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Experimental and Theoretical Ultrasonic Velocities of Binary Liquid Mixtures at Temperatures (303.15, 308.15, 313.15 and 318.15)K – Comparative Study

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Abstract. Ultrasonic velocities of binary liquid mixtures of anisaldehyde with *o*-xylene, *m*-xylene and *p*-xylene were measured using ultrasonic interferometer at 303.15, 308.15, 313.15 and 318.15 K over the entire composition range. A comparative study of Nomoto, Van Dael-Vangeel, Impedance dependence, Rao's specific velocity and Junjie's relations for predicting the ultrasonic velocities of a liquid was carried out to test their validity for the binary systems over the entire mole fraction range at the four temperatures. A good agreement was found between experimental and Nomoto's ultrasonic velocities followed by Rao's specific velocity. U^2_{exp}/U^2_{imx} was also evaluated for non-ideality in the mixtures. The results are explained in terms of molecular interactions occurring in these binary liquid mixtures.

Keywords: ultrasonic velocities, anisaldehyde, xylenes, binary mixtures, theoretical models

Introduction

In estimating the nature of molecular interactions and to know the physico-chemical behaviour, measurement of ultrasonic velocities in liquids and liquid mixtures has gained much importance. Several researchers (Narendra *et al.,* 2010; Uvarani and Punitha, 2009; Rao *et al.,* 2005; Ali *et al.,* 2001; Arumugam *et al.,* 1998) carried out ultrasonic investigations on binary liquid mixtures and compared the experimental results with the theoretical relations (Nomoto, 1958) of Van Dael and Vangeel (Bhatia *et al.,* 2010), Impedance dependence (Baluja and Parsania, 1995), Rao's specific velocity (Kumar and Rao, 2007) and Junjie's (Azhagiri *et al.,* 2009) equations and the results are explained in terms of molecular interactions. Densities and ultrasonic velocities in three binary liquid mixtures are measured experimentally and the experimental values of velocities are compared with the above mentioned theoretical relations at four temperatures. Based on the deviation in U^2_{exp}/U^2_{imx} the molecular interactions are studied.

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Materials and Methods

The chemicals used were of AnalaR grade and obtained from SRL Chemicals (anisaldehyde) and Merck (xylenes). The chemicals were purified by standard procedure (Perrin and Armarego, 1980). The purity of samples was checked by comparing experimental values of density and ultrasonic velocity with the available literature (Baskaran and Kubendran, 2008; Al-Kandary *et al.,* 2006). Job's method of continuous variation was used to prepare the mixtures of required proportions. The prepared mixtures were preserved in well-stoppard conical flasks. After mixing the liquids thoroughly, the flasks were left undisturbed to allow them to attain thermal equilibrium.

The densities of pure liquids and liquid mixtures were measured using a specific gravity bottle with an accuracy of ± 0.5%. Weights were measured with an electronic balance (Shimadzu AUY220, Japan) capable of measuring up to 0.1 mg. An average of 4-5 measurements was taken for each sample.

The ultrasonic velocities were measured using single crystal ultrasonic pulse echo interferometer (Mittal enterprises, India; Model: F-80X). It consists of a high

frequency generator and a measuring cell. The measurements of ultrasonic velocities were made at the fixed frequency of 3 MHz. The calibration of the equipment was done by measuring the velocity in carbon tetrachloride and benzene. The results were in good agreement with the literature values (Lide, 1995). The ultrasonic velocity had an accuracy of ± 0.5 m/s. The temperature was controlled by circulating water around the liquid cell from thermostatically controlled constant temperature water bath.

Results and Discussion

Comparison of the experimental values with the earlier reported values of density, for checking the purity of samples, is given in Table 1. Theoretical values of ultrasonic velocities in the present binary liquid mixtures were calculated using different theories and empirical relations. Comparison of theoretical values of ultrasonic velocities with those obtained experimentally in the present binary liquid mixtures is expected to reveal the nature of interaction between the component molecules in the mixture. Such theoretical study is useful in building the comprehensive theoretical model for the liquid mixtures. Theoretical values of ultrasonic velocities in the mixtures: anisaldehyde + *o*-xylene, + *m*-xylene and + *p*-xylene at different mole fractions of anisaldehyde for different temperatures were calculated using the following theories and relations:

Nomoto (1958) established an empirical relation for ultrasonic velocity in binary liquid mixtures as:

$$U_N = [(x_1R_1+x_2R_2)/(x_1V_1+x_2V_2)]^3 \quad (1)$$

Where, R is molar sound velocity, x_1 and x_2 are the mole fractions of the 1st and the 2nd components of the liquid mixture and V is molar volume.

Table 1. Experimental and literature values of density and ultrasonic velocity of pure liquids at 303.15K.

Pure liquid	ρ. 10^{-3}/(kg/m^3)		u/(m/s)	
	Exp.	Lit.	Exp.	Lit.
Anisaldehyde	1.1252	1.1255[a]	1694	1684[a]
o-xylene	0.8707	0.8707[b]	1339	1328.30[b]
m-xylene	0.8557	0.8555[b]	1304	1300.34[b]
p-xylene	0.8528	0.8523[b]	1288	1289.68[b]

[a]Baskaran and Kubendran (2008); [b]Al-Kandary *et al.* (2006).

Van Deal and Vangeel ideal mixing relation is:

$$U_{imx} = [(x_1/M_1U^2_1 + x_2/M_2U^2_2)(x_1M_1+x_2M_2)]^{-1/2} \quad (2)$$

Where, U_{imx} is the ideal mixing ultrasonic velocity in liquid mixture. U_1 and U_2 are ultrasonic velocities of individual compounds.

Impedance dependent relation:

$$U_{Im} = \Sigma x_iZ_i/ \Sigma x_i\rho_i \quad (3)$$

Where, x_i is the mole fraction, ρ_i the density of the mixture and Z_i is the acoustic impedance.

Rao's specific velocity:

$$U_R = (\Sigma x_i r_i \rho_i)^3 \quad (4)$$

Where, x_i is the mole fraction, U_i is the ultrasonic velocity, ρ_i the density of the mixture and r_i is the Rao's specific sound velocity = $U^{1/3}_i/\rho_i$

Junjie's equation:

$$U_J=(x_1M_1/\rho_1+x_2M_2/\rho_2)/[\{x_1M_1+x_2M_2\}^{1/2} x \{x_1M_1/\rho_1 U^2_1+x_2M_2/\rho_2U^2_2\}]^{1/2} \quad (5)$$

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

The theoretical evaluation of sound velocity based on different models in liquid mixtures has been used to correlate with the experimental findings. The theoretical values of ultrasonic velocities calculated using the equations 1-5 along with the experimental values for all the three mixtures at temperatures of 303.15, 308.15, 313.15 and 318.15K are given in Tables 2-4. The validity of these theories was checked by percentage deviation for all the mixtures at all the temperatures and is given in Tables 5-7.

It can be seen from Tables 2-4 that the theoretical values of ultrasonic velocity calculated using various theories show deviation from the experimental values. The limitations and approximation incorporated in these theories are responsible for the deviations of the theoretical values from the experimental values. In Nomoto's theory, it is supposed that the volume does not change on mixing. 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 dispersive forces, charge transfer, hydrogen bonding, dipole-dipole and dipole-induced dipole interactions. Thus, the observed deviation of

Table 2. Experimental and theoretical values of velocities (m/s) in anisaldehyde + *o*- xylene system at different temperatures

x_1	U_{exp}	U_N	U_{imx}	U_{Im}	U_R	U_J
			303.15K			
0.0000	1339	1338.75	1338.75	1338.75	1338.75	1429.23
0.1007	1382	1371.83	1367.64	1383.69	1372.06	1437.51
0.2012	1415	1405.44	1397.76	1426.08	1405.85	1447.47
0.3016	1451	1439.60	1429.19	1466.11	1440.15	1459.18
0.4018	1485	1474.31	1462.01	1503.99	1474.95	1472.77
0.5019	1520	1509.57	1496.33	1539.88	1510.25	1488.36
0.6018	1555	1545.39	1532.25	1573.93	1546.05	1506.11
0.7016	1596	1581.77	1569.87	1606.28	1582.36	1526.22
0.8012	1650	1618.72	1609.33	1637.06	1619.17	1548.93
0.9007	1673	1656.24	1650.77	1666.37	1656.50	1574.53
1.0000	1694	1694.33	1694.33	1694.33	1694.33	1603.38
			308.15K			
0.0000	1315	1315.00	1315.00	1315.00	1315.00	1410.31
0.1007	1357	1348.36	1343.80	1359.54	1348.27	1418.40
0.2012	1390	1382.21	1373.84	1401.65	1382.05	1428.18
0.3016	1425	1416.55	1405.21	1441.52	1416.33	1439.75
0.4018	1460	1451.38	1438.00	1479.34	1451.12	1453.23
0.5019	1495	1486.70	1472.30	1515.24	1486.42	1468.75
0.6018	1530	1522.50	1508.22	1549.39	1522.24	1486.49
0.7016	1570	1558.80	1545.88	1581.89	1558.57	1506.66
0.8012	1620	1595.60	1585.42	1612.87	1595.41	1529.52
0.9007	1647	1632.89	1626.96	1642.43	1632.78	1555.37
1.0000	1671	1670.67	1670.67	1670.67	1670.67	1584.59
			313.15K			
0.0000	1297	1297.50	1297.50	1297.50	1297.50	1392.91
0.1007	1335	1328.92	1324.78	1339.31	1328.83	1399.93
0.2012	1367	1360.77	1353.18	1378.83	1360.61	1408.53
0.3016	1400	1393.05	1382.80	1416.26	1392.85	1418.80
0.4018	1433	1425.78	1413.69	1451.75	1425.54	1430.83
0.5019	1466	1458.94	1445.95	1485.45	1458.69	1444.74
0.6018	1499	1492.54	1479.67	1517.50	1492.29	1460.67
0.7016	1535	1526.57	1514.95	1548.00	1526.36	1478.80
0.8012	1581	1561.05	1551.90	1577.08	1560.89	1499.34
0.9007	1608	1595.97	1590.65	1604.83	1595.88	1522.55
1.0000	1631	1631.33	1631.33	1631.33	1631.33	1548.74
			318.15K			
0.0000	1278	1278.15	1278.15	1278.15	1278.15	1373.56
0.1007	1309	1304.70	1301.49	1313.00	1304.58	1377.71
0.2012	1336	1331.56	1325.68	1345.97	1331.33	1383.17
0.3016	1363	1358.71	1350.79	1377.20	1358.40	1389.97
0.4018	1391	1386.15	1376.85	1406.83	1385.80	1398.18
0.5019	1419	1413.89	1403.93	1434.98	1413.52	1407.84
0.6018	1446	1441.92	1432.09	1461.76	1441.56	1419.04
0.7016	1476	1470.25	1461.40	1487.27	1469.93	1431.86
0.8012	1515	1498.87	1491.93	1511.59	1498.63	1446.43
0.9007	1536	1527.79	1523.77	1534.80	1527.65	1462.88
1.0000	1557	1557.00	1557.00	1556.98	1557.00	1481.38

Table 3. Experimental and theoretical values of velocities (m/s) in anisaldehyde + *m*- xylene system at different temperatures

x_1	U_{exp}	U_N	U_{imx}	U_{Im}	U_R	U_J
			303.15K			
0.0000	1304	1304.21	1304.21	1304.21	1304.21	1409.90
0.1023	1354	1340.20	1335.65	1355.03	1341.02	1417.38
0.2040	1391	1376.84	1368.48	1402.55	1378.33	1426.86
0.3053	1430	1414.15	1402.79	1447.07	1416.13	1438.45
0.4060	1467	1452.12	1438.68	1488.87	1454.43	1452.30
0.5062	1505	1490.77	1476.26	1528.19	1493.21	1468.60
0.6060	1543	1530.10	1515.66	1565.25	1532.48	1487.59
0.7052	1589	1570.12	1557.01	1600.23	1572.22	1509.54
0.8040	1646	1610.82	1600.46	1633.31	1612.45	1534.82
0.9022	1671	1652.23	1646.17	1664.63	1653.16	1563.88
1.0000	1694	1694.33	1694.33	1694.33	1694.33	1597.29
			308.15K			
0.0000	1285	1285.26	1285.27	1285.27	1285.26	1395.12
0.1023	1332	1320.94	1316.32	1335.31	1321.63	1402.96
0.2040	1369	1357.24	1348.73	1382.14	1358.48	1412.77
0.3053	1407	1394.17	1382.61	1426.06	1395.82	1424.66
0.4060	1446	1431.73	1418.06	1467.32	1433.65	1438.78
0.5062	1483	1469.94	1455.18	1506.18	1471.96	1455.32
0.6060	1520	1508.78	1494.10	1542.82	1510.75	1474.51
0.7052	1566	1548.27	1534.96	1577.43	1550.02	1496.63
0.8040	1618	1588.42	1577.89	1610.19	1589.77	1522.04
0.9022	1647	1629.21	1623.07	1641.22	1629.98	1551.17
1.0000	1671	1670.67	1670.67	1670.67	1670.67	1584.57
			313.15K			
0.0000	1266	1266.32	1266.32	1266.32	1266.32	1376.92
0.1023	1309	1300.16	1295.98	1313.77	1300.86	1383.74
0.2040	1345	1334.57	1326.89	1358.17	1335.84	1392.42
0.3053	1381	1369.57	1359.15	1399.78	1371.26	1403.08
0.4060	1417	1405.17	1392.85	1438.88	1407.12	1415.82
0.5062	1453	1441.35	1428.08	1475.67	1443.41	1430.83
0.6060	1488	1523.75	1464.95	1510.36	1480.14	1448.30
0.7052	1530	1550.41	1503.57	1543.12	1517.30	1468.48
0.8040	1577	1577.23	1544.08	1574.12	1554.89	1491.68
0.9022	1607	1604.20	1586.61	1603.48	1592.90	1518.27
1.0000	1631	1631.33	1631.33	1631.33	1631.33	1548.74
			318.15K			
0.0000	1244	1244.21	1244.21	1244.21	1244.21	1357.14
0.1023	1280	1273.42	1270.28	1284.95	1274.08	1361.13
0.2040	1311	1303.08	1297.33	1323.03	1304.26	1366.72
0.3053	1341	1333.19	1325.42	1358.72	1334.77	1373.98
0.4060	1372	1363.77	1354.61	1392.24	1365.58	1382.99
0.5062	1403	1394.80	1384.97	1423.76	1396.72	1393.84
0.6060	1434	1426.30	1416.57	1453.48	1428.16	1406.66
0.7052	1467	1458.27	1449.48	1481.53	1459.91	1421.62
0.8040	1510	1490.70	1483.79	1508.05	1491.97	1438.89
0.9022	1534	1523.61	1519.60	1533.18	1524.33	1458.71
1.0000	1557	1557.00	1557.00	1557.00	1557.00	1481.38

Table 4. Experimental and theoretical values of velocities (m/s) in anisaldehyde + *p*-xylene system at different temperatures

x_1	U_{exp}	U_N	U_{imx}	U_{Im}	U_R	U_J
			303.15K			
0.0000	1288	1288.43	1288.43	1288.43	1288.43	1395.20
0.1026	1342	1325.73	1320.86	1341.62	1326.70	1403.35
0.2046	1380	1363.75	1354.77	1391.27	1365.50	1413.59
0.3060	1420	1402.48	1390.27	1437.71	1404.82	1426.07
0.4068	1459	1441.94	1427.46	1481.25	1444.66	1440.94
0.5071	1499	1482.13	1466.48	1522.15	1485.01	1458.44
0.6068	1538	1523.07	1507.46	1560.64	1525.87	1478.82
0.7059	1586	1564.75	1550.56	1596.93	1567.24	1502.42
0.8045	1645	1607.18	1595.94	1631.20	1609.11	1529.66
0.9025	1671	1650.37	1643.79	1663.62	1651.47	1561.06
1.0000	1694	1694.33	1694.33	1694.33	1694.33	1597.29
			308.15K			
0.0000	1276	1275.79	1275.79	1275.79	1275.79	1387.06
0.1026	1326	1312.27	1307.47	1327.36	1313.08	1395.21
0.2046	1363	1349.40	1340.57	1375.53	1350.86	1405.39
0.3060	1402	1387.19	1375.20	1420.64	1389.14	1417.73
0.4068	1441	1425.65	1411.45	1462.97	1427.91	1432.40
0.5071	1479	1464.78	1449.45	1502.77	1467.17	1449.59
0.6068	1518	1504.59	1489.32	1540.25	1506.91	1469.55
0.7059	1565	1545.08	1531.21	1575.62	1547.14	1492.59
0.8045	1617	1586.25	1575.28	1609.04	1587.84	1519.10
0.9025	1647	1628.11	1621.70	1640.68	1629.02	1549.56
1.0000	1671	1670.67	1670.67	1670.67	1670.67	1584.59
			313.15K			
0.0000	1254	1253.68	1253.68	1253.68	1253.68	1365.44
0.1026	1299	1288.58	1284.17	1303.06	1289.41	1372.77
0.2046	1336	1324.10	1315.99	1349.18	1325.60	1382.05
0.3060	1374	1360.25	1349.23	1392.35	1362.25	1393.39
0.4068	1411	1397.04	1384.00	1432.85	1399.35	1406.95
0.5071	1448	1434.46	1420.39	1470.90	1436.91	1422.90
0.6068	1484	1472.53	1458.53	1506.73	1474.91	1441.47
0.7059	1529	1511.24	1498.54	1540.53	1513.36	1462.94
0.8045	1576	1550.61	1540.57	1572.47	1552.25	1487.67
0.9025	1607	1590.64	1584.78	1602.69	1591.57	1516.08
1.0000	1631	1631.33	1631.33	1631.33	1631.33	1548.74
			318.15K			
0.0000	1235	1234.73	1234.73	1234.74	1234.74	1349.69
0.1026	1273	1264.73	1261.50	1276.99	1265.53	1353.96
0.2046	1304	1295.22	1289.30	1316.41	1296.64	1359.91
0.3060	1336	1326.19	1318.18	1353.29	1328.09	1367.60
0.4068	1368	1357.65	1348.22	1387.86	1359.85	1377.12
0.5071	1400	1389.61	1379.47	1420.33	1391.93	1388.59
0.6068	1431	1422.07	1412.03	1450.89	1424.33	1402.14
0.7059	1466	1455.04	1445.97	1479.69	1457.03	1417.95
0.8045	1510	1488.51	1481.37	1506.90	1490.05	1436.24
0.9025	1534	1522.50	1518.35	1532.63	1523.37	1457.28
1.0000	1557	1557.00	1557.00	1557.00	1557.00	1481.38

theoretical values of velocity from the experimental values shows that the molecular interactions are taking place (Saravanakumar *et al.,* 2010; Rao *et al.,* 2007; Anuradha *et al.,* 2005; Rao *et al.,* 2005; Ali *et al.,* 2002) between the unlike molecules in the liquid mixture.

Anisaldehyde + *o*-xylene mixture. A close perusal of Table 5 indicates that Nomoto's relation, with minimum deviations in the range 0.60 to 1.91%, predicts the experimental data well, followed by Rao's relation, with deviations in the range 0.56 to 1.88%, then by impedance relation showing deviations in the range -1.31 to 0.80%. However, ideal mixing relation and Junjie's theory show the maximum deviations in the range 1.02 to 2.48% and -6.76 to 6.14%, respectively, over the whole mole fraction of anisaldehyde at a temperature of 303.15 K.

Anisaldehyde + *m*-xylene mixture. For this mixture, Table 6 reveals that percentage deviations for Nomoto's relation, Ideal mixing relation, Impedance relation, Rao's specific velocity relation and Junjie theory are respectively in the range 0.86 to 2.15; 1.34 to 2.78; -1.54 to 0.79; 0.70 to 2.05 and -8.10 to 6.77over the whole mole fraction range of anisaldehyde at 303.15K. Thus, for this mixture the Nomoto's relation seems to predict the experimental data well, followed by Rao's relation at all temperatures studied.

Anisaldehyde + *p*-xylene mixture. It can be seen from Table 7 that the percentage deviation is minimum for Nomoto's relation followed by Rao's relation in the range 1.00 to 2.29 and 0.81 to 2.17, respectively, over the whole mole fraction range of anisaldehyde at 303.15K. At all the temperatures studied, the minimum deviation is observed in Nomoto's relation followed by Rao's relation.

It was also observed (Tables 5-7) that, the percentage deviations between theoretical and experimental value of ultrasonic velocities decrease with increase of temperature. It may be due to breaking of hetero - and homo-molecular clusters at higher temperatures. On increasing the temperature, the ultrasonic velocity decresases in the three binary liquid mixtures. This is probably due to the fact that the thermal energy activates the molecule, which would increase the rate of association of unlike molecules (Rastogi *et al.,* 2002).

Plots of U^2exp/ U^2_{imx} against mole fraction of anisaldehyde for all the three mixtures of anisaldehyde with *o*-xylene, with *m*-xylene and with *p*-xylene are given in Fig. 1 to 3, respectively. U^2_{exp}/U^2_{imx} is observed

Table 5. Percentage deviation between experimental and theoretical values of velocities in anisaldehyde + *o*-xylene system at varying temperatures

x_1	$\%U_N$	$\%U_{imx}$	$\%U_{Im}$	$\%U_R$	$\%U_J$
		303.15K			
0.0000	0.00	0.00	0.00	0.00	-6.76
0.1007	0.72	1.02	-0.14	0.70	-4.04
0.2012	0.71	1.25	-0.75	0.68	-2.26
0.3016	0.77	1.49	-1.06	0.73	-0.58
0.4018	0.75	1.58	-1.25	0.71	0.86
0.5019	0.69	1.56	-1.31	0.64	2.08
0.6018	0.60	1.45	-1.24	0.56	3.13
0.7016	0.92	1.66	-0.62	0.88	4.40
0.8012	1.91	2.48	0.80	1.88	6.14
0.9007	1.03	1.36	0.42	1.01	5.91
1.0000	0.00	0.00	0.00	0.00	5.37
		308.15 K			
0.0000	0.00	0.00	0.00	0.00	-7.25
0.1007	0.62	0.95	-0.21	0.62	-4.54
0.2012	0.56	1.16	-0.84	0.57	-2.75
0.3016	0.60	1.40	-1.15	0.62	-1.02
0.4018	0.60	1.52	-1.31	0.62	0.48
0.5019	0.56	1.52	-1.35	0.57	1.76
0.6018	0.48	1.42	-1.28	0.50	2.84
0.7016	0.72	1.55	-0.75	0.74	4.05
0.8012	1.51	2.14	0.44	1.52	5.59
0.9007	0.88	1.24	0.30	0.88	5.58
1.0000	0.00	0.00	0.00	0.00	5.15
		313.15 K			
0.0000	0.00	0.00	0.00	0.00	-7.35
0.1007	0.47	0.78	-0.30	0.48	-4.84
0.2012	0.47	1.02	-0.85	0.48	-3.03
0.3016	0.50	1.24	-1.15	0.52	-1.34
0.4018	0.49	1.34	-1.32	0.51	0.14
0.5019	0.48	1.36	-1.33	0.50	1.45
0.6018	0.42	1.28	-1.24	0.44	2.55
0.7016	0.54	1.30	-0.86	0.55	3.65
0.8012	1.26	1.84	0.24	1.27	5.16
0.9007	0.75	1.08	0.20	0.76	5.32
1.0000	0.00	0.00	0.00	0.00	5.06
		318.15 K			
0.0000	0.00	0.00	0.00	0.00	-7.4
0.1007	0.31	0.55	-0.33	0.32	-5.27
0.2012	0.32	0.76	-0.76	0.34	-3.54
0.3016	0.32	0.90	-1.04	0.34	-1.97
0.4018	0.34	1.01	-1.15	0.37	-0.52
0.5019	0.34	1.04	-1.15	0.36	0.76
0.6018	0.30	0.98	-1.07	0.32	1.88
0.7016	0.37	0.97	-0.79	0.39	2.97
0.8012	1.06	1.51	0.22	1.07	4.52
0.9007	0.54	0.80	0.09	0.55	4.77
1.0000	0.00	0.00	0.00	0.00	4.86

Table 6. Percentage deviation between experimental and theoretical values of velocities in anisaldehyde + *m*-xylene system at different temperatures

x_1	$\%U_N$	$\%U_{imx}$	$\%U_{Im}$	$\%U_R$	$\%U_J$
		303.15K			
0.0000	0.00	0.00	0.00	0.00	-8.10
0.1023	1.00	1.34	-0.10	0.94	-4.70
0.2040	1.05	1.66	-0.79	0.95	-2.54
0.3053	1.09	1.89	-1.21	0.96	-0.61
0.4060	1.05	1.96	-1.46	0.89	1.03
0.5062	0.95	1.91	-1.54	0.78	2.42
0.6060	0.86	1.79	-1.42	0.70	3.61
0.7052	1.21	2.04	-0.68	1.08	5.03
0.8040	2.15	2.78	0.79	2.05	6.77
0.9022	1.15	1.51	0.41	1.09	6.44
1.0000	0.00	0.00	0.00	0.00	5.73
		308.15 K			
0.0000	0.00	0.00	0.00	0.00	-8.55
0.1023	0.83	1.17	-0.25	0.78	-5.33
0.2040	0.86	1.48	-0.96	0.77	-3.19
0.3053	0.93	1.75	-1.34	0.81	-1.24
0.4060	0.96	1.90	-1.50	0.83	0.47
0.5062	0.87	1.87	-1.57	0.74	1.86
0.6060	0.76	1.73	-1.47	0.64	3.02
0.7052	1.17	2.02	-0.69	1.06	4.46
0.8040	1.82	2.47	0.48	1.74	5.92
0.9022	1.07	1.45	0.34	1.03	5.81
1.0000	0.00	0.00	0.00	0.00	5.15
		313.15 K			
0.0000	0.00	0.00	0.00	0.00	-8.73
0.1023	0.69	1.01	-0.35	0.64	-5.70
0.2040	0.76	1.33	-0.99	0.67	-3.54
0.3053	0.83	1.59	-1.35	0.71	-1.59
0.4060	0.82	1.69	-1.56	0.69	0.07
0.5062	0.78	1.69	-1.58	0.64	1.50
0.6060	-2.38	1.57	-1.48	0.55	2.69
0.7052	-1.35	1.71	-0.87	0.81	4.01
0.8040	-0.02	2.08	0.18	1.40	5.40
0.9022	0.17	1.26	0.21	0.87	5.52
1.0000	0.00	0.00	0.00	0.00	4.86
		318.15 K			
0.0000	0.00	0.00	0.00	0.00	4.86
0.1023	0.53	0.77	-0.37	0.48	4.86
0.2040	0.57	1.01	-0.95	0.48	4.86
0.3053	0.60	1.18	-1.31	0.48	4.86
0.4060	0.62	1.29	-1.45	0.49	4.86
0.5062	0.62	1.32	-1.44	0.49	4.86
0.6060	0.57	1.25	-1.32	0.44	4.86
0.7052	0.60	1.20	-0.99	0.48	4.86
0.8040	1.29	1.75	0.15	1.21	4.86
0.9022	0.68	0.95	0.06	0.64	4.86
1.0000	0.00	0.00	0.00	0.00	4.86

Table 7. Percentage deviation between experimental and theoretical values of velocities in anisaldehyde + *p*-xylene system at varying temperatures

x_1	$\%U_N$	$\%U_{imx}$	$\%U_{Im}$	$\%U_R$	$\%U_J$
		303.15K			
0.0000	0.00	0.00	0.00	0.00	-8.29
0.1026	1.20	1.56	0.02	1.13	-4.58
0.2046	1.20	1.85	-0.80	1.07	-2.42
0.3060	1.25	2.11	-1.23	1.08	-0.41
0.4068	1.18	2.18	-1.51	1.00	1.25
0.5071	1.10	2.14	-1.57	0.91	2.68
0.6068	1.00	2.01	-1.45	0.81	3.87
0.7059	1.35	2.24	-0.68	1.19	5.28
0.8045	2.29	2.97	0.83	2.17	7.00
0.9025	1.22	1.62	0.43	1.16	6.57
1.0000	0.00	0.00	0.00	0.00	5.73
		308.15 K			
0.0000	0.00	0.00	0.00	0.00	-8.72
0.1026	1.04	1.40	-0.10	0.97	-5.22
0.2046	0.99	1.63	-0.93	0.88	-3.12
0.3060	1.04	1.89	-1.35	0.90	-1.14
0.4068	1.05	2.04	-1.54	0.89	0.58
0.5071	0.99	2.03	-1.58	0.83	2.02
0.6068	0.90	1.91	-1.45	0.75	3.21
0.7059	1.30	2.18	-0.65	1.17	4.65
0.8045	1.89	2.56	0.48	1.79	6.04
0.9025	1.13	1.52	0.37	1.07	5.90
1.0000	0.00	0.00	0.00	0.00	5.15
		313.15 K			
0.0000	0.00	0.00	0.00	0.00	-8.91
0.1026	0.81	1.15	-0.30	0.75	-5.67
0.2046	0.91	1.52	-0.96	0.80	-3.42
0.3060	0.98	1.78	-1.36	0.83	-1.44
0.4068	1.01	1.93	-1.53	0.84	0.31
0.5071	0.94	1.91	-1.58	0.77	1.73
0.6068	0.79	1.73	-1.51	0.63	2.88
0.7059	1.14	1.97	-0.78	1.00	4.30
0.8045	1.61	2.25	0.23	1.51	5.61
0.9025	1.01	1.37	0.26	0.95	5.65
1.0000	0.00	0.00	0.00	0.00	5.06
		318.15 K			
0.0000	0.00	0.00	0.00	0.00	-9.31
0.1026	0.62	0.87	-0.34	0.56	-6.39
0.2046	0.68	1.14	-0.94	0.57	-4.28
0.3060	0.73	1.33	-1.30	0.59	-2.37
0.4068	0.73	1.42	-1.48	0.57	-0.69
0.5071	0.71	1.44	-1.48	0.55	0.79
0.6068	0.65	1.35	-1.37	0.49	2.04
0.7059	0.74	1.36	-0.94	0.60	3.27
0.8045	1.45	1.92	0.23	1.35	4.91
0.9025	0.77	1.04	0.11	0.72	5.02
1.0000	0.00	0.00	0.00	0.00	4.86

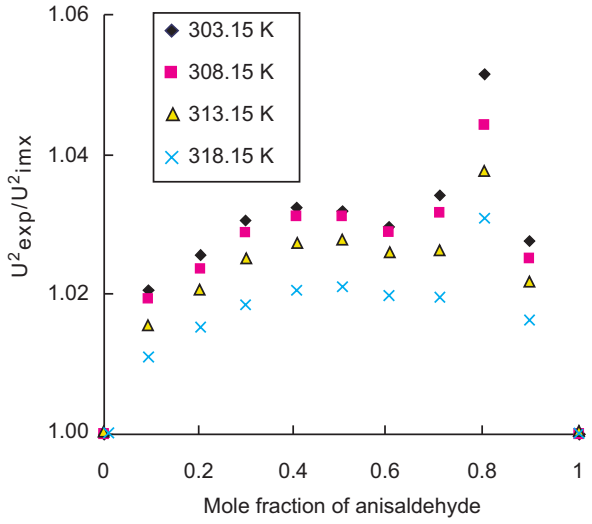

Fig. 1. Variation of U^2_{exp}/U^2_{imx} in anisaldehyde + *o*-xylene system.

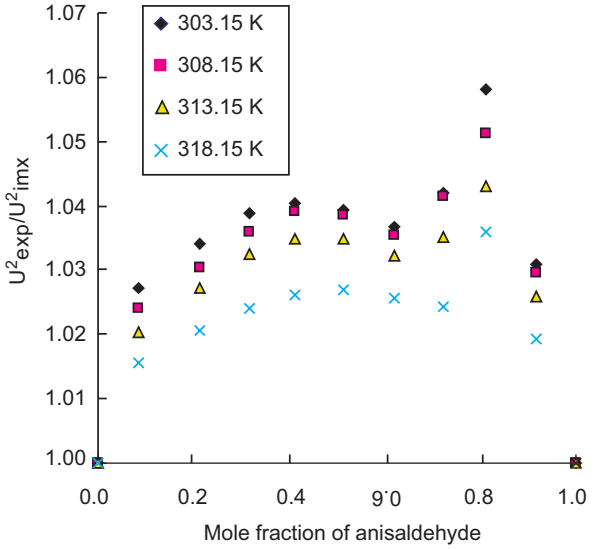

Fig. 2. Variation of U^2_{exp}/U^2_{imx} in anisaldehyde + *m*-xylene system.

to be maximum at mole fraction of anisaldehyde = 0.8045 at all temperatures in all the three systems. The ratio U^2_{exp}/U^2_{imx} is used to measure the non-ideality in liquid mixtures, especially in those cases where the properties other than sound velocity are not known.

Conclusion

Theoretical evaluations of ultrasonic velocities in three binary liquid mixtures were determined, and the validity of different theories was checked. It was observed that

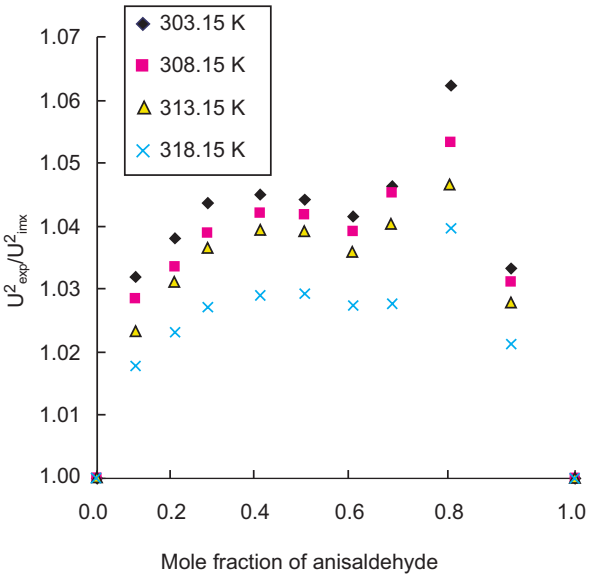

Fig. 3. Variation of U^2_{exp}/U^2_{imx} in anisaldehyde + *p*-xylene system.

of all the theories Nomoto's theory gave the best results, followed by Rao's theory, in all the systems studied. Such conclusions are also derived by other researchers through their studies on different mixtures.

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