1.0000	1176.00	1176.00	1176.00	1176.00	1176.00	1176.00
308.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1449.50	1449.50	1449.50	1449.50	1449.50	1449.50
0.1208	1414.20	1417.96	1413.05	1391.39	1410.36	1415.40
0.2362	1380.50	1386.90	1378.47	1344.31	1374.07	1382.72
0.3464	1348.20	1356.31	1345.63	1305.45	1340.28	1351.25
0.4519	1317.20	1326.18	1314.40	1272.92	1308.72	1320.32
0.5529	1287.40	1296.52	1284.66	1245.37	1279.15	1289.79
0.6498	1258.80	1267.31	1256.30	1221.81	1251.38	1260.26
0.7427	1231.20	1238.56	1229.25	1201.49	1225.22	1231.92
0.8319	1204.70	1210.26	1203.39	1183.87	1200.52	1204.71
0.9176	1179.30	1182.41	1178.67	1168.49	1177.15	1179.20
1.0000	1155.00	1155.00	1155.00	1155.00	1155.00	1155.00
313.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1436.80	1436.80	1436.80	1436.80	1436.80	1436.80
0.1208	1400.50	1404.34	1399.51	1376.72	1396.10	1402.66
0.2362	1365.90	1372.41	1364.12	1328.25	1358.52	1369.38
0.3464	1332.70	1340.98	1330.49	1288.39	1323.68	1336.97
0.4519	1301.00	1310.07	1298.50	1255.10	1291.27	1305.35
0.5529	1270.50	1279.66	1268.02	1226.97	1261.01	1274.18
0.6498	1241.20	1249.75	1238.95	1202.95	1232.67	1243.88
0.7427	1213.00	1220.33	1211.20	1182.26	1206.06	1215.16
0.8319	1185.90	1191.41	1184.68	1164.33	1181.01	1187.32
0.9176	1159.90	1162.96	1159.30	1148.70	1157.36	1160.77
1.0000	1135.00	1135.00	1135.00	1135.00	1135.00	1135.00
318.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1424.20	1424.20	1424.20	1424.20	1424.20	1424.20
0.1208	1387.10	1390.90	1386.20	1362.33	1382.00	1389.83
0.2362	1351.60	1358.17	1350.12	1312.62	1343.23	1356.47
0.3464	1317.70	1326.00	1315.82	1271.87	1307.45	1323.26
0.4519	1285.30	1294.39	1283.16	1237.93	1274.28	1290.95
0.5529	1254.10	1263.32	1252.04	1209.30	1243.42	1259.05
0.6498	1224.20	1232.80	1222.34	1184.89	1214.62	1228.39
0.7427	1195.50	1202.81	1193.97	1163.90	1187.65	1199.01
0.8319	1167.90	1173.35	1166.84	1145.72	1162.33	1170.46
0.9176	1141.40	1144.42	1140.87	1129.87	1138.49	1143.02
1.0000	1116.00	1116.00	1116.00	1116.00	1116.00	1116.00

The collision factor theory treats molecules as real non elastic substances, which is not really the case. The deviations in values of Van Dael and Vangeel equation might be due to the compressibility of the component liquids in the present mixture. The deviations of experimental values and values calculated from impedance relation and Rao's relation imply non-additivety of acoustic impedance and Rao's velocity in the liquid mixture. But on mixing two liquids, the interaction between the molecules of the two liquids takes place because of the presence of various types of forces such as hydrogen bonding, formation of charge transfer complexes, dipole-dipole, dipole-induced dipole interactions and dispersive forces, which are contributed for the deviation of experimental values of velocities from theoretical ones.

From the Tables 2-4 it is observed that for all the systems of DMC+cresol(s) there is good agreement between the experimental and theoretical values in impedance relation, Rao's specific velocity, than the results obtained from ideal mixing relation, Nomoto relation and Junjie's relation at all the four different temperatures. Perusal of Tables 5-7 shows the

Table 4 Experimental and Theoretical values of ultrasonic velocities in binary liquid mixtures containing dimethyl carbonate and p-cresol over the entire mole fraction range of DMC at four different temperatures T= (303.15, 308.15, 313.15, 318.15) K.

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
303.15K						
0.0000	1468.43	1468.43	1468.43	1468.43	1468.43	1468.43
0.1207	1433.40	1437.22	1432.21	1411.06	1429.94	1432.19
0.2360	1399.90	1406.46	1397.86	1364.44	1394.14	1397.91
0.3463	1367.80	1376.14	1365.24	1325.89	1360.73	1365.49
0.4517	1337.00	1346.25	1334.22	1293.56	1329.44	1334.71
0.5527	1307.40	1316.81	1304.69	1266.14	1300.06	1304.95
0.6496	1279.00	1287.79	1276.54	1242.66	1272.40	1276.17
0.7425	1251.70	1259.21	1249.68	1222.41	1246.30	1248.63
0.8317	1225.50	1231.05	1224.02	1204.82	1221.61	1222.83
0.9175	1200.30	1203.32	1199.49	1189.47	1198.22	1198.66
1.0000	1176.00	1176.00	1176.00	1176.00	1176.00	1176.00
308.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1455.80	1455.80	1455.80	1455.80	1455.80	1455.80
0.1207	1419.70	1423.56	1418.61	1396.22	1415.59	1418.86
0.2360	1385.20	1391.80	1383.32	1348.03	1378.36	1384.27
0.3463	1352.20	1360.54	1349.79	1308.33	1343.77	1351.41
0.4517	1320.50	1329.76	1317.90	1275.13	1311.50	1319.73
0.5527	1290.10	1299.46	1287.52	1247.03	1281.32	1288.70
0.6496	1260.90	1269.63	1258.55	1223.02	1253.00	1259.13
0.7425	1232.80	1240.28	1230.90	1202.33	1226.36	1230.93
0.8317	1205.80	1211.39	1204.48	1184.38	1201.24	1204.09
0.9175	1179.90	1182.97	1179.20	1168.72	1177.49	1178.90
1.0000	1155.00	1155.00	1155.00	1155.00	1155.00	1155.00
313.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1443.70	1443.70	1443.70	1443.70	1443.70	1443.70
0.1207	1406.60	1410.45	1405.62	1381.98	1401.75	1406.52
0.2360	1371.20	1377.74	1369.46	1332.29	1363.12	1371.51
0.3463	1337.30	1345.57	1335.09	1291.50	1327.38	1337.62
0.4517	1304.80	1313.93	1302.37	1257.48	1294.19	1304.94
0.5527	1273.60	1282.82	1271.20	1228.75	1263.26	1273.31
0.6496	1243.60	1252.23	1241.45	1204.24	1234.34	1243.11
0.7425	1214.80	1222.16	1213.05	1183.16	1207.23	1214.32
0.8317	1187.10	1192.60	1185.89	1164.88	1181.73	1186.75
0.9175	1160.50	1163.55	1159.90	1148.95	1157.70	1160.56
1.0000	1135.00	1135.00	1135.00	1135.00	1135.00	1135.00
318.15 K						
X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}
0.0000	1432.70	1432.70	1432.70	1432.70	1432.70	1432.70
0.1207	1394.60	1398.44	1393.69	1368.77	1389.00	1395.64
0.2360	1358.20	1364.77	1356.65	1317.54	1348.94	1359.76
0.3463	1323.40	1331.69	1321.41	1275.64	1312.05	1324.68
0.4517	1290.10	1299.18	1287.86	1240.80	1277.93	1291.28
0.5527	1258.10	1267.26	1255.88	1211.44	1246.25	1258.84
0.6496	1227.30	1235.90	1225.35	1186.44	1216.73	1227.83
0.7425	1197.80	1205.10	1196.18	1164.96	1189.13	1198.36
0.8317	1169.40	1174.85	1168.29	1146.37	1163.26	1169.76
0.9175	1142.10	1145.15	1141.59	1130.18	1138.93	1142.39
1.0000	1116.00	1116.00	1116.00	1116.00	1116.00	1116.00

percentage deviations of the ultrasonic velocity are both negative and positive, indicating the non ideal behavior of liquid mixture. Positive deviation in velocity is attributed to the molecular associations, whereas negative deviations indicate molecular dissociations. The ratio U^2_{exp}/U^2_{Imix} 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_{exp}/U^2_{Imix} for all the three systems of DMC+ isomeric cresols at all the different temperatures and over the entire composition range of DMC, indicate dominance of associations over dispersion forces among the molecules of liquid mixture.

Figures 1-3 represent the variation of U^2_{exp}/U^2_{Imix} with mole fraction of DMC with isomeric cresols. It is observed that in DMC+OC, DMC+MC, DMC+PC systems show maximum positive deviation at approximately 0.45M at all the temperatures, which infers the maximum hetero molecular associations at this mole fraction of DMC. The deviation of the ratio U^2_{exp}/U^2_{Imix} from unity is a direct measure of non-ideality of the system as a consequence of association or dissociation which is called as molecular interaction parameter (α). The positive values of α in all the binary systems clearly indicate the existence of strong interaction in the liquid mixture.

Table 5 Percentage deviation between experimental and theoretical values of ultrasonic velocity, U^2_{exp}/U^2_{imix} and molecular interaction parameter (α) in Dimethyl carbonate and o-cresol system at different temperatures.

X1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1197	0.2474	-0.0676	-1.6723	-0.3408	-0.1432	1.0343	0.0343
0.2343	0.4360	-0.1185	-2.7179	-0.5801	-0.2644	1.0567	0.0567
0.3441	0.5678	-0.1529	-3.2901	-0.7300	-0.3236	1.0692	0.0692
0.4494	0.6379	-0.1779	-3.4995	-0.8075	-0.3402	1.0738	0.0738
0.5504	0.6640	-0.1778	-3.4041	-0.8052	-0.3675	1.0717	0.0717
0.6474	0.6349	-0.1658	-3.0694	-0.7429	-0.3761	1.0643	0.0643
0.7407	0.5543	-0.1399	-2.5329	-0.6247	-0.3893	1.0526	0.0526
0.8304	0.4184	-0.1056	-1.8299	-0.4607	-0.3379	1.0376	0.0376
0.9168	0.2320	-0.0601	-0.9807	-0.2525	-0.2019	1.0199	0.0199
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15 K							
X1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1197	0.2544	-0.0580	-1.7237	-0.3675	-0.1115	1.0354	0.0354
0.2343	0.4443	-0.1057	-2.8016	-0.6286	-0.1607	1.0585	0.0585
0.3441	0.5786	-0.1364	-3.3882	-0.7902	-0.1734	1.0714	0.0714
0.4494	0.6522	-0.1574	-3.5989	-0.8707	-0.1848	1.0761	0.0761
0.5504	0.6754	-0.1601	-3.5018	-0.8711	-0.2260	1.0739	0.0739
0.6474	0.6441	-0.1506	-3.1576	-0.8049	-0.2361	1.0663	0.0663
0.7407	0.5621	-0.1269	-2.6049	-0.6767	-0.2302	1.0542	0.0542
0.8304	0.4257	-0.0945	-1.8801	-0.4974	-0.1867	1.0387	0.0387
0.9168	0.2395	-0.0505	-1.0039	-0.2689	-0.1033	1.0204	0.0204
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15 K							
X1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1197	0.2627	-0.0466	-1.7994	-0.4075	-0.0470	1.0370	0.0370
0.2343	0.4564	-0.0883	-2.9218	-0.6978	-0.0764	1.0611	0.0611
0.3441	0.5894	-0.1188	-3.5335	-0.8808	-0.0843	1.0746	0.0746
0.4494	0.6637	-0.1382	-3.7500	-0.9696	-0.0971	1.0794	0.0794
0.5504	0.6899	-0.1379	-3.6436	-0.9667	-0.1348	1.0771	0.0771
0.6474	0.6637	-0.1239	-3.2778	-0.8868	-0.1545	1.0689	0.0689
0.7407	0.5808	-0.1022	-2.7011	-0.7435	-0.1527	1.0563	0.0563
0.8304	0.4367	-0.0790	-1.9515	-0.5491	-0.1200	1.0402	0.0402
0.9168	0.2443	-0.0432	-1.0431	-0.2981	-0.0608	1.0212	0.0212
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15 K							
X1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1197	0.2632	-0.0430	-1.8722	-0.4498	-0.0031	1.0385	0.0385
0.2343	0.4591	-0.0802	-3.0340	-0.7669	0.0019	1.0636	0.0636
0.3441	0.5962	-0.1052	-3.6622	-0.9634	-0.0045	1.0775	0.0775
0.4494	0.6687	-0.1257	-3.8859	-1.0619	-0.0284	1.0825	0.0825
0.5504	0.6947	-0.1254	-3.7740	-1.0586	-0.0633	1.0800	0.0800
0.6474	0.6698	-0.1105	-3.3924	-0.9696	-0.0816	1.0715	0.0715
0.7407	0.5814	-0.0953	-2.7993	-0.8175	-0.0883	1.0584	0.0584
0.8304	0.4415	-0.0695	-2.0179	-0.5991	-0.0528	1.0416	0.0416
0.9168	0.2461	-0.0389	-1.0793	-0.3260	-0.0185	1.0219	0.0219
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table 6. Percentage deviation between experimental and theoretical values of ultrasonic velocity, U^2_{exp}/U^2_{imix} and molecular interaction parameter (α) in Dimethyl carbonate and m-cresol system at different temperatures.

X_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1208	0.2574	-0.0930	-1.5379	-0.2340	0.0448	1.0315	0.0315
0.2362	0.4504	-0.1648	-2.5031	-0.4013	0.1045	1.0520	0.0520
0.3464	0.5884	-0.2093	-3.0277	-0.5029	0.1855	1.0634	0.0634
0.4519	0.6669	-0.2340	-3.2136	-0.5520	0.1593	1.0675	0.0675
0.5529	0.6965	-0.2310	-3.1200	-0.5456	0.1116	1.0654	0.0654
0.6498	0.6658	-0.2144	-2.8095	-0.5016	0.0515	1.0587	0.0587
0.7427	0.5785	-0.1828	-2.3173	-0.4222	-0.0146	1.0480	0.0480
0.8319	0.4393	-0.1343	-1.6691	-0.3082	-0.0698	1.0342	0.0342
0.9176	0.2530	-0.0660	-0.8837	-0.1595	-0.0240	1.0179	0.0179
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15 K							
X_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1208	0.2661	-0.0815	-1.6127	-0.2713	0.0852	1.0331	0.0331
0.2362	0.4637	-0.1470	-2.6218	-0.4661	0.1609	1.0546	0.0546
0.3464	0.6014	-0.1906	-3.1709	-0.5878	0.2265	1.0666	0.0666
0.4519	0.6820	-0.2128	-3.3616	-0.6440	0.2369	1.0708	0.0708
0.5529	0.7084	-0.2131	-3.2648	-0.6407	0.1853	1.0686	0.0686
0.6498	0.6764	-0.1982	-2.9388	-0.5897	0.1158	1.0615	0.0615
0.7427	0.5981	-0.1587	-2.4127	-0.4860	0.0588	1.0501	0.0501
0.8319	0.4619	-0.1084	-1.7292	-0.3470	0.0006	1.0355	0.0355
0.9176	0.2638	-0.0535	-0.9170	-0.1821	-0.0085	1.0186	0.0186
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15 K							
X_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1208	0.2745	-0.0708	-1.6978	-0.3145	0.1543	1.0348	0.0348
0.2362	0.4764	-0.1304	-2.7564	-0.5404	0.2549	1.0575	0.0575
0.3464	0.6217	-0.1657	-3.3251	-0.6766	0.3203	1.0700	0.0700
0.4519	0.6972	-0.1924	-3.5280	-0.7478	0.3341	1.0745	0.0745
0.5529	0.7211	-0.1954	-3.4265	-0.7469	0.2898	1.0722	0.0722
0.6498	0.6889	-0.1812	-3.0821	-0.6869	0.2159	1.0646	0.0646
0.7427	0.6046	-0.1485	-2.5339	-0.5719	0.1781	1.0527	0.0527
0.8319	0.4643	-0.1033	-1.8185	-0.4124	0.1197	1.0374	0.0374
0.9176	0.2641	-0.0517	-0.9656	-0.2186	0.0754	1.0196	0.0196
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15 K							
X_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1208	0.2742	-0.0646	-1.7856	-0.3674	0.1967	1.0367	0.0367
0.2362	0.4863	-0.1092	-2.8838	-0.6190	0.3603	1.0603	0.0603
0.3464	0.6302	-0.1427	-3.4779	-0.7782	0.4219	1.0734	0.0734
0.4519	0.7071	-0.1663	-3.6855	-0.8577	0.4397	1.0780	0.0780
0.5529	0.7354	-0.1646	-3.5726	-0.8517	0.3947	1.0755	0.0755
0.6498	0.7024	-0.1523	-3.2114	-0.7829	0.3422	1.0675	0.0675
0.7427	0.6115	-0.1283	-2.6435	-0.6568	0.2940	1.0550	0.0550
0.8319	0.4668	-0.0909	-1.8994	-0.4772	0.2195	1.0391	0.0391
0.9176	0.2643	-0.0460	-1.0098	-0.2549	0.1421	1.0205	0.0205
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table 7. Percentage deviation between experimental and theoretical values of ultrasonic velocity, U^2_{exp}/U^2_{imix} and molecular interaction parameter (α) in dimethyl carbonate and o-cresol system at different temperatures.

X_1	$\%U_{NOM}$	$\%U_{IMP}$	$\%U_{VDV}$	$\%U_{JUN}$	$\%U_{RAO}$	U^2_{exp} / U^2_{imix}	α
303.15K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1207	0.2666	-0.0830	-1.5586	-0.2410	-0.0844	1.0319	0.0319
0.2360	0.4684	-0.1456	-2.5331	-0.4111	-0.1423	1.0527	0.0527
0.3463	0.6095	-0.1870	-3.0642	-0.5170	-0.1687	1.0642	0.0642
0.4517	0.6922	-0.2076	-3.2492	-0.5655	-0.1716	1.0683	0.0683
0.5527	0.7196	-0.2070	-3.1561	-0.5614	-0.1877	1.0662	0.0662
0.6496	0.6876	-0.1920	-2.8411	-0.5159	-0.2215	1.0593	0.0593
0.7425	0.5999	-0.1611	-2.3401	-0.4315	-0.2454	1.0485	0.0485
0.8317	0.4530	-0.1204	-1.6873	-0.3172	-0.2176	1.0346	0.0346
0.9175	0.2512	-0.0677	-0.9025	-0.1736	-0.1370	1.0183	0.0183
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
308.15 K							
X_1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1207	0.2716	-0.0770	-1.6537	-0.2897	-0.0589	1.0339	0.0339
0.2360	0.4767	-0.1358	-2.6830	-0.4937	-0.0673	1.0559	0.0559
0.3463	0.6167	-0.1781	-3.2443	-0.6237	-0.0587	1.0682	0.0682
0.4517	0.7011	-0.1970	-3.4359	-0.6812	-0.0586	1.0724	0.0724
0.5527	0.7253	-0.1999	-3.3385	-0.6804	-0.1083	1.0703	0.0703
0.6496	0.6924	-0.1860	-3.0044	-0.6263	-0.1402	1.0629	0.0629
0.7425	0.6065	-0.1538	-2.4717	-0.5222	-0.1516	1.0513	0.0513
0.8317	0.4635	-0.1095	-1.7763	-0.3783	-0.1420	1.0365	0.0365
0.9175	0.2598	-0.0591	-0.9472	-0.2041	-0.0845	1.0192	0.0192
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
313.15 K							
X_1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1207	0.2735	-0.0700	-1.7504	-0.3447	-0.0058	1.0359	0.0359
0.2360	0.4768	-0.1269	-2.8376	-0.5895	0.0229	1.0593	0.0593
0.3463	0.6182	-0.1654	-3.4252	-0.7419	0.0239	1.0722	0.0722
0.4517	0.6997	-0.1860	-3.6269	-0.8131	0.0104	1.0767	0.0767
0.5527	0.7239	-0.1887	-3.5215	-0.8118	-0.0231	1.0743	0.0743
0.6496	0.6941	-0.1726	-3.1648	-0.7443	-0.0396	1.0664	0.0664
0.7425	0.6060	-0.1444	-2.6049	-0.6233	-0.0392	1.0542	0.0542
0.8317	0.4636	-0.1021	-1.8715	-0.4521	-0.0298	1.0385	0.0385
0.9175	0.2629	-0.0520	-0.9949	-0.2411	0.0052	1.0202	0.0202
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
318.15 K							
X_1	**$\%U_{NOM}$**	**$\%U_{IMP}$**	**$\%U_{VDV}$**	**$\%U_{JUN}$**	**$\%U_{RAO}$**	**U^2_{exp} / U^2_{imix}**	**α**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
0.1207	0.2751	-0.0649	-1.8524	-0.4019	0.0747	1.0381	0.0381
0.2360	0.4836	-0.1144	-2.9934	-0.6817	0.1145	1.0627	0.0627
0.3463	0.6261	-0.1502	-3.6088	-0.8574	0.0965	1.0763	0.0763
0.4517	0.7041	-0.1736	-3.8215	-0.9430	0.0914	1.0810	0.0810
0.5527	0.7278	-0.1768	-3.7085	-0.9416	0.0592	1.0785	0.0785
0.6496	0.7004	-0.1590	-3.3289	-0.8611	0.0429	1.0701	0.0701
0.7425	0.6091	-0.1350	-2.7413	-0.7236	0.0468	1.0572	0.0572
0.8317	0.4662	-0.0949	-1.9692	-0.5255	0.0307	1.0406	0.0406
0.9175	0.2675	-0.0449	-1.0438	-0.2778	0.0256	1.0212	0.0212
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000

Table 8. Experimental and calculated values of viscosity (η) for the binary mixtures of dimethyl carbonate and studied cresols (+OC, +MC, +PC) at the temperatures (303.15, 308.15, 313.15 and 318.15)K

X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
DMC+OC										
303.15K						**308.15K**				
0.0000	7.479	7.479	7.479	7.479	7.479	5.963	5.963	5.963	5.963	5.963
0.1197	6.115	6.576	6.577	6.577	6.222	4.915	5.187	5.187	5.188	4.973
0.2343	5.091	5.548	5.549	5.548	5.128	4.075	4.366	4.367	4.366	4.111
0.3441	4.216	4.515	4.516	4.515	4.179	3.351	3.571	3.572	3.571	3.365
0.4494	3.419	3.562	3.563	3.562	3.361	2.725	2.850	2.850	2.850	2.722
0.5504	2.729	2.736	2.737	2.736	2.661	2.201	2.227	2.227	2.227	2.172
0.6474	2.114	2.054	2.054	2.054	2.066	1.742	1.708	1.708	1.708	1.705
0.7407	1.618	1.511	1.511	1.511	1.567	1.351	1.290	1.290	1.290	1.313
0.8304	1.171	1.093	1.093	1.093	1.153	1.015	0.962	0.962	0.962	0.989
0.9168	0.798	0.779	0.779	0.779	0.816	0.731	0.709	0.709	0.709	0.726
1.0000	0.549	0.549	0.549	0.549	0.549	0.518	0.518	0.518	0.518	0.518
313.15K						**318.15K**				
X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
0.0000	4.238	4.238	4.238	4.238	4.238	2.215	2.215	2.215	2.215	2.215
0.1197	3.533	3.658	3.658	3.658	3.567	1.905	1.940	1.940	1.940	1.925
0.2343	2.961	3.087	3.088	3.088	2.981	1.654	1.685	1.686	1.686	1.668
0.3441	2.461	2.557	2.557	2.557	2.472	1.442	1.456	1.456	1.456	1.441
0.4494	2.036	2.083	2.083	2.083	2.031	1.250	1.250	1.251	1.250	1.241
0.5504	1.661	1.674	1.674	1.674	1.652	1.075	1.070	1.070	1.070	1.065
0.6474	1.351	1.329	1.329	1.329	1.329	0.920	0.912	0.912	0.912	0.910
0.7407	1.078	1.045	1.045	1.045	1.055	0.786	0.776	0.776	0.776	0.776
0.8304	0.845	0.815	0.815	0.815	0.826	0.664	0.659	0.659	0.659	0.659
0.9168	0.641	0.631	0.631	0.631	0.638	0.562	0.558	0.558	0.558	0.559
1.0000	0.486	0.486	0.486	0.486	0.486	0.473	0.473	0.473	0.473	0.473
DMC+MC										
303.15K						**308.15K**				
X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
0.0000	8.929	8.929	8.929	8.929	8.929	7.412	7.412	7.412	7.412	7.412
0.1208	8.215	10.855	10.856	10.854	8.149	6.791	8.671	8.672	8.670	6.758
0.2362	7.415	11.412	11.414	11.410	7.344	6.159	8.908	8.911	8.907	6.087
0.3464	6.525	10.568	10.572	10.565	6.521	5.451	8.174	8.177	8.172	5.405
0.4519	5.645	8.760	8.762	8.757	5.683	4.715	6.794	6.796	6.792	4.713
0.5529	4.781	6.593	6.594	6.591	4.836	3.995	5.181	5.182	5.180	4.016
0.6498	3.899	4.560	4.560	4.559	3.981	3.256	3.665	3.664	3.664	3.315
0.7427	3.069	2.932	2.931	2.931	3.123	2.569	2.429	2.428	2.428	2.613
0.8319	2.235	1.768	1.767	1.768	2.263	1.874	1.521	1.520	1.520	1.912
0.9176	1.415	1.009	1.009	1.009	1.405	1.205	0.907	0.906	0.906	1.213
1.0000	0.549	0.549	0.549	0.549	0.549	0.518	0.518	0.518	0.518	0.518
313.15K						**318.15K**				
X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
0.0000	6.116	6.116	6.116	6.116	6.116	5.019	5.019	5.019	5.019	5.019
0.1208	5.596	6.888	6.889	6.888	5.578	4.571	5.404	5.404	5.404	4.571
0.2362	5.102	6.919	6.920	6.919	5.028	4.171	5.288	5.289	5.288	4.117
0.3464	4.528	6.292	6.293	6.291	4.469	3.725	4.763	4.763	4.762	3.660
0.4519	3.945	5.244	5.245	5.243	3.904	3.264	3.989	3.989	3.989	3.201
0.5529	3.365	4.053	4.053	4.052	3.334	2.786	3.137	3.137	3.137	2.741
0.6498	2.751	2.931	2.931	2.931	2.762	2.298	2.335	2.335	2.335	2.282
0.7427	2.154	2.002	2.002	2.002	2.191	1.815	1.658	1.657	1.657	1.825
0.8319	1.561	1.301	1.301	1.301	1.620	1.315	1.129	1.129	1.129	1.371
0.9176	1.012	0.810	0.810	0.810	1.051	0.865	0.742	0.742	0.742	0.920
1.0000	0.486	0.486	0.486	0.486	0.486	0.473	0.473	0.473	0.473	0.473
DMC+PC										
303.15K						**308.15K**				
X_1	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}	η_{Expt}	η_{GN}	η_{KC}	η_{HB}	η_{H}
0.0000	9.5390	9.5390	9.5390	9.5390	9.5390	8.1190	8.1190	8.1190	8.1190	8.1190
0.1207	8.5610	11.1275	11.1280	11.1269	8.5455	7.2650	9.1703	9.1702	9.1700	7.2600
0.2360	7.6140	11.3443	11.3450	11.3428	7.5730	6.4580	9.1697	9.1704	9.1688	6.4244
0.3463	6.6510	10.2806	10.2814	10.2784	6.6212	5.6610	8.2435	8.2446	8.2420	5.6114
0.4517	5.7190	8.4095	8.4105	8.4072	5.6920	4.8710	6.7559	6.7570	6.7543	4.8220
0.5527	4.7890	6.2897	6.2898	6.2877	4.7837	4.0840	5.1068	5.1066	5.1053	4.0540
0.6496	3.8850	4.3500	4.3491	4.3484	3.8956	3.3010	3.5969	3.5961	3.5957	3.3067
0.7425	3.0150	2.8117	2.8106	2.8108	3.0290	2.5490	2.3836	2.3828	2.3828	2.5805
0.8317	2.1590	1.7134	1.7127	1.7129	2.1829	1.8450	1.4979	1.4974	1.4975	1.8743
0.9175	1.3290	0.9915	0.9913	0.9914	1.3560	1.1570	0.8985	0.8983	0.8984	1.1867
1.0000	0.5490	0.5490	0.5490	0.5490	0.5490	0.5180	0.5180	0.5180	0.5180	0.5180

Table 8 (continued)
Experimental and calculated values of viscosity (η) for the binary mixtures of dimethyl carbonate and studied cresols (+OC, +MC, +PC) at the temperatures 303.15, 308.15, 313.15 and 318.15K

313.15K						318.15K				
0.0000	6.7410	6.7410	6.7410	6.7410	6.7410	5.4690	5.4690	5.4690	5.4690	5.4690
0.1207	6.0120	7.3186	7.3183	7.3185	6.0166	4.8860	5.7266	5.7272	5.7266	4.8868
0.2360	5.3490	7.1456	7.1458	7.1451	5.3168	4.3650	5.4823	5.4831	5.4822	4.3253
0.3463	4.7050	6.3592	6.3592	6.3584	4.6402	3.8500	4.8539	4.8538	4.8534	3.7833
0.4517	4.0650	5.2221	5.2218	5.2211	3.9871	3.3410	4.0160	4.0158	4.0154	3.2609
0.5527	3.4150	3.9973	3.9966	3.9963	3.3552	2.7960	3.1319	3.1314	3.1312	2.7562
0.6496	2.7510	2.8777	2.8769	2.8769	2.7434	2.2690	2.3196	2.3190	2.3190	2.2683
0.7425	2.1350	1.9651	1.9645	1.9645	2.1518	1.7640	1.6434	1.6431	1.6430	1.7970
0.8317	1.5310	1.2816	1.2813	1.2813	1.5791	1.2940	1.1204	1.1202	1.1201	1.3413
0.9175	0.9760	0.8029	0.8028	0.8027	1.0239	0.8590	0.7385	0.7384	0.7384	0.9000
1.0000	0.4860	0.4860	0.4860	0.4860	0.4860	0.4730	0.4730	0.4730	0.4730	0.4730

Table 9. Interaction Parameters calculated from Eqns. (7-10) and the corresponding standard deviations (σ) for the binary mixtures dimethyl carbonate and studied cresols (+OC, +MC, +PC) at the temperatures 303.15, 308.15, 313.15 and 318.15K

T/K	G_{12}	σ	Wvis/RT	σ	Δ_{12}	σ	H_{12}	σ
DCM+OC								
303.15K	1.746	0.235	1.763	0.236	1.763	0.235	1.986	0.053
308.15K	1.454	0.152	1.469	0.153	1.470	0.153	1.635	0.030
313.15K	1.063	0.068	1.076	0.068	1.079	0.068	1.310	0.018
318.15K	0.494	0.016	0.505	0.016	0.510	0.016	0.957	0.010
DCM+MC								
303.15K	5.011	2.305	5.023	2.306	5.027	2.303	5.831	0.049
308.15K	4.503	1.570	4.514	1.571	4.519	1.569	4.806	0.040
313.15K	4.000	1.020	4.008	1.021	4.015	1.020	3.971	0.043
318.15K	3.382	0.612	3.388	0.612	3.398	0.612	3.222	0.044
DCM+PC								
303.15K	4.698	2.091	4.714	2.092	4.714	2.090	5.476	0.023
308.15K	4.277	1.502	4.291	1.502	4.293	1.501	4.594	0.031
313.15K	3.765	0.974	3.777	0.974	3.781	0.974	3.758	0.045
318.15K	3.217	0.599	3.227	0.600	3.233	0.599	3.069	0.044

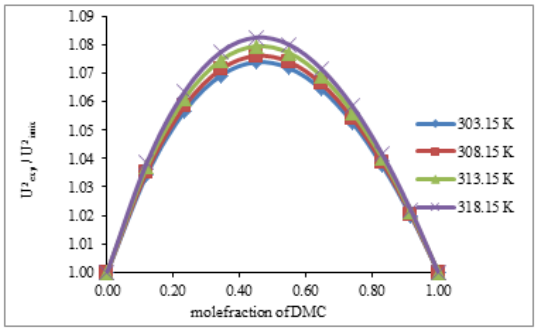


Fig. 1. Variation of U^2_{exp}/U^2_{Imix} with mole fraction of DMC in o-cresol

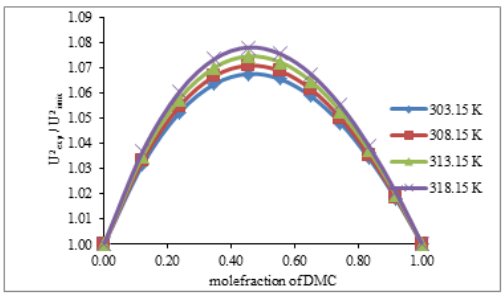


Fig. 2. Variation of U^2_{exp}/U^2_{Imix} with mole fraction of DMC in m-cresol

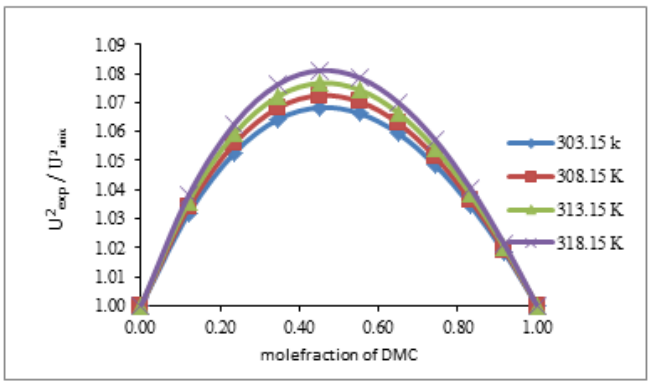


Fig. 3.Variations of U^2_{exp}/U^2_{Imix} with mole fraction of DMC in p-cresol.

4.2. Analyzing Viscosity of Liquid Mixtures by Semi empirical Models

Several empirical and semi empirical models (equations) have been put forth for correlating the viscosity of liquid mixtures to interpret the molecular interaction in the liquid mixture in terms of interaction parameter of the viscosity model. In this article we use the equations of Grunberg–Nissan, Katti–Chaudhri, and Heric-Brewer and Hind et al., to correlate the viscosities of binary mixtures of DMC + cresol (ortho, meta and para).

Experimental and calculated values of viscosity (η) for the binary mixtures of dimethyl carbonate and studied cresols (+OC, +MC, +PC) at the temperatures 303.15, 308.15, 313.15 and 318.15K are represented in the Table 8. Interaction (adjustable) parameters calculated from Eqns. (6-9) and the corresponding standard deviations (σ) for the binary mixtures dimethyl carbonate and studied cresols (+OC, +MC, +PC) at the temperatures (303.15, 308.15, 313.15 and 318.15)K are shown in Table 9.

An examination of data in Table 8 shows that all the empirical relations gave a reasonable fit, but the viscosity values calculated using Hind et al. are in good agreement with the experimental values. Perusal of data in Table 9 shows that the values of interaction parameters (d) calculated from different viscosity theories are positive for the systems: DMC+ isomeric cresols (ortho, meta and para).

G_{12} may be regarded as an approximate measure of the strength of the interaction between the components. According to Fort and Moore [23] if the G_{12} is positive, then the system exhibits strong interaction; if it is negative they show weak interaction. Nigam and Mahl [24] concluded from the study of binary mixtures dimethyl slphoxide with chlroethanes & chlroethenes, that

i. If $\Delta\eta > 0$, $G_{12} > 0$ and magnitude of both are large then strong specific interaction would be present.
ii. If $\Delta\eta < 0$, $G_{12} > 0$ then weak specific interaction would be present.
iii. If $\Delta\eta < 0$, $G_{12} < 0$ magnitude of both are large then the dispersion force would be dominant.

In the present binary systems DMC+ cresols(+OC, +MC, +PC), G_{12} values in the Table 9, are positive and interaction parameter W_{vis} shows almost the same trend as that of G_{12}, hence one could say that all binary mixtures are showing strong specific interactions.

5. Conclusions

Experimental data of ultrasonic velocity of the liquid mixtures of DMC with cresols have been compared with the above five theoretical models at (303-318.15) K with interval of 5K. It may be concluded that out of five theories and relations discussed above impedance relation, Rao's specific velocity gave good agreement. The experimental values of viscosity were correlated with the semi empirical relations of viscosity like Grunberg-Nissan, Katti-Chaudhri, Heric-Brewer, and Hind et al. Among all the relations, Hind et al. gave good agreement with the experimental values. From the value of the U^2_{exp}/U^2_{Imix} for all the three systems of DMC+ isomeric cresols, positive values of α computed from theoretical velocities and positive values of interaction parameters (d) calculated from different viscosity theories it would be concluded that, prevalence of strong specific interactions among the binary mixtures of DMC+isomeric cresols (ortho, meta and para) at all the four different temperatures.

Acknowledgment

One of the author Sk.Beebi is thankful to the department of chemistry, Acharya Nagarjuna University for the facilities provided and the encouragement shown towards this work.

References

[1] S. Baluja and S. Oza, "Studies of some acoustical properties inbinary solutions," The Journal of Pure and Applied Ultrasonics, vol. 24, 580, 2002.

[2] A. Ali, A. Yasmin, and A. K. Nain, "Study of intermolecular interactions in binary liquid mixtures through ultrasonic speed measurement," Indian Journal of Pure and Applied Physics, vol. 40, no. 5, pp. 315–322, 2002.

[3] M. Rastogi, A. Awasthi, M. Gupta, and J. P. Shukla, "Ultrasonic investigations of X...HO bond complexes," Indian Journal of Pure and Applied Physics, vol. 40, no. 4, pp. 256-263, 2002

[4] Zareena Begum, P. B. Sandhya Sri, and C. Rambabu, "Theoretical Evaluation of UltrasonicVelocities in Binary Liquid Mixtures of Anisaldehyde with Some Alcoxyethanols at Different Temperatures," ISRN Physical Chemistry,p12, 2012.

[5] P.B.Sandhya Sri, Zareena Begum and C.Rambabu , " Theoretical Evaluation of Ultrasonic Velocities in Binary Liquid Mixtures of Anisic Aldehyde with some Esters at Different Temperatures Using Different Theories and Models," J Thermodyn Catal , vol.4, 2013

[6] O. Nomoto, Journal of the Physical Society of Japan, vol. 4, p.280, 1949.

[7] O. Nomoto, "Empirical Formula for Sound Velocity in LiquidMixtures," Journal of the Physical Society of Japan, vol. 13, pp.1528–1532, 1958.

[8] W. van Dael and E. Vangeel, in Proceedings of the International Conference on Calorimetry and Thermodynamics, p. 555,Warsaw, Poland, 1955.

[9] S. Baluja and R. H. Parsania, "Studies on acoustical properties of diclofanac sodium methanol-water system at 30◦C," Asian Journal of Chemistry, vol. 9, no. 1, pp. 149–152, 1997.

[10] Z. Junjie, Journal of University of Science and Technology of China, vol. 14, p. 298, 1984.

[11] M. Rama rao, "Velocity of Sound in Liquids and Chemical Constitution" Journal of chemical Physics, vol.9, p.682, 1941.

[12] H.Matsuda, S.Yoshii, A. Nagashima, K. Kurihara, and K.Ochi, "Excess Molar Enthalpies of the Binary Carbon Dioxide + Dimethyl Carbonate System at Temperatures of (298.15 to 308.15) and Pressures of (5.0 to 7.5) MPa" Journal of Chemical and Engineering Data, vol. 50, no. 4, pp.1419-1424, 2005.

[13] J.H. Oh, K.J. Han, and S.J. Park, "Excess Molar Volumes at 298.15 K and Isothermal Vapour Liquid Equilibria at 333.15 K for the Binary Mixtures of Dimethyl Carbonate with Benzene, Toluene, n-Heptane, and Isooctane" Journal of Chemical and Engineering Data, vol. 51, no. 5, 1868-1872, 2006.

[14] A.I.Vogel, Vogel's textbook of practical organic chemistry, 5th Edition. Wiley, New York, 1989.

[15] J.A.Riddick, W.B.Bunger, T.K.Sakano, "Techniques of Chemistry, Organic Solvents, Physical Properties and Methods of Purification," Techniques of Chemistry, vol.II, 4th Ed; WileyInterscience, New York. 1986.

[16] R.Ren, Y. Zuo, Q. Zhou, H.Zhang, and S.Zhang, "Density, Excess Molar Volume and Conductivity of Binary Mixtures of the Ionic Liquid 1, 2-Dimethyl-3-hexylimidazolium Bis(trifluoromethylsulfonyl)imide and Dimethyl Carbonate" Journal of Chemical an Engineering Data, vol.56, no.1, pp 27– 30, 2011.

[17] S.Sharma, P. Patel and J.Bhalodia, "Volumetric and viscometric study of binary mixtures of 1,8- cineole with o-,m- and p-cresol at 303.15, 308.15 and 313.15K", Physics and chemistry of liquids, p.16,2015, http://dx.doi.org/10.1080/00319104.2015.1068661

[18] A. Rodrı´guez, J. Canosa, and J. Tojo; "Physical Properties of Binary Mixtures (Dimethyl Carbonate + Alcohols) at Several Temperatures" Journal of Chemical and Engineering Data, vol.46, no.6, pp1476-1486, 2001. http://dx.doi.org/10.1080/00319104.2015.1068661

[19] A. Rodrı´guez, J. Canosa, and J. Tojo; "Physical Properties of Binary Mixtures (Dimethyl Carbonate + Alcohols) at Several Temperatures" Journal of Chemical and Engineering Data, vol.46, no.6, pp1476-1486, 2001.

[19] S.C. Bhatia, R. Rani, and R. Bhatia, "Densities, Speeds of Sound, and Refractive Indices of Binary Mixtures of Decan-1-ol with Anisole, o-Cresol, m-Cresol, and p-Cresol at (298.15,303.15, and 308.15) K" Journal of chemical and engineering data, vol. 56 pp.1669–1674, 2011

[20] A.B.Pereiro, A.Rodrı´guez, J.Canosa, and J.Tojo; "Density, Viscosity, and Speed of Sound of Dialkyl Carbonates with Cyclopentane and Methyl Cyclohexane at Sever Temperatures" Journal of chemical and engineering data, vol. 49, no.5, pp.1392-1399, 2004.

[21] P. Umadevi a , K. Rambabu a , M. N. Rao a , K. S. Rao a & C.Rambabu**;** "Densities, Adiabatic Compressibility, Free-Length, Viscosities and Excess Volumes of P-Cresol(1) +Dimethyl Sulfoxide (2), and 1, 4-Dioxane (2) at 303.15–318.15 K Physics and Chemistry of Liquids" Vol. 30, pp. 29-46, 1995.

[22] Sk Fakruddin, P. Shakira, Ch Srinivasu, K. Narendra "Comparative study of theoretical Ultrasonic velocities of binary liquid mixtures containing quinoline and mesitylene at temperaturesT= (303.15, 308.15, 313.15 and 318.15) K" Karbala International Journal of Modern Science vol.1 PP.172-177, 2015.

[23] R. J. Fort and W. R. Moore, "Viscosities of binary liquid mixtures," Transactions of the Faraday Society, vol. 62, pp. 1112–1119, 1966.

[24] R. K. Nigam and B. S. Mahl, "Molecular interaction in binary liquid mixtures of Dimethylslphoxide with chlroehanes & chlroehenes," Indian Journal of Chemistry, vol. 9, p. 1255, 1971.