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Theoretical Prediction of Ultrasonic Velocities in Liquid Mixtures of Cyclohexanone with Di-hydroxy Glycols at Various Temperatures

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Abstract- Ultrasonic velocity and density values have been measured for the binary liquid mixtures of cyclohexanone as a common component with glycols(Mono ethylene glycol, Diethylene glycol and Tri etyhlyene glycol) at 303, 308, 313 and 318K over the entire composition range. Theoretical velocity values have been evaluated by various relations viz., Nomoto, Free Length Theory (FLT), Van deal and Vangeel ideal mixing relation (IMR), Impedance Dependence Relation (IDR), and Junjie for three binary liquid mixtures. An attempt has been made to compare the merits of the relations and the relative applicability of these theories to the present systems have been checked and discussed. The results are explained in terms of intermolecular interactions occurring in these binary systems. The deviation in the variation of U^2_{exp} / U^2_{imx} from unity has also been evaluated for explaining the non-ideality in the mixtures.

Index Terms: ultrasonic velocity; binary liquid mixture; theoretical velocity; intermolecular interactions; non-ideality.

1. INTRODUCTION

In recent years much interest has been shown on the study of physico-chemical properties, behaviour and molecular interactions in liquid mixtures. The analysis of thermodynamic properties of the liquid mixtures can be used to get the qualitative information about the energetic and structural effects and packing phenomena that govern the mixing process. Ultrasonic velocity studies in binary and multi component liquid mixtures which are capable to reveal the hydrogen bonding among the molecules has been carried out by many researchers [1-3].

Theoretical evaluation of ultrasonic velocity in binary liquid mixtures and its correlation to study molecular interaction has been successfully done in recent years[4-6]. Ultrasonic velocities of liquid mixtures are of considerable importance in understanding intermolecular interaction between component molecules, and they find applications in several industrial and technological processes. Several relations, semi-empirical formula and theories are available for the theoretical computation of ultrasonic velocity in liquid and liquid mixtures. Using the theories available in literature, ultrasonic velocities in liquid mixtures have been calculated and compared with those obtained experimentally. The comparison of theoretical ultrasonic velocities with those obtained experimentally reveals the nature of interactions between the component molecules in the mixtures. Dihydroxy glycols are important organic liquids with extensive use. They are self-associated because of the hydrogen bonding ability of its two hydroxyl groups; this ability is stronger in dihydroxy glycols than in mono hydroxyl alcohols. Similarly Cyclohexanone is also an industrially important liquid.

The aim of the present investigation is to compare the ultrasonic sound velocity in three binary liquid mixtures from various theoretical relations of Nomoto, Free Length Theory (FLT), Van deal and Vangeel ideal mixing relation (IMR), Impedance Dependence Relation (IDR), and Junjie. An attempt has been made to compare the merits of the relations for the binary liquid mixtures investigated at four different temperatures. The relative applicability of these theories to the present systems have been checked and discussed. The results are explained in terms of intermolecular interactions occurring in these binary systems. The deviation in the variation of U^2_{exp} / U^2_{imx} from unity has also been evaluated for explaining the non-ideality of the mixtures.

2. EXPERIMENTAL

The binary liquid mixtures under study are:
1.Cyclohexanone + Monoethylene glycol (CY+MEG)

2.Cyclohexanone + Diethylene glycol (CY+DEG) and
3.Cyclohexanone + Triethylene glycol (CY+TEG)

All the chemicals used in the present research work are analytical reagent of minimum assay of 99.9% obtained from E-Merck, Germany and Sd. Fine Chemicals, India, which were used without further purification. The liquid mixtures were prepared by mixing calculated amount of pure liquids. The ultrasonic velocities in the liquid mixtures were measured using a single crystal variable path interferometer operating at a frequency of 2MHz (MITTAL ENTERPRISES, New Delhi, Model:F-81) with an overall accuracy of ± 0.1%. The temperature during the experiment was controlled by circulating water around the liquid cell from the thermostatically controlled adequately stirred water bath. The densities of pure liquids and liquid mixtures were determined from the weight measurements using 10ml specific gravity bottle by the standard procedure with an accuracy of ±0.1kg m^{-3}.

3. THEORETICAL ASPECTS

3.1 Nomoto's Relation:

Rao found experimentally that[7], for pure liquids, the ratio of temperature coefficients of sound velocity U and molar volume remains almost constant:

$$\frac{\left(\frac{1}{U}\right)\left(\frac{dU}{dT}\right)}{\left(\frac{1}{V}\right)\left(\frac{dV}{dT}\right)} = -3$$

Where T is the absolute temperature. On Integrating this equation we get

$$VU^{1/3} = cons\tan t = \frac{M}{\rho U^{1/3}} = R$$

Where M is molecular weight and ρ is density. The constant R is called the molar sound velocity or Rao's constant. It was found to be additive i.e., it can be calculated as a sum of increments from the atoms or atom groups in the molecule and from the chemical bonds.On assuming the additivity of molar sound velocity (R) and no volume change on mixing, Nomoto established the following relation for a liquid mixture

$$R = \frac{M}{\rho U^{1/3}}$$

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

$$M = \left(X_1 M_1 + X_2 M_2\right)$$

Where X_1 and X_2 are the mole fractions and M_1 and M_2 are molecular weights of constituent components respectively. Simple theoretical treatment gives the following relation

$$U_{Nomoto} = \left[\frac{\left(X_1 R_1 + X_2 R_2\right)}{\left(X_1 V_1 + X_2 V_2\right)}\right]^3 \quad (1)$$

3.2 Relation based on Free Length Theory

Jacobson[8] deduce an empirical relation for ultrasonic velocity (U_{FLT}) making use of intermolecular free length (L_f) and density (ρ) as

$$U_{FLT} = \left[\frac{K}{L_{f_{mix}} \rho_{\exp}^{1/2}}\right] \quad (2)$$

Where K is temperature dependent called Jacobson's constant and the value of K at the working temperatures of the experiment were calculated (MKS units) and they are given below

Temp(^{0}K)	303	308	313	318
Value of K	2.075 ×10^{-6}	2.095 ×10^{-6}	2.115 ×10^{-6}	2.135 ×10^{-6}

3.3 Ideal Mixing Relation based on the Van Deal and Vangeel Theory

Van Deal and Vangeel [9] proposed the ideal mixing theory in the light of assumptions made by Blandamer and Wadding[10], yield the following relation for adiabatic compressibility $(\beta_{ad})_{imix}$

$$\left(\beta_{ad}\right)_{imix} = \Phi_1 \frac{\gamma_1}{\gamma_{imix}} \left(\beta_{ad}\right)_1 + \Phi_2 \frac{\gamma_2}{\gamma_{imix}} \left(\beta_{ad}\right)_2$$

Where Φ_1 and Φ_2 volume fractions of the liquids 1 and 2, γ_1 and γ_2 are the ratios of specific heats of the respective liquids. This relation holds good if the mixture is ideal and if $\gamma_{1=}\ \gamma_{2=}\ \gamma_{imix}$. Using the additional assumption that $V_1=V_2$ the above equation can be transformed into a linear combination of mole fraction X_1 and X_2,

$$\left(\beta_{ad}\right)_{imix} = X_1 \left(\beta_{ad}\right)_1 + X_2 \left(\beta_{ad}\right)_2$$

On the basis of this equation, Van Deal and Vangeel obtained the relation for ultrasonic velocity in liquid mixtures as

$$U_{IMR} = \left[\frac{1}{X_1 M_1 + X_2 M_2}\right]^{\frac{1}{2}} \left[\frac{X_1}{M_1 U_1^2} + \frac{X_2}{M_2 U_2^2}\right]^{\frac{-1}{2}} \quad (3)$$

Where U_1 and U_2 are the ultrasonic velocities of the pure liquid components.

3.4 Impedance Dependence Relation

The ultrasonic velocity can be evaluated by the Impedance Dependence Relation [11] of the following form

$$U_{IDR} = \frac{X_1 Z_1 + X_2 Z_2}{X_1 \rho_1 + X_2 \rho_2} \quad (4)$$

where X_1 and X_2 are the mole fractions, ρ_1 and ρ_2 are the densities and Z_1 and Z_2 are the acoustic impedances of the liquid components.

3.5 Junjie's Relation

Junjie's Relation[12] for ultrasonic velocity is given by

$$U_{Junjie} = \left[\frac{X_1V_1 + X_2V_2}{\left(X_1M_1 + X_2M_2\right)^{1/2}}\right]\left[\frac{X_1V_1}{\rho_1U_1^2} + \frac{X_2V_2}{\rho_2U_2^2}\right]^{-1/2} \quad (5)$$

Where, 1& 2 represents the first and second component of the liquid mixture and the other symbols have their usual meanings.

3.6 Percentage Deviation

The percentage deviation is calculated from the relation

$$Percentage Deviation = \sum \frac{\left(U_{mix(obs)} - U_{mix(cal)}\right)}{U_{mix(obs)}} X100 \quad (6)$$

Here, $U_{mix(obs)}$ is experimental value of ultrasonic velocity and $U_{mix(cal)}$ is computed value of ultrasonic velocity. The worst-case error is the maximum value of deviation of the theoretical values from experimental values of ultrasonic velocity.

3.7 Degree of interaction, α

The deviation of the ratio U^2_{exp} / U^2_{imx} from unity is called degree of interaction, α.

4. RESULTS AND DISCUSSION

The theoretical relations used to calculate ultrasonic velocity in all the above liquid mixtures are mentioned above at different temperatures 303, 308, 313 and 318K and the values along with the experimental values are given in the Tables from 1.1 to 1.3. Also the validity of different theoretical formulae is checked by percentage deviation for all the mixtures and at all the temperatures are shown.

It is observed from the tabulated values that the theoretical values of ultrasonic velocities evaluated by the above mentioned relations show deviations from the experimental values. The reason for the deviation may be the limitations and approximations incorporated in these theories. The effect of volume change due to mixing was not considered in the Nomoto's relation. That is interaction between the molecules was not taken into account. In Free Length theory, it was assumed that the molecules are of spherical shape but it is not true at all times. In the case of Ideal mixing relation, it was assumed that, the ratio of specific heats and volumes are equal. Again no molecular interactions were considered.

Upon mixing two liquids, the interaction between the molecules of the two liquids take place because of the 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 the molecular interactions between the unlike molecules in the liquid mixture[13-18].

4.1Cyclohexanone+Monoethyleneglycol (CY+ MEG)

From the reported values, Table 1.1, it can be observed that the experimental values are very close in agreement with the computed values by the Impedance Dependence Relation, followed by the values obtained by Nomoto's relation, Ideal Mixing Relation and Junjie's relation. The percentage deviations are very less positive in the case of IDR values , where as the deviations are negative for the values obtained by the other relations. More over the deviations are slightly increase with increase in temperature. Very large deviations are observed for the values evaluated by the FLT, at all temperatures. The Impedance Dependence Relation gives the best approximation for this binary mixture.

4.2 Cyclohexanone + Diethylene glycol (CY + DEG)

A perusal of Table 1.2 reveals that the values calculated on the basis of Impedance Dependence Relation are in good agreement with the experimental values and there is no significant deviation at all temperatures. Next to that, the values obtained by Nomoto's relation are very close to that of the experimental values and a slight negative deviation is observed. The values evaluated by the Ideal Mixing Relation and Junjie's relation follows the above respectively with a little more deviations. For this mixture also the FLT gives a large deviation in evaluated ultrasonic velocity values compared to the values obtained by the other four relations.

4.3 Cyclohexanone + Triethylene glycol (CY + TEG)

A close look at Table 1.3 reveals that velocities determined by Impedance Dependence Relation give a very close approximation with the measured values and the deviation observed is almost nil. The deviation in values calculated by Nomoto's relation, Junjie's relation and Ideal Mixing Relation follows the deviation of the values obtained by Impedance Dependence Relation respectively. In this case also the observed fact is that, FLT approximated values are much higher than the experimental values, the percentage deviations are also high and decrease with increase in temperature.

Velocities were determined on the basis of different theories and relations are discussed by other researchers earlier[19-21] and the validity of different theoretical formulae is checked by percentage deviation at different temperatures. As per the earlier studies, the limitations and approximations

incorporated in these theories are responsible for the deviations between theoretical and experimental values.

Table 1.1 : Experimental and Theoretical values of Ultrasonic velocityand Percentage of Deviation at different temperatures for the binary liquid mixture- I (Cyclohexanone + Monoethylyne Glycol)

Mole fraction of CY	Exp. Velocity	Theoritical velocity					Percentage Deviation					$\frac{U^2}{U^2_{imx}}$
X_1	U_{exp}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Junjie}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Jun}	
303K												
0.0000	1647.8	1647.8	1647.8	1647.8	1647.8	1647.8	0.00	0.00	0.00	0.00	0.00	1.0000
0.0564	1636.1	1622.7	1301.9	1619.2	1636.1	1612.0	-0.8	-25	-1.0	0.00	-1.4	1.0209
0.1188	1623.0	1597.8	608.24	1590.4	1623.0	1579.7	-1.5	-166	-2.0	0.00	-2.7	1.0413
0.1879	1608.2	1573.2	2925.6	1561.8	1608.2	1550.4	-2.2	154	-2.9	0.00	-3.7	1.0602
0.2647	1591.4	1548.8	5586.2	1533.5	1591.4	1523.9	-2.7	71.5	-3.7	0.00	-4.4	1.0768
0.3505	1572.1	1524.7	3067.6	1506.0	1572.1	1499.9	-3.1	48.7	-4.3	0.00	-4.8	1.0895
0.4474	1549.6	1500.9	2383.8	1479.7	1549.8	1477.9	-3.2	34.9	-4.7	0.01	-4.8	1.0965
0.5574	1523.5	1477.3	2014.6	1455.3	1523.5	1457.9	-3.1	24.3	-4.6	0.00	-4.4	1.0957
0.6835	1492.3	1453.9	1765.7	1434.0	1492.3	1439.7	-2.6	15.4	-4.0	0.00	-3.6	1.0829
0.8292	1454.6	1430.8	1573.1	1417.3	1454.6	1423.1	-1.6	7.53	-2.6	0.00	-2.2	1.0532
1.0000	1408.0	1408.0	1408.0	1408.0	1408.0	1408.0	0.00	0.00	0.00	0.00	0.00	1.0000
308K												
0.0000	1631.0	1631.0	1631.0	1631.0	1631.0	1631.0	0.00	0.00	0.00	0.00	0.00	1.0000
0.0564	1617.8	1603.9	1167.1	1601.3	1617.8	1593.3	-0.8	-38.	-1.0	0.00	-1.5	1.0206
0.1188	1603.0	1576.9	5192.9	1571.4	1603.0	1558.8	-1.6	69.1	-2.0	0.00	-2.8	1.0405
0.1879	1586.3	1550.0	2383.4	1541.4	1586.3	1527.3	-2.3	33.4	-2.9	0.00	-3.8	1.0590
0.2647	1567.4	1523.3	2101.2	1511.6	1567.5	1498.4	-2.8	25.4	-3.6	0.00	-4.6	1.0750
0.3505	1546.0	1496.9	1930.7	1482.4	1546.0	1471.9	-3.2	19.9	-4.2	0.00	-5.0	1.0876
0.4474	1521.2	1470.5	1788.5	1453.9	1521.2	1447.4	-3.4	14.9	-4.6	0.00	-5.0	1.0945
0.5574	1492.2	1444.3	1667.3	1427.0	1492.2	1424.8	-3.3	10.5	-4.5	0.00	-4.7	1.0934
0.6835	1457.9	1418.3	1562.8	1402.4	1458.0	1403.9	-2.7	6.71	-3.9	0.00	-3.8	1.0806
0.8292	1416.8	1392.5	1463.9	1381.6	1416.9	1384.6	-1.7	3.22	-2.5	0.01	-2.3	1.0515
1.0000	1366.8	1366.8	1366.8	1366.8	1366.8	1366.8	0.00	0.00	0.00	0.00	0.00	1.0000
313K												
0.0000	1621.8	1621.8	1621.8	1621.8	1621.8	1621.8	0.00	0.00	0.00	0.00	0.00	1.0000
0.0564	1607.4	1593.9	328.46	1591.7	1607.8	1583.5	-0.8	-389	-0.9	0.02	-1.5	1.0197
0.1188	1591.8	1566.1	2081.4	1561.2	1592.2	1548.2	-1.6	23.5	-1.9	0.02	-2.8	1.0394
0.1879	1574.2	1538.3	1881.4	1530.6	1574.7	1515.8	-2.3	16.3	-2.8	0.03	-3.8	1.0576
0.2647	1554.5	1510.6	1801.0	1500.2	1554.9	1485.9	-2.9	13.6	-3.6	0.02	-4.6	1.0736
0.3505	1532.3	1483.1	1728.6	1470.1	1532.4	1458.3	-3.3	11.3	-4.2	0.00	-5.0	1.0862
0.4474	1506.4	1455.6	1645.5	1440.7	1506.4	1432.6	-3.4	8.45	-4.5	0.00	-5.1	1.0931
0.5574	1476.4	1428.2	1563.4	1412.7	1476.2	1408.8	-3.3	5.56	-4.5	0.01	-4.7	1.0922
0.6835	1440.8	1401.0	1490.4	1386.6	1440.7	1386.6	-2.8	3.32	-3.9	0.01	-3.9	1.0795
0.8292	1398.1	1373.8	1420.4	1364.0	1398.3	1366.0	-1.7	1.57	-2.4	0.01	-2.3	1.0505
1.0000	1346.8	1346.8	1346.8	1346.8	1346.8	1346.8	0.00	0.00	0.00	0.00	0.00	1.0000
318K												
0.0000	1614.0	1614.0	1614.0	1614.0	1614.0	1614.0	0.00	0.00	0.00	0.00	0.00	1.0000
0.0564	1598.8	1585.4	1924.8	1583.4	1599.3	1575.1	-0.8	16.9	-0.9	0.03	-1.5	1.0194
0.1188	1582.4	1556.7	1699.6	1552.4	1582.8	1539.1	-1.6	6.86	-1.9	0.03	-2.8	1.0389
0.1879	1564.0	1528.1	1659.4	1521.2	1564.4	1505.8	-2.3	5.75	-2.8	0.02	-3.8	1.0569
0.2647	1543.4	1499.4	1633.5	1490.1	1543.6	1474.9	-2.9	5.51	-3.5	0.01	-4.6	1.0727
0.3505	1520.0	1470.9	1602.3	1459.3	1520.1	1446.2	-3.3	5.13	-4.1	0.00	-5.0	1.0849
0.4474	1493.0	1442.3	1544.4	1428.9	1493.0	1419.4	-3.5	3.32	-4.4	0.00	-5.1	1.0916
0.5574	1461.6	1413.8	1489.6	1399.7	1461.7	1394.4	-3.3	1.88	-4.4	0.00	-4.8	1.0903
0.6835	1424.8	1385.2	1436.3	1372.3	1424.9	1370.9	-2.8	0.80	-3.8	0.00	-3.9	1.0778
0.8292	1380.8	1356.8	1384.8	1347.9	1381.2	1349.0	-1.7	0.29	-2.4	0.03	-2.3	1.0492
1.0000	1328.4	1328.4	1328.4	1328.4	1328.4	1328.4	0.00	0.00	0.00	0.00	0.00	1.0000

Table 1.2 : Experimental and Theoretical values of Ultrasonic velocityand Percentage of Deviation at different temperatures for the binary liquid mixture- II (Cyclohexanone + Diethylyne Glycol)

Mole fraction of CY	Exp. Velocity	Theoritical velocity					Percentage Deviation					$\frac{U^2}{U^2_{imx}}$
X_1	U_{exp}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Junjie}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Jun}	
303K												
0.0000	1561.2	1561.2	1561.2	1561.2	1561.2	1561.2	0.00	0.00	0.0	0.00	0.00	1.0000
0.0925	1548.9	1545.4	1766.8	1543.7	1548.9	1539.1	-0.2	12	-0.3	0.00	-0.6	1.0067
0.1916	1535.4	1528.9	1969.9	1525.8	1535.4	1518.0	-0.4	22	-0.6	0.00	-1.1	1.0125
0.2829	1522.6	1514.1	2030.9	1510.1	1522.6	1500.4	-0.5	25	-0.8	0.00	-1.4	1.0165
0.3803	1508.6	1498.6	1856.7	1494.1	1508.6	1483.4	-0.6	18	-0.9	0.00	-1.6	1.0194
0.4792	1494.0	1483.3	1725.6	1478.5	1493.9	1467.8	-0.7	13	-1.0	0.00	-1.7	1.0209
0.5801	1478.4	1467.9	1633.2	1463.5	1478.3	1453.6	-0.7	9.	-1.0	0.00	-1.7	1.0204
0.6823	1462.2	1452.8	1558.5	1448.9	1462.1	1440.5	-0.6	6.	-0.9	0.00	-1.5	1.0183
0.7864	1445.0	1437.8	1501.7	1434.8	1445.0	1428.6	-0.5	3.	-0.7	0.00	-1.1	1.0142
0.8922	1427.0	1422.8	1453.7	1421.1	1427.0	1417.8	-0.2	1.8	-0.4	0.00	-0.6	1.0081
1.0000	1408.0	1408.0	1408.0	1408.0	1408.0	1408.0	0.00	0.00	0.0	0.00	0.00	1.0000
308K												
0.0000	1550.8	1550.8	1550.8	1550.8	1550.8	1550.8	0.00	0.00	0.00	0.00	0.00	1.0000
0.0925	1536.2	1531.7	1617.6	1529.5	1536.1	1523.7	-0.2	5.03	-0.4	0.00	-0.8	1.0086
0.1916	1519.9	1511.7	1742.2	1507.9	1519.9	1497.9	-0.5	12.7	-0.7	0.00	-1.4	1.0159
0.2829	1504.6	1493.8	1796.7	1488.9	1504.6	1476.7	-0.7	16.2	-1.0	0.00	-1.8	1.0211
0.3803	1487.8	1475.1	1684.7	1469.6	1487.7	1456.3	-0.8	11.6	-1.2	0.00	-2.1	1.0248
0.4792	1470.2	1456.7	1593.9	1451.0	1470.1	1437.7	-0.9	7.76	-1.3	0.00	-2.2	1.0266
0.5801	1451.6	1438.3	1521.5	1432.9	1451.5	1420.7	-0.9	4.59	-1.3	0.00	-2.1	1.0261
0.6823	1431.8	1420.2	1469.2	1415.5	1431.9	1405.3	-0.8	2.54	-1.1	0.01	-1.8	1.0230
0.7864	1411.4	1402.2	1426.4	1398.7	1411.4	1391.2	-0.6	1.05	-0.9	0.00	-1.4	1.0182
0.8922	1389.7	1384.4	1392.0	1382.4	1389.7	1378.4	-0.3	0.16	-0.5	0.00	-0.8	1.0104
1.0000	1366.8	1366.8	1366.8	1366.8	1366.8	1366.8	0.00	0.00	0.00	0.00	0.00	1.0000
313K												
0.0000	1543.5	1543.5	1543.5	1543.5	1543.5	1543.5	0.00	0.00	0.00	0.00	0.00	1.0000
0.0925	1527.9	1523.0	1565.5	1520.6	1527.8	1514.3	-0.3	2.40	-0.4	0.00	-0.8	1.0095
0.1916	1510.6	1501.6	1636.3	1497.4	1510.5	1486.5	-0.5	7.68	-0.8	0.00	-1.6	1.0176
0.2829	1494.2	1482.4	1687.1	1477.0	1494.1	1463.7	-0.7	11.4	-1.1	0.00	-2.0	1.0233
0.3803	1476.1	1462.4	1592.9	1456.4	1476.1	1441.9	-0.9	7.33	-1.3	0.00	-2.3	1.0271
0.4792	1457.3	1442.7	1517.0	1436.5	1457.2	1422.1	-1.0	3.94	-1.4	0.00	-2.4	1.0291
0.5801	1437.4	1423.1	1462.3	1417.2	1437.3	1404.0	-1.0	1.70	-1.4	0.00	-2.3	1.0286
0.6823	1416.5	1403.7	1418.7	1398.6	1416.5	1387.6	-0.9	0.15	-1.2	0.00	-2.0	1.0256
0.7864	1394.4	1384.5	1385.6	1380.7	1394.5	1372.7	-0.7	-0.6	-0.9	0.00	-1.5	1.0198
0.8922	1371.3	1365.6	1362.4	1363.4	1371.3	1359.1	-0.4	-0.6	-0.5	0.00	-0.8	1.0115
1.0000	1346.8	1346.8	1346.8	1346.8	1346.8	1346.8	0.00	0.00	0.00	0.00	0.00	1.0000
318K												
0.0000	1536.2	1536.2	1536.2	1536.2	1536.2	1536.2	0.00	0.00	0.00	0.00	0.00	1.0000
0.0925	1519.6	1514.5	1533.9	1511.9	1519.6	1505.2	-0.3	0.93	-0.5	0.00	-0.9	1.0101
0.1916	1501.4	1491.8	1566.2	1487.2	1501.4	1475.8	-0.6	4.13	-0.9	0.00	-1.7	1.0190
0.2829	1484.0	1471.5	1581.8	1465.7	1484.0	1451.6	-0.8	6.18	-1.2	0.00	-2.2	1.0250
0.3803	1465.1	1450.4	1514.6	1443.9	1465.0	1428.6	-1.0	3.27	-1.4	0.00	-2.5	1.0295
0.4792	1445.2	1429.6	1456.2	1422.8	1445.0	1407.7	-1.0	0.75	-1.5	0.00	-2.6	1.0316
0.5801	1424.0	1408.9	1410.8	1402.5	1424.0	1388.7	-1.0	-0.9	-1.5	0.00	-2.5	1.0308
0.6823	1402.0	1388.4	1376.3	1382.9	1402.0	1371.4	-0.9	-1.8	-1.3	0.00	-2.2	1.0277
0.7864	1378.8	1368.2	1353.7	1364.0	1378.7	1355.7	-0.7	-1.8	-1.0	0.00	-1.7	1.0216
0.8922	1354.4	1348.2	1336.8	1345.9	1354.3	1341.4	-0.4	-1.3	-0.6	0.00	-0.9	1.0126
1.0000	1328.4	1328.4	1328.4	1328.4	1328.4	1328.4	0.00	0.00	0.000	0.00	0.00	1.0000

Table 1.3 : Experimental and Theoretical values of Ultrasonic velocityand Percentage of Deviation at different temperatures for the binary liquid mixture- III (Cyclohexanone + Triethylyne Glycol)

Mole fraction of CY	Exp. Velocity	Theoritical velocity					Percentage Deviation					$\frac{U^2}{U^2_{imx}}$
X_1	U_{exp}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Junjie}	U_{Nom}	U_{FLT}	U_{IMR}	U_{IDR}	U_{Jun}	
303K												
0.0000	1592.0	1592.0	1592.0	1592.0	1592.0	1592.0	0.00	0.00	0.00	0.00	0.00	1.0000
0.1255	1572.0	1572.9	2169.1	1524.8	1572.0	1565.0	0.06	27.5	-3.0	0.00	-0.4	1.0627
0.2444	1552.4	1554.0	2205.7	1476.2	1552.4	1540.4	0.10	29.6	-5.1	0.00	-0.7	1.1058
0.3568	1533.0	1535.2	2110.0	1441.5	1533.1	1518.0	0.14	27.3	-6.3	0.01	-0.9	1.1309
0.4633	1514.3	1516.5	2038.5	1417.4	1514.2	1497.6	0.15	25.7	-6.8	0.00	-1.1	1.1412
0.5643	1495.8	1498.1	1957.7	1401.8	1495.7	1478.9	0.15	23.5	-6.6	0.00	-1.1	1.1384
0.6601	1477.6	1479.7	1859.5	1393.1	1477.5	1462.0	0.14	20.5	-6.0	0.00	-1.0	1.1248
0.7513	1459.7	1461.6	1761.3	1390.1	1459.6	1446.5	0.13	17.1	-5.0	0.00	-0.9	1.1025
0.8381	1442.2	1443.6	1660.9	1392.0	1442.1	1432.4	0.09	13.1	-3.6	0.00	-0.6	1.0734
0.9209	1425.0	1425.7	1533.1	1398.1	1424.9	1419.6	0.05	7.05	-1.9	0.00	-0.3	1.0388
1.0000	1408.0	1408.0	1408.0	1408.0	1408.0	1408.0	0.00	0.00	0.00	0.00	0.00	1.0000
308K												
0.0000	1586.0	1586.0	1586.0	1586.0	1586.0	1586.0	0.00	0.00	0.00	0.00	0.00	1.0000
0.1255	1562.0	1563.0	1924.1	1511.2	1562.3	1552.9	0.06	18.8	-3.3	0.01	-0.5	1.0682
0.2444	1538.4	1540.3	1943.4	1456.9	1538.9	1523.1	0.12	20.8	-5.5	0.03	-1.0	1.1149
0.3568	1515.3	1517.8	1928.0	1417.8	1516.0	1496.2	0.16	21.4	-6.8	0.05	-1.2	1.1421
0.4633	1493.0	1495.5	1874.0	1390.2	1493.5	1471.8	0.16	20.3	-7.3	0.03	-1.4	1.1532
0.5643	1471.0	1473.4	1805.8	1371.7	1471.5	1449.8	0.16	18.5	-7.2	0.03	-1.4	1.1500
0.6601	1449.2	1451.7	1735.5	1360.3	1449.8	1429.8	0.17	16.5	-6.5	0.04	-1.3	1.1348
0.7513	1427.8	1430.1	1661.8	1355.0	1428.5	1411.7	0.16	14.0	-5.3	0.05	-1.1	1.1102
0.8381	1407.1	1408.8	1580.8	1354.7	1407.6	1395.2	0.12	10.9	-3.8	0.03	-0.8	1.0787
0.9209	1386.8	1387.7	1484.6	1358.8	1387.0	1380.3	0.06	6.59	-2.0	0.01	-0.4	1.0415
1.0000	1366.8	1366.8	1366.8	1366.8	1366.8	1366.8	0.00	0.00	0.00	0.00	0.00	1.0000
313K												
0.0000	1564.4	1564.4	1564.4	1564.4	1564.4	1564.4	0.00	0.00	0.00	0.00	0.00	1.0000
0.1255	1541.1	1541.7	1749.5	1490.3	1540.7	1532.1	0.04	11.9	-3.4	0.00	-0.5	1.0692
0.2444	1517.6	1519.2	1829.7	1436.5	1517.4	1502.8	0.11	17.0	-5.6	0.00	-0.9	1.1159
0.3568	1494.6	1497.0	1817.3	1397.8	1494.6	1476.3	0.16	17.7	-6.9	0.00	-1.2	1.1432
0.4633	1472.5	1474.9	1781.5	1370.4	1472.2	1452.2	0.16	17.3	-7.4	0.00	-1.3	1.1543
0.5643	1450.6	1453.0	1743.6	1352.0	1450.3	1430.3	0.17	16.8	-7.2	0.01	-1.4	1.1510
0.6601	1429.0	1431.4	1701.2	1340.7	1428.8	1410.4	0.17	16.0	-6.5	0.00	-1.3	1.1359
0.7513	1407.8	1409.9	1631.6	1335.4	1407.7	1392.2	0.15	13.7	-5.4	0.00	-1.1	1.1113
0.8381	1387.0	1388.7	1561.8	1335.0	1387.0	1375.6	0.12	11.1	-3.8	0.00	-0.8	1.0792
0.9209	1366.8	1367.6	1455.2	1339.0	1366.7	1360.5	0.06	6.07	-2.0	0.00	-0.4	1.0419
1.0000	1346.8	1346.8	1346.8	1346.8	1346.8	1346.8	0.00	0.00	0.00	0.00	0.00	1.0000
318K												
0.0000	1556.3	1556.3	1556.3	1556.3	1556.3	1556.3	0.00	0.00	0.00	0.00	0.00	1.0000
0.1255	1532.0	1532.7	1717.5	1480.0	1531.3	1522.7	0.04	10.8	-3.5	0.04	-0.6	1.0714
0.2444	1507.2	1509.2	1825.2	1424.6	1506.8	1492.3	0.13	17.4	-5.7	0.02	-0.9	1.1192
0.3568	1483.1	1485.9	1799.0	1384.7	1482.8	1464.7	0.19	17.5	-7.1	0.01	-1.2	1.1471
0.4633	1459.8	1462.8	1756.9	1356.3	1459.4	1439.5	0.20	16.9	-7.6	0.00	-1.4	1.1583
0.5643	1436.8	1439.9	1711.6	1337.0	1436.4	1416.6	0.21	16.0	-7.4	0.00	-1.4	1.1547
0.6601	1414.4	1417.2	1668.8	1325.0	1413.9	1395.7	0.20	15.2	-6.7	0.00	-1.3	1.1394
0.7513	1392.4	1394.7	1617.2	1318.9	1391.9	1376.5	0.17	13.9	-5.5	0.00	-1.1	1.1144
0.8381	1370.8	1372.4	1553.8	1317.9	1370.3	1359.0	0.12	11.7	-4.0	0.00	-0.8	1.0818
0.9209	1349.6	1350.3	1455.1	1321.2	1349.1	1343.0	0.05	7.25	-2.1	0.00	-0.4	1.0433
1.0000	1328.4	1328.4	1328.4	1328.4	1328.4	1328.4	0.00	0.00	0.00	0.00	0.00	1.0000

In present study of three binary mixtures, viz., cyclohexanone with di-hydroxy glycols, the velocities predicted by the IDR relation are in very good agreement than the other relations. Though the NR, IMR and Junjie's relations give a reasonably good values, the IDR relation gives the best prediction. Deviations obtained by FLT are quite large and in the present case this theory does not yield satisfactory results. The discrepancy in the values obtained from FLT is that the FLT is not strictly applicable to systems wherein the components are self-associated in nature[9]. Since the di-hydroxy glycols are self-associated, larger deviations are observed. The small deviations between the computed and experimental values suggests that the linearity of sound velocity and additivity property of molar volumes of the mixtures[7,8,21]. Deviations in values based on IMR can be attributed to the non-ideal nature of the mixture. The deviations in values according to Junjie's relation also confirm the above prediction.

The deviation of the ratio U^2_{exp} / U^2_{imx} from unity (degree of interaction, α) and its variation as a function of mole fraction of cyclohexanone is a direct measure of the non-ideality of the system as a consequence of association or other type of interactions. The positive values of α in all the system clearly indicate the existence of strong tendency for the formation of association in mixture through hydrogen bonded complexes.

Figs 1, 2 and 3 represent the variation of U^2_{exp} / U^2_{imx} with mole fraction of cyclohexanone. It is observed that the curves are similar in all the three systems with maximum approximately at 0.5 mole fraction of cyclohexanone at all temperatures. They are increasing with increase in temperature. The trend of the curves reveals a fact that the mixtures tend move towards more non-ideality up to the middle mole fraction of cyclohexanone, which suggests the formation of association in liquid mixtures through dipole-dipole interactions as reported by Shukla et al[22].

5. CONCLUSION

In the binary systems Cyclohexanone + Monoethylene glycol, Cyclohexanone + Diethylene glycol, Cyclohexanone + Triethylene glycol, the velocities determined by Impedance Dependence Relation give a very close approximation with the measured values and the deviation observed is almost nil. The deviation in values calculated by Nomoto's relation, Junjie's relation and Ideal Mixing Relation follows the deviation of the values obtained by Impedance Dependence Relation respectively.

Graphical representation for variation of U^2_{exp} / U^2_{imx} with mole fraction of cyclohexanone

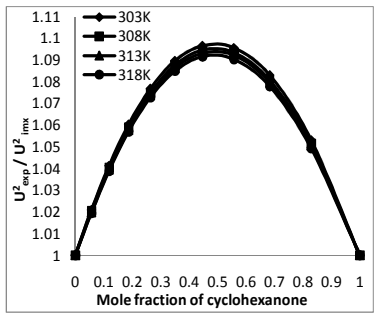

Fig.1 for CY+MEG

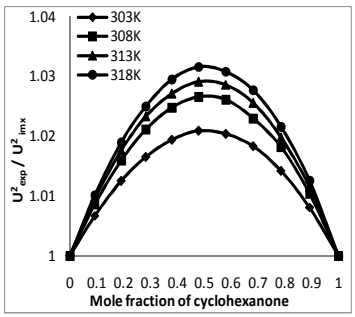

Fig.2 for CY+DEG

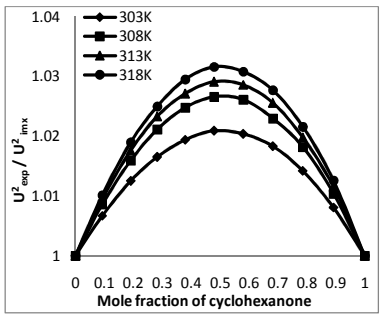

Fig.3 for CY+DEG

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