Theoretical Velocities and Viscosities of Binary Mixtures of Anisaldehyde with Higher Alkanols

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Abstract

Experimental and theoretical ultrasonic velocity and viscosity of the binary mixtures of anisaldehyde + 1- Octanol, anisaldehyde + 1- nonanol and anisaldehyde + 1- decanol have been reported at 303.15, 308.15, 313.15 and 318.15K, the theoretical methods such as Nomoto's relation, Van Dael relation, Impedance relation, Junjie's relation, Impedance relation, Rao relation, Kudriavtsev Relation are used to calculate the theoretical ultrasonic velocity. Theoretical values are compared with experimental values to find the merits of the relations and check the validity of theses theoretical models by using average percentage deviations and chi square test. The results are discussed in terms of inter molecular interactions occurring in the systems.

Keywords: Ultrasonic velocity, Molecular interaction parameter, Chi square test, theoretical velocities

1. Introduction

The molecular interactions of pure liquids and liquid mixtures are shown by ultrasonic velocity[1-3]. Many publications[4-6] use different theoretical methods to determine the ultrasonic velocity of pure, binary, and ternary mixtures. S. Babu[7] used the Free Length Theory (FLT), Collision Factor Theory (CFT), and Nomoto's relation to forecast the sound velocity data for binary liquid mixes of chlorobenzene and benzene at different temperatures. The findings show that every theory provided a reasonable approximation of the sound velocity.

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The densities of binary mixes of 1,4-butanediol (1,4-BD) with methyl pyridine isomers (-picoline and -picoline) have been measured over the full range of composition at temperatures T = (303.15,308.15,313.15 and 318.15) K and at atmospheric pressure, according to J Srinivas et al[8]. Relationships such as Nomoto (U_N), Impedance (U_I), Collision factor theory (U_C), Van-Dael and Vangeel (U_V), Junjie (U_J), Free Length Theory (U_F), and Rao's particular velocity (U_R) have been used to examine the experimental sound speeds. There is a good match between the theoretical and experimental values. It has also been determined whether U^2_{exp} / U^2_{imx} exhibit non - ideality in liquid combinations. To determine how well these ideas match the existing systems, the chi-square test for goodness of fit is used.

K.A.K. Raj Kumar et. al[9]. used theoretical models of Nomoto (NOM), Impedance (IMP), Van Deal and Vangeel (VDV), Junjie's (JUN), and Rao's specific velocity (RAO) relations to calculate the theoretical velocities of binary liquid mixtures of ethyl lactate (EL) with 2-propanol (PNL), 2-butanol (BNL), and 2-methy,1-propanol (MPL), at different temperatures (303.15, 308.15, 313.15, and 318.15 K). Experimental measurements have also been made of the ultrasonic velocities and densities of these mixtures in relation to temperature and EL concentration. The existence of molecular interactions between the molecules of the constituent liquids is confirmed by the difference between experimental results and calculated values from various theories. A non- ideality analysis of U^2_{exp} / U^2_{imx} has also been performed on the mixes.

It is of great interest to examine the sound velocity in liquids and liquid mixtures theoretically as a function of composition. Additionally, it is discovered that comparing experimental and theoretically determined sound velocities helps understand the thermodynamics of liquids and liquid mixtures and offers a more effective way to assess the reliability of different empirical relations and theories[10,11].

Numerous workers used various methods to verify the theoretical ultrasonic velocity for liquid mixes. models including Rao's specific velocity[13], Junjie[11], Nomoto[12], Van Deal and Vangeel[14], Impedance Relation[15], Kudriavtsev equation[16] and Analysis of ultrasonic velocity theoretically in binary liquid mixes and comparison with the experimental values accurately depict the interactions between molecules in liquid mixtures, which is highly helpful for building thorough theoretical representations of liquids.

In the current study, the theoretical relationships Nomoto, Van Dael and Vangeel, Impedance Relation, Rao's Specific Velocity, and Junjie Relation are compared to empirically observed ultrasonic sound velocities at various temperatures. 1- octanol, 1- nonanol, and 1-decanol are examples of higher alkanols that are combined with anisaldehyde at various mole fractions to examine the interactions between the constituent molecules. The molecular interactions found in the systems under investigation are used to explain and discuss the results. For additional support, the average percentage deviation, chi square test[17] for goodness of fit from unity, and variance in the variation of U^2_{exp}/U^2_{imx} have been calculated.

2. Experimental Techniques

An important consideration in any experimental investigation of thermodynamic properties is the purity of the chemicals employed. The reasons for the errors in experimental measurements include the impurities, such as water, which the chemicals absorb, the dissociation of the molecules after exposure or standing, association, etc. Every thermodynamics experiment must include continuous testing of the chemicals' purity in addition to their initial purification.

Many purification methods have been covered in the literature[18,19]. These methods were created in accordance with the characteristics and functional groups of the substances that require purification. The several organic liquids that are being used in this investigation are excellent samples. Prior to use, the liquids are distilled, combined in the necessary ratios using a burette, and allowed to reach temperature equilibrium for a minimum of five to six hours.

According to Nikam et al[20], the densities and ultrasonic sound velocities of the three binary liquid mixtures and pure liquids under study were measured at 303.15, 308.15, 313.15, and 318.15 K using a pulse-echo interferometer (MODEL M-81) supplied by Mittal Enterprises, New Delhi, and a 105 m3 double-arm pycnometer. The accuracy of the distance that can be measured largely determines the precision of the velocity, since 'd' may be determined with a micrometre down to a minimum value of 0.01 mm. Velocity measurements were accurate to +0.02%.

The double-arm pycnometer was calibrated with conductivity water with a density of 995.61 kg/m3 at 303.15 K. The specific gravity bottle was placed in the thermostat for fifteen minutes in order to reach thermal equilibrium. They are removed from the thermostat once they have warmed to room temperature and weighed. The temperature is maintained at 0.01K with the help of an accurate thermostat. The digital balance used for the weigh-ins is manufactured by METTLER TOLEDO in Switzerland and has a precision of 0.01 mg.

The aids 1- octanol, 1- nonanol, and 1-decanol used in this work, together with the anisaldehyde experimental materials, are of the highest quality and were obtained from S.D. Fine Chemicals in India with purity > 99%. The experimental findings are contrasted with those from the literature in Table 1[21-23]. The experimental and reported values rather closely match, as seen in Table 1.

Table-1: Comparison of Experimental Values with Literatures Data 303.15K

Liquid	Ultrasonic Velocity(U)m/s		Density(ρ) Kg/m3	
	Exptl	Lit	Exptl	Lit
Anisaldehyde	1542.0	1.1204[a]	1.1204	1.1204[a]
1- Octanol	1333.5	1335.4[b]	0.8124	0.81825[b]
1 - Nonanol	1348.5	1348.4[c]	0.81645	0.8164[c]
1 - Decanol	1363.5	1364[b]	0.8228	0.8228[b]

3.Theoretical Considerations

It is anticipated that a comparison between the theoretical and experimental values of ultrasonic velocities in the current binary liquid mixtures will disclose the type of interaction between the mixture's constituent components. Finding a thorough theoretical model for liquid mixtures is helped by such theoretical research.

3.1 Nomoto's Relation

Nomoto established the following relation for the ultrasonic velocity of binary liquid mixtures, assuming the additivity of molar sound velocity (R) and no volume change upon mixing:

$R = M/rU^{1/3}$

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

$M = (X_1M_1 + X_2M_2)$

where M_1 and M_2 are the molecular weights of constituent components.

The following relationship is produced by simple manipulation:

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

3.2 Ideal Mixing Relation

The following relationship was proposed by Van Deal and Vangeel for the sound velocity:

$1/(X_1M_1+X_2+M_2)*1/U^2_{imx} = X_1/M_1U_1^2 + X_2/M_2U_2^2$

where U_{imx} is the optimal liquid mixture mixing ultrasonic velocity, U_1 and U_2 are the individual component velocities.

3.3 The Impedance Relation

The product of ultrasonic velocity (U) and a liquid mixture's density (ρ) is impedance (Z). As a result, the impedance relation uses just the impedance (Z_i) and density (ρ) variables to forecast the ultrasonic velocity of the given combination. The given impedance relation is $U = SX_i Z_i / S X_i r_i$

where Zi is the acoustic impedance, Xi mole percentage, and ρ is the mixture's density.

3.4 The Rao's specific velocity method relation

Rao's specific velocity method[11] $U = (S X_i r_i d)^3$

where X_i mole fraction, U_i is the ultrasonic velocity, r_i is the density of the mixture, r_i is the Rao's specific sound velocity = $Ui^{1/3}/r_i$ and Z_i is the acoustic impedance.

3.5 The Junjie equation

Junjie equation

$U_J = (X_1M_1 / r_1 + X_2 M_2 / r_2) / [\{X_1 M_1 + X_2 M_2\}^{1/2} \{X_1 M_1 /r_1 U_1^2 + X_2 M_2 / r_2 U_2^2)\}^{1/2}]$

where M_1, M_2 are molecular weights of constituent components. r_1 and r_2 are the densities of constituent components.

3.6 Kudriavtsev theory

Kudriavtsev theory gives the velocity theoretically UKT, through the following relation:

where M_A, M_B, and M represent the mol. wts. of components A and B, the effective molecular weight $Meff = (X_AM_A + X_BM_B)$, L represents the heat capacity of the mixture in cal/g.

3.7 **Chi-Square Test:**

The formula given below, proposed by Karl Pearson[17] is used for evaluating chi square value for the studied binary mixtures.

n

$\chi 2 = \sum((U_{(obs)} - U_{(cal))}^{2} / U_{(cal))}$ ..... (6)

i=1

where n is the number of observations, and

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

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

3.8 Relative percentage of error (σ):

The calculation of average percentage error can be done with the help of following equation.

$\sigma = 1/n\sum((U_{(obs)} - U_{(cal))} / U_{(obs)}) X 100\%$ ..... (7)

The number of observations is represented as n.

$U_{(obs)}$ = values of experimentally determined ultrasonic velocities

3.9 Molecular Associations:

The degree of intermolecular interaction or molecular association is given by

$\alpha U^{2}_{exp} / U^{2}_{imx} -1$

4. Results & Discussion

Aprotic solvents do not significantly solvate anions, but polar protic solvents perform a good job of solubilizing cations and anions. Anisaldehyde falls under the category of polar aprotic solvent because it contains a carbonyl group (CHO), in which hydrogen is attached to the carbon atom, which is less electronegative than the oxygen atom. In the present investigation, it is seen that alkanols exhibit polar protic characteristics, hence displaying an ability to quickly engage in hydrogen bonding, as envisioned. Continuing to bind in carbon because oxygen is significantly more electronegative than carbon and hence has a strong tendency to draw electrons in a carbon-oxygen bond towards itself, the carbonyl group of anisaldehyde is polar. A carbon-oxygen double bond is extremely polar because one of the two pairs of electrons that make it up is even more readily drawn towards the oxygen.

This polarity, which has a dipole moment of 3.7855[24], makes an additional attempt to extract hydrogen from protonators, or alkanol molecules, which are already self-associated. This is the main event that takes place when new hydrogen bonds are formed between hetero molecules. Weakening of connections between dissimilar molecules is anticipated when the length of the carbon chain grows from 1- octanol to 1 - decanol due to stearic hindrance of the long carbon chain.

For the binary systems of anisaldehyde + 1- octanol, anisaldehyde + 1 – nonanol, anisaldehyde + 1 - decanol, the applicability of several theoretical liquid methods has been

evaluated by contrasting theoretical sound speeds with those found empirically in the temperature range of 303–318 K. For each of the three binaries, the experimental sound speed values are compared with the theoretical values and percentage deviations for the following: Nomoto's Relation (U_N), Van Deal Vangeel Ideal Mixing Relation (U_{imx}), Impedance Dependence Relation (U_{IR}), Rao's specific velocity method (U_R), Junjie's relation (U_J) and Kudriavtsev relation (U_K)

It is often assumed that all molecules have a spherical form, yet this isn't always the case. According to Nomoto's idea, mixing should not cause the volume to alter. Consequently, no consideration has been given to the interaction between the constituents of liquid mixes. The ratio of the ideal mixtures' specific temperatures to their volumes must also be equal in order for an ideal mixing relation to form. Once more, little consideration is given to molecular interactions. Similar to this, the collision factor theory treats molecules as genuine nonelastic things, which is not the case in reality.

However, when two liquids are mixed, a variety of forces, including dispersion forces, charge transfer, hydrogen bonding, dipole-dipole and dipole-induced dipole interactions, produce interactions between the molecules of the two liquids. The observed difference between theoretical and experimental velocity values demonstrates that dissimilar molecules in a liquid mixture are interacting through molecular means. The theoretical values of ultrasonic velocity calculated by several theories can be found to deviate from experimental values in Tables 2. It results from the approximations and constraints that these theories have.

Table 2:Theoretical velocities computed using various theories along with the experimental velocities, standard deviation and chi square test values for the systems anisaldehyde (AA) + 1 – Octanol, 1- Nonanol, 1- Decanol.

X_1	U_{EXP}	U_{NOM}	U_{IMP}	U_{VDV}	U_{JUN}	U_{RAO}	U_{KUD}
Anisaldehyde + 1 - Octanol							
303.15K							
0.0000	1335.4	1335.4	1335.4	1335.4	1335.4	1335.4	1348.5
0.1278	1385.7	1355.2	1370.1	1356.3	1341.7	1362.8	1348.5
0.2480	1427.1	1375.1	1400.0	1377.1	1350.6	1389.4	1397.2
0.3612	1462.6	1395.3	1425.9	1397.8	1362.0	1414.5	1436.6
0.4679	1490.6	1415.7	1448.6	1418.5	1376.3	1437.1	1468.1
0.5688	1510.4	1436.2	1468.7	1439.2	1393.6	1458.0	1493.0
0.6643	1521.6	1457.0	1486.6	1459.8	1414.3	1476.9	1512.2
0.7548	1529.0	1477.9	1502.6	1480.4	1438.9	1495.1	1526.2
0.8407	1535.8	1499.1	1517.0	1501.0	1467.9	1512.1	1535.8

0.9223	1540.2	1520.4	1530.1	1521.5	1501.9	1528.5	1541.4
1.0	**1542**	1542.0	1542.0	1542.0	1542.0	1542.0	1543.4
	σ	-0.0039	0.0351	-0.0639	-0.1147	0.4074	0.5614
	χ^2	0.0	0.2	0.7	2.1	29.9	31
308.15K							
0.0000	1320.0	1320.0	1320.0	1320.0	1320.0	1320.0	1333.6
0.1278	1369.4	1338.8	1352.9	1339.9	1326.0	1348.2	1378.8
0.2480	1409.1	1357.8	1381.2	1359.8	1334.3	1374.4	1417.6
0.3612	1443.0	1377.0	1405.8	1379.6	1345.2	1398.8	1448.7
0.4679	1469.7	1396.3	1427.3	1399.2	1358.7	1420.5	1473.5
0.5688	1487.9	1415.8	1446.4	1418.9	1375.2	1440.5	1489.0
0.6643	1498.4	1435.5	1463.4	1438.4	1395.0	1458.3	1497.2
0.7548	1504.8	1455.4	1478.6	1457.9	1418.4	1475.1	1501.2
0.8407	1510.7	1475.4	1492.3	1477.3	1445.8	1490.8	1505.1
0.9223	1514.3	1495.6	1504.7	1496.7	1478.1	1505.3	1508.3
1.0000	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0
	σ	0.0045	0.0470	-0.0617	-0.1145	0.4370	0.5997
	χ^2	0.0017	0.3568	0.6050	2.0513	34.036	35.24
313.15K							
0.0000	1305.9	1305.9	1305.9	1305.9	1305.9	1305.9	1337.0
0.1278	1356.3	1325.4	1339.7	1326.3	1312.5	1336.5	1380.0
0.2480	1396.9	1345.0	1368.9	1346.7	1321.5	1364.0	1415.5
0.3612	1430.7	1364.9	1394.2	1367.0	1333.0	1388.9	1447.3
0.4679	1457.6	1384.9	1416.5	1387.3	1347.2	1411.9	1469.0
0.5688	1476.4	1405.1	1436.2	1407.6	1364.3	1432.1	1478.5
0.6643	1487.2	1425.4	1453.8	1427.8	1384.7	1450.7	1484.0
0.7548	1494.8	1445.9	1469.6	1448.0	1408.7	1468.7	1490.2
0.8407	1501.2	1466.6	1483.8	1468.2	1436.9	1484.8	1495.2
0.9223	1505.6	1487.4	1496.7	1488.3	1469.8	1499.9	1502.7
1.0000	**1508.4**	1508.4000	1508.4	1508.4	1508.4	1508.4	
	σ	0.0070	0.0473	-0.0533	-0.1061	0.4638	05518
	χ^2	0.0	0.4	0.4	1.7	37.6	40.15
318.15K							
0.0	1284.8	1284.8	1284.8	1284.8	1284.8	1284.8	1329.0
0.1278	1335.3	1304.9	1319.4	1305.6	1292.0	1318.5	1372.4
0.2480	1376.4	1325.1	1349.3	1326.4	1301.5	1346.6	1412.3
0.3612	1410.5	1345.4	1375.3	1347.2	1313.5	1371.6	1441.4
0.4679	1438.3	1366.0	1398.1	1368.0	1328.2	1394.5	1465.7
0.5688	1457.4	1386.7	1418.4	1388.8	1345.9	1415.6	1477.1
0.6643	1470.1	1407.5	1436.4	1409.5	1366.7	1434.6	1482.0
0.7548	1478.4	1428.6	1452.6	1430.3	1391.3	1452.8	1485.0
0.8407	1484.5	1449.7	1467.3	1451.0	1419.9	1469.8	1488.0
0.9223	1488.8	1471.1	1480.5	1471.8	1453.4	1485.8	1489.9

1.0000	1492.6	1492.6	1492.6	1492.6	1492.6	1492.6	1492.6
	σ	0.0	0.1	0.0	-0.1	0.5	0.7152
	χ^2	0.0243	0.4601	0.3738	1.6171	39.621	40.125
Anisaldehyde + 1 - Nonanol							
303.15K							
0.0000	1348.5	1348.5	1348.5	1348.5	1348.5	1348.5	1348.5
0.1055	1389.4	1362.4	1375.5	1366.3	1352.7	1359.3	1397.2
0.2098	1425.0	1377.2	1400.2	1384.3	1358.6	1372.2	1436.6
0.3127	1457.0	1393.1	1422.9	1402.8	1366.5	1386.6	1468.1
0.4145	1488.3	1410.0	1443.8	1421.5	1376.8	1401.9	1493.0
0.5150	1503.0	1428.1	1463.2	1440.6	1390.2	1418.9	1512.2
0.6143	1515.0	1447.5	1481.3	1460.1	1407.3	1437.6	1526.2
0.7124	1522.5	1468.4	1498.0	1480.0	1429.3	1459.2	1535.8
0.8094	1528.0	1491.0	1513.7	1500.2	1457.4	1483.6	1541.4
0.9053	1533.1	1515.4	1528.3	1520.9	1494.0	1511.6	1543.4
1.0000	1542.0	1542.0	1542.0	1542.0	1542.0	1542.0	1542.0
	σ	-0.0039	0.0351	-0.0639	-0.1147	0.4074	0.5518
	χ^2	0.0028	0.1999	0.6546	2.0782	29.877	31.25
308.15K							
0.0000	1333.6	1333.6	1333.6	1333.6	1333.6	1333.6	1333.6
0.1055	1378.8	1346.8	1358.9	1350.5	1337.6	1345.4	1380.5
0.2098	1417.6	1360.8	1382.1	1367.6	1343.2	1358.0	1418.3
0.3127	1448.7	1375.8	1403.5	1385.0	1350.7	1372.2	1448.4
0.4145	1473.5	1391.8	1423.3	1402.8	1360.6	1387.0	1472.1
0.5150	1489.0	1408.9	1441.6	1420.8	1373.2	1403.1	1490.2
0.6143	1497.2	1427.2	1458.6	1439.2	1389.5	1420.4	1503.3
0.7124	1501.2	1446.9	1474.4	1457.9	1410.3	1440.4	1512.0
0.8094	1505.1	1468.1	1489.2	1476.9	1436.8	1463.3	1516.8
0.9053	1508.3	1491.1	1503.0	1496.3	1471.1	1489.3	1518.0
1.0000	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0
	σ	0.0023	0.0470	-0.0617	-0.1145	0.4370	0.5122
	χ^2	0.0017	0.3568	0.6050	2.0513	34.036	36.15
313.15K							
0.0000	1337.0	1337.0	1337.0	1337.0	1337.0	1337.0	1337.0
0.1055	1380.0	1349.5	1360.7	1353.0	1340.8	1350.0	1382.3
0.2098	1415.5	1362.8	1382.5	1369.2	1346.0	1362.8	1418.7
0.3127	1447.3	1376.9	1402.5	1385.7	1353.1	1375.9	1447.7
0.4145	1469.0	1391.9	1421.1	1402.4	1362.5	1390.3	1470.2
0.5150	1478.5	1408.0	1438.3	1419.4	1374.5	1404.8	1487.2
0.6143	1484.0	1425.3	1454.3	1436.6	1389.9	1421.4	1499.3
0.7124	1490.2	1443.8	1469.2	1454.2	1409.5	1440.8	1507.1
0.8094	1495.2	1463.7	1483.1	1471.9	1434.5	1462.2	1511.0
0.9053	**1502.7**	1485.2	1496.2	1490.0	1466.6	1486.7	1511.3

1.0000	**1508.4**	1508.4	1508.4	1508.4	1508.4	1508.4	1508.4
	σ	0.00696	0.0473	-0.05333	-0.1061	0.4638	06180
	χ^2	0.0	0.4	0.4	1.7	37.6	39.15
318.15K							
0.0000	1329.0	1329.0	1329.0	1329.0	1329.0	1329.0	1329.0
0.1055	1372.4	1341.0	1351.5	1344.4	1332.6	1344.0	1373.1
0.2098	1412.3	1353.7	1372.2	1359.9	1337.8	1356.6	1408.4
0.3127	1441.4	1367.3	1391.4	1375.7	1344.6	1369.2	1436.4
0.4145	1465.7	1381.7	1409.0	1391.7	1353.6	1382.2	1458.1
0.5150	1477.1	1397.0	1425.5	1407.9	1365.2	1396.4	1474.3
0.6143	1482.0	1413.5	1440.8	1424.4	1380.0	1413.0	1485.8
0.7124	1485.0	1431.1	1455.0	1441.0	1398.7	1430.2	1492.9
0.8094	1488.0	1450.1	1468.4	1458.0	1422.6	1450.7	1496.2
0.9053	1489.9	1470.5	1480.9	1475.2	1453.1	1473.8	1496.0
1.0000	**1492.6**	1492.6	1492.6	1492.6	1492.6	1492.6	1492.6
	σ	0.0127	0.0547	-0.0484	-0.1025	0.4809	05147
	χ^2	0.0	0.5	0.4	1.6	39.6	41.25
Anisaldehyde + 1 -Decanol							
303.15K							
0.0000	1364.0	1364.0	1364.0	1364.0	1364.0	1364.0	1364.0
0.1496	1405.0	1381.1	1398.4	1387.9	1369.4	1364.9	1389.9
0.2835	1440.8	1398.4	1426.3	1410.0	1377.1	1371.8	1413.4
0.4042	1478.7	1415.9	1449.5	1430.6	1387.0	1383.5	1434.6
0.5135	1510.4	1433.5	1469.0	1449.8	1399.5	1398.2	1454.0
0.6129	1519.0	1451.2	1485.6	1467.7	1414.6	1415.8	1471.8
0.7037	1523.9	1469.1	1500.0	1484.5	1432.7	1436.3	1488.1
0.7869	1528.8	1487.1	1512.5	1500.2	1454.0	1459.2	1503.1
0.8636	1532.6	1505.2	1523.5	1515.0	1479.0	1484.8	1517.1
0.9344	1537.4	1523.5	1533.3	1528.9	1508.1	1513.1	1530.0
1.0000	1542.0	1542.0	1542.0	1542.0	1542.0	1542.0	1542.0
	σ	-0.0039	0.0351	-0.0639	-0.1147	0.4074	0.6547
	χ^2	0.0028	0.1999	0.6546	2.0782	29.877	31.251
308.15K							
0.0000	1345.0	1345.0	1345.0	1345.0	1345.0	1345.0	1345.0
0.1496	1395.1	1361.5	1378.0	1368.0	1350.2	1347.0	1369.9
0.2835	1435.5	1378.2	1404.8	1389.3	1357.5	1354.1	1392.4
0.4042	1472.1	1394.9	1427.0	1409.1	1367.2	1365.7	1412.8
0.5135	1498.7	1411.8	1445.8	1427.5	1379.2	1380.1	1431.5
0.6129	1510.5	1428.9	1461.7	1444.7	1393.7	1397.2	1448.5
0.7037	1513.6	1446.0	1475.6	1460.8	1411.1	1416.5	1464.2
0.7869	1514.7	1463.3	1487.6	1475.9	1431.6	1438.7	1478.7
0.8636	1515.5	1480.8	1498.2	1490.1	1455.6	1462.9	1492.0
0.9344	1515.8	1498.3	1507.6	1503.4	1483.5	1489.7	1504.5

1.0000	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0	1516.0
	σ	0.0023	0.0470	-0.0617	-0.1145	0.4370	0.5523
	χ^2	0.0017	0.3568	0.6050	2.0513	34.036	38.15
313.15K							
0.0000	1329.0	1329.0	1329.0	1329.0	1329.0	1329.0	1329.0
0.1496	1368.7	1346.3	1363.6	1353.0	1334.8	1334.0	1355.2
0.2835	1410.2	1363.8	1391.7	1375.3	1342.8	1342.9	1378.8
0.4042	1445.5	1381.4	1415.0	1396.0	1353.1	1355.2	1400.2
0.5135	1475.4	1399.1	1434.6	1415.3	1365.8	1371.0	1419.7
0.6129	1489.0	1417.0	1451.4	1433.4	1381.1	1388.8	1437.6
0.7037	1495.5	1435.0	1465.9	1450.3	1399.3	1409.2	1454.1
0.7869	1498.9	1453.1	1478.5	1466.2	1420.6	1432.4	1469.2
0.8636	1500.4	1471.4	1489.7	1481.1	1445.6	1457.6	1483.3
0.9344	1504.5	1489.8	1499.6	1495.1	1474.6	1484.8	1496.3
1.0000	1508.4	1508.4	1508.4	1508.4	1508.4	1508.4	1508.4
	σ	0.0070	0.0473	-0.0533	-0.1061	0.4638	0.6548
	χ^2	0.0087	0.3556	0.4498	1.7430	37.559	40.15
318.15K							
0.0000	1321.0	1321.0	1321.0	1321.0	1321.0	1321.0	1321.0
0.1496	1362.2	1337.6	1354.0	1344.1	1326.5	1327.4	1346.0
0.2835	1405.0	1354.3	1380.9	1365.4	1334.1	1336.0	1368.6
0.4042	1445.5	1371.2	1403.2	1385.2	1343.8	1347.8	1389.1
0.5135	1473.4	1388.2	1422.0	1403.7	1356.0	1362.1	1407.8
0.6129	1485.5	1405.3	1438.0	1421.0	1370.7	1379.4	1424.9
0.7037	1489.2	1422.5	1451.9	1437.1	1388.1	1399.9	1440.6
0.7869	1490.4	1439.8	1464.0	1452.3	1408.6	1421.6	1455.1
0.8636	1490.7	1457.3	1474.7	1466.5	1432.5	1445.7	1468.6
0.9344	1491.0	1474.9	1484.1	1480.0	1460.3	1471.5	1481.0
1.0000	1492.6	1492.6	1492.6	1492.6	1492.6	1492.6	1492.6
	σ	0.0127	0.0547	-0.0484	-0.1025	0.4809	0.6152
	χ^2	0.0243	0.4601	0.3738	1.6171	39.621	45.12

Generally speaking, the degree of interactions present in a binary system determines how predictively accurate different ultrasonic theories can be. When there are significant interactions between the molecules in a mixture, the theoretical prediction of velocity deviates significantly from that of the molecules in the mixture with less contacts.

The findings indicate that, among the three binary systems, the sound speed calculated using Nomoto's relation demonstrates a higher level of concordance with the experimental data within the temperature range of 303.15 K–318.15 K compared to alternative methodologies.

Table 2 demonstrates that there is good agreement between actual and theoretical values obtained using Nomoto relation for all systems[25,26].

Both positive and negative percentage deviations exist for the ultrasonic velocity. These variations show that liquid mixes do not behave in a perfect manner. In situations where parameters other than sound velocity are unknown, the ratio U^2_{exp} / U^2_{imx} is a crucial tool for determining the nonideality of the mixtures.

In the present study, it is observed that positive values are maximum for Anisaldehyde + 1- octanol (1.1042) than Anisaldehyde + 1 - nonanol (1.0962) and Anisaldehyde + 1 – Decanol (1.0853) and at about equimolar concentration at all studied temperatures because of more complex formations between unlike molecules through hydrogen bonding.

The fluctuation of the mole fraction of anisaldehyde with each of the three alkanols is shown in Figures 1, 2, and 3. A minimum of roughly 0.522 M is recorded at all temperatures in anisaldehyde and 1 - decanol systems, and a maximum of approximately 0.52 M in anisaldehyde + 1- octanol and anisaldehyde + ethoxyethanol systems.

Figure Captions

Fig 1: Variation of U^2_{exp}/U^2_{imx} with the mole fraction of Anisaldehyde for the system Anisaldehyde + 1- Octanol

Fig.2: Variation of U^2_{exp}/U^2i_{mx} with the mole fraction of Anisaldehyde for AA + 1-Nonanol system

Fig 3: Variation of U^2_{exp}/U^2_{imx} with the mole fraction of Anisaldehyde for the system Anisaldehyde + 1-Decanol

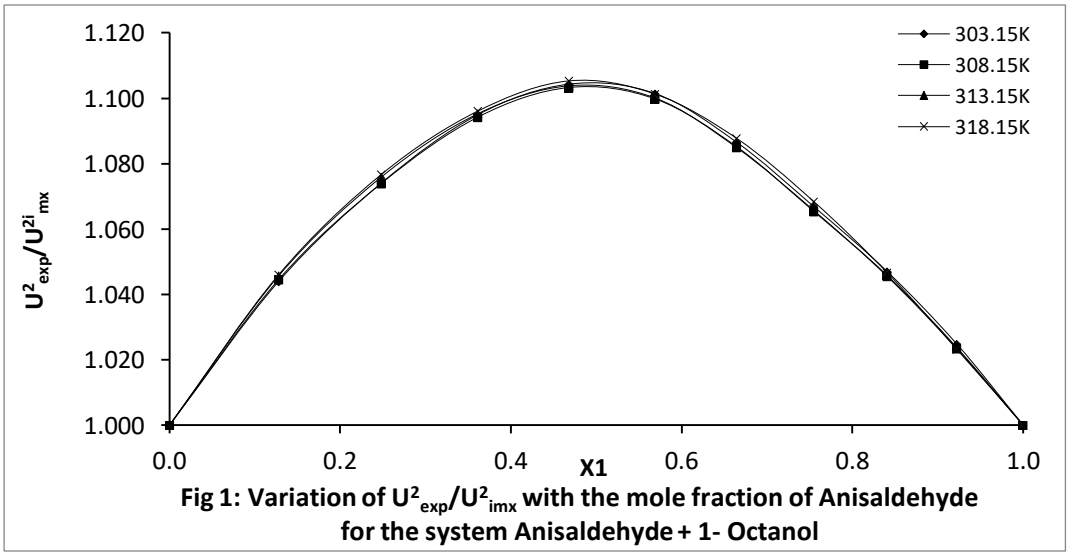

Fig 1: Variation of U^2_{exp}/U^2_{imx} with the mole fraction of Anisaldehyde for the system Anisaldehyde + 1- Octanol

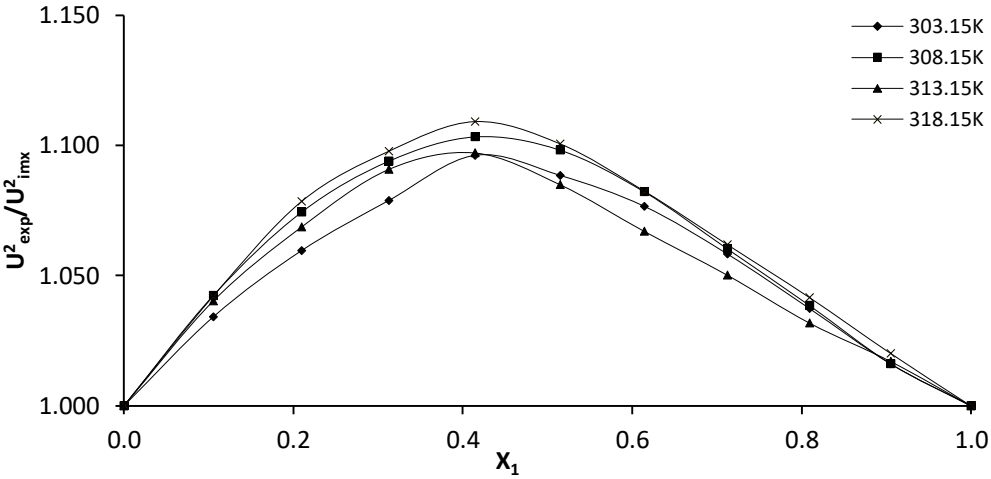

Fig.2 : Variation of U^2_{exp}/U^2i_{mx} with the mole fraction of Anisaldehyde for AA + 1-Nonanol system

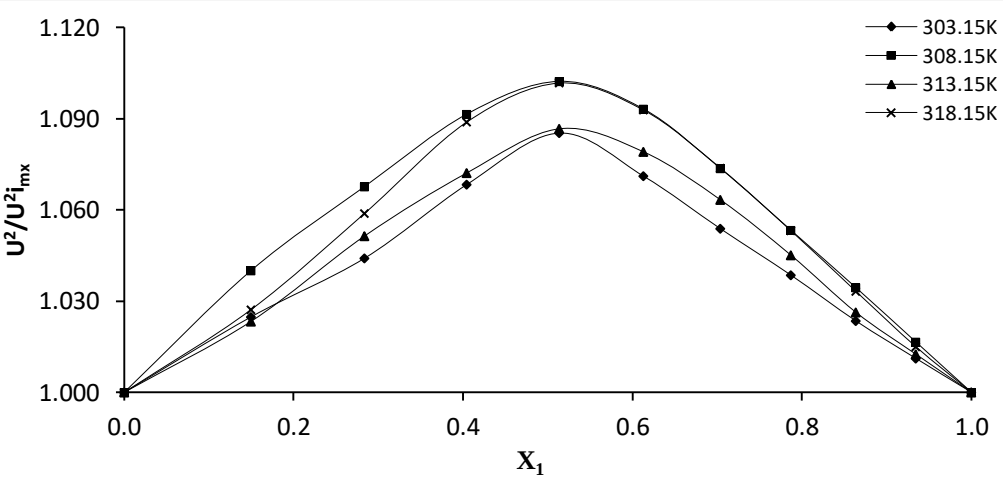

Fig 3 :Variation of U^2_{exp}/U^2_{imx} with the mole fraction of Anisaldehyde for the system Anisaldehyde + 1-Decanol

The temperature, molar mass, and composition all affect the interaction parameter that describes a system. It is used to take into consideration how much of the enthalpy and non-combinatorial entropy of mixing contribute to the Gibbs energy of mixing. Strong interaction between the mixing molecules is indicated by interaction parameter values that have a positive sign. While hydrogen bonds are present in the systems under study, we found that the interaction values are negative for every mixture provided, indicating weaker interactions that decrease from 1 - octanol to 1 - decanol.

Because hetero- and homo molecular clusters break at higher temperatures, the differences between the theoretical and experimental values of ultrasonic velocities reduce as temperature rises[25]. In the three binary liquid mixtures, the ultrasonic velocity values drop as

the temperature rises. This is most likely caused by the thermal energy activating the molecule, which would speed up the interaction of dissimilar molecules.

5. Conclusion

We may infer that among the six theories and relations that were previously presented, the Impedance relation and the Nomotos g relation produced the best results, along with ideal mixing relation. Hence, the previously described binary liquid mixtures demonstrate the characteristics of molar sound velocity linearity, molar volume additivity, and impedance relation, as postulated by Nomoto, Van Dael, and Vangeel, in their formulation of the empirical relationships. Additionally, it has been noted by others that Nomoto's equation effectively predicts experimental ultrasonic velocities for mixtures of non-polar and polar liquids.

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