Experimental and Theoretical Evaluation of Ultrasonic Velocities of Binary Liquid Mixtures of Anisaldehyde and Toluene at Different Temperatures

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Abstract: Theoretical velocities of binary liquid mixtures of anisaldehyde with toluene at 303.15, 308.15, 313.15 and 318.15 K have been evaluated by using theoretical models of liquid mixtures such as Nomoto, Van Dael-Vangeel, Schaff's collision factor theory and Junjie's relations. Density and ultrasonic velocity of these mixtures have also been measured as a function of concentration and temperature and the experimental values are compared with the theoretical values. A good agreement has been found between experimental and Nomoto's theoretical ultrasonic velocities. The results are explained in terms of intermolecular interactions occurring in these binary liquid mixtures.

Keywords: Theoretical ultrasonic velocities, Binary liquid mixtures, Anisaldehyde, Toluene

Introduction

Ultrasonic velocity in a medium is related to the binding forces between the molecules. Ultrasonic velocities in liquid mixtures consisting of polar and non-polar components are of considerable importance in understanding the intermolecular interaction between component molecules and find applications in several industrial and technological processes¹⁻³. Several researchers⁴⁻⁷ carried out ultrasonic investigations on liquid mixtures and correlated the experimental results with the theoretical relations of Nomoto⁸, Van Dael and Vangeel⁹, Schaff's¹⁰ and Junjie's¹¹ equations and interpreted the results in terms of molecular interactions. In the present paper ultrasonic velocity in binary mixtures from various theoretical models has been compared. The ultrasonic velocities of the chosen binary liquid mixture at 303.15, 308.15, 313.15 and 318.15 K over the entire range of composition have been evaluated by using various theories and compared with the experimental values.

Experimental

Anisaldehyde and toluene from Merk were purified using standard methods^{12,13}. The purity of samples is checked by density and viscosity measurements. The densities of all the mixtures have been determined by using a single pan electrical balance for the determination of mass of a given volume of the liquid. The results of the densities are accurate to $\pm 0.5\%$. Velocities were determined using single crystal ultrasonic pulse echo-interferometer (Model F-80X, Mittal enterprises, India) working at 2 MHz. The temperature of the solution was maintained constant by circulating water through jacket of double walled cell. All the measurements were made using constant temperature bath with in ± 0.01 K.

Results and Discussion

Sound speeds were determined on the basis of different theories and relations as discussed earlier¹⁴ and the values are presented in Table 1 for the binary system at four different temperatures. The validity of different theoretical formulae is checked by percentage deviation at all the temperatures and is given in Table 2. The limitations and approximations incorporated in these theories are responsible for the deviations between theoretical and experimental values. When two liquids are mixed various types of forces are act due to interactions. Thus, the observed deviations between theoretical and experimental values of velocity shows that there is molecular interaction between the unlike molecules in the liquid mixture.

Table 1. Experimental and theoretical values of velocities in anisaldehyde + toluene system at different temperatures

Mole fraction x	U_{exp} ms^{-1}	U_{Nomoto} ms^{-1}	U_{idmix} ms^{-1}	U_{CFT} ms^{-1}	U_{Junjee} ms^{-1}
303.15 K					
0.0000	1694.33	1694.33	1694.33	1694.33	1597.29
0.1151	1655.67	1651.60	1585.58	1645.84	1556.48
0.2265	1644.67	1644.50	1505.92	1598.96	1521.63
0.3342	1590.00	1544.89	1445.70	1553.62	1491.77
0.4384	1530.66	1471.91	1399.26	1509.73	1466.15
0.5394	1491.33	1506.33	1363.06	1467.24	1444.19
0.6372	1444.33	1559.94	1334.71	1426.08	1425.41
0.7321	1416.00	1364.97	1312.60	1386.17	1409.47
0.8241	1368.00	1369.86	1295.56	1347.48	1396.05
0.9133	1329.00	1451.77	1282.74	1309.94	1384.92
1.0000	1273.50	1273.50	1273.50	1273.50	1375.89
308.15 K					
0.0000	1670.67	1670.67	1670.67	1670.67	1584.59
0.1151	1640.67	1671.77	1565.89	1623.75	1545.80
0.2265	1583.33	1653.92	1488.86	1578.40	1512.41
0.3342	1530.00	1564.56	1430.50	1534.53	1483.60
0.4384	1482.00	1492.17	1385.45	1492.07	1458.71
0.5394	1434.00	1518.25	1350.29	1450.96	1437.22
0.6372	1419.00	1573.56	1322.76	1411.13	1418.72
0.7321	1386.67	1374.18	1301.30	1372.52	1402.88
0.8241	1325.00	1368.77	1284.78	1335.08	1389.44
0.9133	1304.00	1443.02	1272.39	1298.76	1378.17
1.0000	1263.50	1263.50	1263.50	1263.50	1368.91

Mole fraction x	$U_{\text{exp}} \text{ ms}^{-1}$	$U_{\text{Nomoto}} \text{ ms}^{-1}$	$U_{\text{idmix}} \text{ ms}^{-1}$	$U_{\text{CFT}} \text{ ms}^{-1}$	$U_{\text{Junjee}} \text{ ms}^{-1}$
313.15 K					
0.0000	1631.33	1631.33	1631.33	1631.33	1548.74
0.1151	1626.67	1644.64	1535.06	1587.80	1514.50
0.2265	1569.67	1616.87	1463.69	1545.71	1484.94
0.3342	1494.99	1530.52	1409.31	1505.00	1459.40
0.4384	1416.00	1454.92	1367.19	1465.61	1437.33
0.5394	1404.00	1500.91	1334.26	1427.46	1418.31
0.6372	1398.00	1547.17	1308.49	1390.50	1401.98
0.7321	1353.00	1360.59	1288.43	1354.67	1388.07
0.8241	1315.00	1366.63	1273.05	1319.93	1376.36
0.9133	1293.00	1419.43	1261.60	1286.22	1366.66
1.0000	1253.50	1253.50	1253.50	1253.50	1358.81
318.15 K					
0.0000	1557.00	1557.00	1557.00	1557.00	1481.38
0.1151	1544.33	1575.39	1476.74	1520.08	1456.19
0.2265	1499.00	1556.48	1416.24	1484.38	1434.30
0.3342	1442.00	1472.97	1369.66	1449.85	1415.33
0.4384	1386.00	1422.08	1333.35	1416.43	1398.93
0.5394	1366.67	1458.69	1304.90	1384.07	1384.85
0.6372	1332.67	1522.06	1282.66	1352.72	1372.88
0.7321	1317.99	1333.97	1265.46	1322.33	1362.82
0.8241	1300.00	1331.58	1252.43	1292.85	1354.53
0.9133	1269.00	1367.98	1242.94	1264.26	1347.90
1.0000	1236.50	1236.50	1236.50	1236.50	1342.83

It is observed from Table 2 that there is a good agreement between experimental and theoretical values calculated by Nomoto's relation followed by CFT while higher deviations are observed in Junjie's relation and Van Dael ideal mixing relation.

Table 2. Percentage deviation between experimental and theoretical values of velocities in anisaldehyde + toluene system at different temperatures

Mole fraction x	$\%U_{\text{Nomoto}} \text{ ms}^{-1}$	$\%U_{\text{imx}} \text{ ms}^{-1}$	$\%U_{\text{CFT}} \text{ ms}^{-1}$	$\%U_{\text{Junjee}} \text{ ms}^{-1}$
303.15 K				
0.0000	0.0000	0.0000	0.0000	5.7275
0.1151	0.2456	4.2331	-0.5937	5.9909
0.2265	0.0102	8.4366	-2.7793	7.4810
0.3342	2.8372	9.0758	-2.2881	6.1779
0.4384	3.8385	8.5843	-1.3674	4.2145
0.5394	-1.0058	8.6012	-1.6153	3.1613
0.6372	-8.0046	7.5894	-1.2636	1.3097
0.7321	3.6041	7.3020	-2.1066	0.4613

Contd...

Mole fraction x	%U _{Nomoto} ms ⁻¹	%U _{imx} ms ⁻¹	%U _{CFT} ms ⁻¹	%U _{Junjee} ms ⁻¹
0.8241	-0.1361	5.2953	-1.5000	-2.0506
0.9133	-9.2377	3.4810	-1.4342	-4.2080
1.0000	0.0000	0.0000	0.0000	-8.0402
308.15 K				
0.0000	0.0000	0.0000	0.0000	5.1525
0.1151	-1.8958	4.5582	-1.0313	5.7826
0.2265	-4.4583	5.9667	-0.3114	4.4789
0.3342	-2.2591	6.5031	0.2961	3.0325
0.4384	-0.6862	6.5151	0.6795	1.5717
0.5394	-5.8750	5.8376	1.1827	-0.2243
0.6372	-10.8919	6.7819	-0.5546	0.0199
0.7321	0.9008	6.1562	-1.0204	-1.1690
0.8241	-3.3033	3.0351	0.7608	-4.8633
0.9133	-10.6612	2.4243	-0.4018	-5.6882
1.0000	0.0000	0.0000	0.0000	-8.3427
313.15 K				
0.0000	0.0000	0.0000	0.0000	5.0628
0.1151	-1.1050	5.6316	-2.3895	6.8959
0.2265	-3.0068	6.7520	-1.5264	5.3976
0.3342	-2.3764	5.7310	0.6696	2.3804
0.4384	-2.7485	3.4472	3.5035	-1.5066
0.5394	-6.9021	4.9669	1.6709	-1.0190
0.6372	-10.6702	6.4028	-0.5365	-0.2846
0.7321	-0.5609	4.7726	0.1234	-2.5922
0.8241	-3.9259	3.1902	0.3749	-4.6662
0.9133	-9.7784	2.4287	-0.5244	-5.6966
1.0000	0.0000	0.0000	0.0000	-8.4015
318.15 K				
0.0000	0.0000	0.0000	0.0000	4.8568
0.1151	-2.0111	4.3765	-1.5703	5.7076
0.2265	-3.8348	5.5211	-0.9753	4.3160
0.3342	-2.1478	5.0169	0.5444	1.8497
0.4384	-2.6035	3.7990	2.1955	-0.9331
0.5394	-6.7330	4.5197	1.2732	-1.3306
0.6372	-14.2115	3.7523	1.5045	-3.0169
0.7321	-1.2124	3.9855	0.3293	-3.4012
0.8241	-2.4295	3.6590	-0.5500	-4.1949
0.9133	-7.7997	2.0536	-0.3735	-6.2179
1.0000	0.0000	0.0000	0.0000	-8.5995

Conclusion

Out of four theories and relations, the Nomoto's relation provides the best results. The Success of Nomoto's relation in predicting the experimental ultrasonic velocities for liquid mixtures has been supported by others^{15,16}.

References

1. Valen A, Lopez M C, Urieta J S, Royo F M and Lafuente C, *J Mol Liq.*, 2002, **95**, 157-165.
2. Pal A and Kumar H, *J Chem Thermodyn*, 2004, **36**, 173.
3. Rao T S, Veeraiah N and Rambabu C, *Indian J Pure Appl Phys.*, 2002, **40**, 850.
4. Suresh reddy K V N, Srinivasa Rao P and Krishnaiah A, *Phys and Chem of Liq.*, 2004, **42(6)**, 561-588.
5. Rama Rao G V, Sandhya Sri P B, Viswanatha Sarma A and Rambabu C, *Indian J Pure Appl Phys.*, 2007, **45(2)**, 135-142.
6. Sundharam N and Palaniappan L, *Indian J Phys.*, 2005, **79**, 1173-1178.
7. Ali A Abida, Nain A K and Hyder S, *Indian J Pure Appl Ultrason*, 2001, **23**, 73.
8. Nomoto O, *J Phys Soc Japan*, 1949, **4**, 280 and 1958, **13**, 1528.
9. Van Dael W and Vangeel E, *Proc Int Conf on Calorimetry and Thermodynamics*, Warasa 1955, 555.
10. Schaffs W, *Acustica*, 1975, **33**, 272.
11. Junjie Z, *J China Univ Sci Techn*, 1984, **14**, 298.
12. Vogel A I, Textbook of Organic Chemistry, 5th Ed., John Wiley: New York, 1989.
13. Riddick J A, Bunger W B and Sakano T K, Organic Solvents, 4th Ed., John Willey and Sons, New York, 1986.
14. Rita Mehra and Avneesh K. Gaur, *J Chem Eng Data*, 2008, **53**, 863.
15. Kaulgud M V, *Acustica*, 1960, **10**, 316.
16. Meyyappan M and Sethupathy, *Indian J Pure Appl Ultrason.*, 2003, **25**, 1.