A COMPARATIVE ANALYSIS OF ULTRASONIC VELOCITY IN THE BINARY SYSTEMS OF 2-ALKOXYETHANOLS IN CYCLOHEXANONE BY EXPERIMENTAL AND MATHEMATICAL METHOS AT FOUR DIFFERENT TEMPERATURES

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Abstract: The fundamental need of measurement of ultrasound velocity for the estimation of transport properties of liquid mixtures or solid systems. Solutions containing liquids of non-polar and polar groups are of considerable importance in transportation of mass and heat, need to investigate for their physical and thermal properties. The investigation of inter-molecular interactions between component molecules followed through the measurement of ultrasound velocity. There are many standard mathematical methods available to measure ultrasonic velocity. The binary solutions of 2-alkoxyethnols (2-Methoxyethanol, 2-Ethoxyethanol and 2-Butoxyethanol) in Cyclohexanone for different concentrations at temperatures T= (303.15,308.15, 313.15, 318.15) K are used for investigation of experimental values and compared with theoretical values obtained with different empirical modals at constant atmospheric pressure. Nomoto's relation, Rao's specific velocity relation, Junjie's relation, Free length theory, Ideal mixing relation and Impedance relation are used for calculating percentage deviation from the experimental values of sound velocity. The most reliable method can be identified by focusing on the calculated deviation in the light of molecular interactions occurring in binary systems. Molecular interaction parameter is useful in revealing the nature of interaction between component molecules specific for the binary system.

***Key Words*: Ultrasound velocity, polar groups, 2-alkoxyethanols, empirical models, inter-molecular interactions.**

I. INTRODUCTION

Thermodynamic properties of fluids are required to design for heat transfer machinery and chemical process in industries like aerospace, natural gas production, dye and chemical engineering technological applications. The significant changes in the properties of fluids can be monitored depending on their application. Since, the molecular structure, the nature and structural patterns of molecular aggregation in liquid binary mixtures causes the changes in their physical and chemical properties as they are sensitive to the variations of composition and association between unlike molecules. When two or more solvents are mixed, the unlike molecules of the solution are associated with one another causes a considerable effect on the properties of the resultant mixture. Ultrasonic velocity: during last two decades the measured values of the velocity in liquid mixtures are gained considerable interest in the assessment of the nature and intensity of molecular interactions among component molecules. Deviations found in ultrasound velocity as a function of composition and component liquids exhibited through molecular interactions [1-4]. Theoretical and experimental study of ultrasound velocity in the liquids of polar and non-polar nature [5] have been the subject of research in recent years. Molecular interactions through theoretical study of ultrasound velocity was performed by many researchers [6-10].

In the present study the interaction behavior of binary mixtures of 2-alkoxyethanols in cyclohexanone were studied with the measured values of ultrasonic velocity. The experimental values compared with the calculated values through empirical methods suggested by, Shipra and Prasania [11], Van Deal and Vangeel [12], Junjie[13], Jacobson [14], Nomoto [15], and Ernst [16]. The best suited mathematical method is identified with percentage deviation and discussed in the light of molecular interactions existing in the liquid systems.

II. MATERIALS AND METHODS

Chemicals for present study are, Cyclohexanone, 2-Methoxyethanol, 2-Ethoxyethanol and 2-Butoxyethanol, obtained from SD fine chemicals (99% Purity), are utilized with purification using standard technique mention in the literature [17-18]. Velocity of ultrasound and density has been measured with Anton Paar DSA – 5000M density and sound analyzer throughout the complete range of mole fraction of the Cyclohexanone ranges from X=0.0 to X=0.6. The purity of chemicals was tested by comparing the ultrasonic velocity values with the literature values. Ultrasonic velocity measurements of liquid mixtures were made at temperatures 303.15, 308.15, 313.15 and 318.15K. Measurements are observed to an accuracy of 0.01 m/s and the temperature variation of the apparatus can be controlled with a built in Peltier device up to ±0.01K.

III. THEORETICAL MODELS OF MEASURING ULTRASONIC VELOCITY

The theoretical ultrasound velocity provides the prediction of better analysis of molecular association in liquid mixtures. Computation of these values using mathematical models like Van Deal and Vangeel (U_{IMR}), Rao's specific velocity relation (U_{RAO}), Junjie's relation (U_J), Impedance dependent relation (U_{IDR}), Free length theory (U_{FLT}), and Nomoto's relations (U_{NOM}) for the liquid mixtures of 2-Methoxyethanol (ME), 2-Ethoxyethanol (EE) and 2-Butoxyethanol (BE) with Cyclohexanone (CH).

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

$$U_J = \frac{X_1M_1}{\rho_1} + \frac{X_2M_2}{\rho_2} \Big/ \left[\{X_1M_1 + X_2M_2\}^{1/2} \left\{ \frac{X_1M_1}{\rho_1 U_1^2} + \frac{X_2M_2}{\rho_2 U_2^2} \right\}^{1/2} \right] \quad (2)$$

$$U_{IMR} = \left[\left(\frac{X_1}{M_1 {U_1}^2} + \frac{X_2}{M_2 {U_2}^2} \right) \left((X_1M_1 + X_2M_2) \right) \right]^{-1/2} \quad (3)$$

$$U_{Rao} = (\sum X_i r_i \rho)^3 \quad (4)$$

$$U_{IDR} = [\sum_{i=1}^{n} X_i Z_i / \sum_{i=1}^{n} X_i \rho_i] \quad (5)$$

$$U_{FLT} = \left[K / L_{fmix} \rho_{exp}^{1/2} \right] \quad (6)$$

Where R is the molar sound velocity, X_1 and X_2 mole fractions and M_1 and M_2 are molecular weights of first and second component. X_i, Z_i and ρ_i represent mole fraction, acoustic impedance, and density of component liquids. Finally, L_f is the free length of the mixture.

The percentage of deviation in the sound velocity calculated by the equation

$$\text{Percentage deviation } \left(\frac{\Delta U}{U}\right)\% = \left(U_{exp} - U_{theory} / U_{exp}\right) * 100 \quad (7)$$

The degree of molecular interaction (α) is given by:

$$\propto = \frac{U_{exp}^2}{U_{imx}^2} - 1 \quad (8)$$

Where U_{exp} is the experimental ultrasound velocity, U_{theory} is the theoretical velocity, and U_{imx} is the ultrasonic velocity of ideal mixture.

IV. RESULTS AND DISCUSSION

The experimentally measured ultrasound velocity and the computed velocities using various mathematical models for the binary systems of 2-Methoxyethanol, 2-Ethoxyethanol and 2-Butoxyethanol in Cyclohexanone for seven different compositions varies with mole fraction from X = 0.0 to X = 6.0 at four different temperatures T= (303.15,308.15, 313.15, 318.15) K are listed in the Table 1, Table 2 and Table 3 simultaneously.

Table 1: Experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Methoxyethanol*.

Mole Fraction *X*	U_{EXP} ms^{-1}	U_{NOM} ms^{-1}	U_J ms^{-1}	U_{FLT} ms^{-1}	U_{IDR} ms^{-1}	U_{RAO} ms^{-1}	U_{IMR} ms^{-1}
303.15 K							
0.0000	1353.14	1353.14	1353.14	1353.14	1353.14	1353.14	1353.14
0.1320	1357.29	1357.27	1357.23	1356.31	1356.37	1353.53	1350.67
0.2754	1361.44	1361.41	1361.34	1359.99	1359.90	1355.26	1349.94
0.4319	1365.59	1365.56	1365.48	1364.19	1363.78	1358.47	1351.46
0.6033	1369.75	1369.71	1369.65	1368.39	1368.05	1363.08	1355.92
0.7917	1373.9	1373.88	1373.83	1372.87	1372.78	1369.45	1364.30
1.0000	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05
308.15 K							
0.0000	1342.63	1342.63	1342.63	1342.63	1342.63	1342.63	1342.63
0.1320	1346.64	1346.63	1346.59	1346.46	1345.75	1343.20	1340.12
0.2754	1350.65	1350.63	1350.56	1350.48	1349.16	1344.96	1339.32
0.4319	1354.67	1354.64	1354.57	1354.66	1352.91	1348.06	1340.73
0.6033	1358.69	1358.66	1358.59	1358.67	1357.04	1352.50	1345.05
0.7917	1362.71	1362.69	1362.64	1362.56	1361.62	1358.57	1353.24
1.0000	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72
313.15 K							
0.0000	1332.71	1332.71	1332.71	1332.71	1332.71	1332.71	1332.71
0.1320	1336.34	1336.26	1336.23	1336.11	1335.49	1333.13	1329.96
0.2754	1339.96	1339.82	1339.77	1339.71	1338.53	1334.66	1328.88
0.4319	1343.55	1343.39	1343.33	1343.36	1341.86	1337.36	1329.94
0.6033	1347.11	1346.96	1346.91	1347.15	1345.53	1341.44	1333.81
0.7917	1350.65	1350.54	1350.50	1350.41	1349.60	1346.78	1341.42
1.0000	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12
318.15 K							
0.0000	1319.51	1319.51	1319.51	1319.51	1319.51	1319.51	1319.51
0.1320	1323.29	1323.30	1323.26	1322.94	1322.49	1320.37	1316.95
0.2754	1327.12	1327.09	1327.03	1326.10	1325.74	1321.97	1316.07
0.4319	1330.93	1330.89	1330.83	1329.84	1329.30	1324.93	1317.36
0.6033	1334.73	1334.70	1334.64	1333.96	1333.21	1329.27	1321.48
0.7917	1338.54	1338.52	1338.48	1337.93	1337.54	1334.90	1329.35
1.0000	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34

Table 2: Experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Ethoxyethanol*.

Mole Fraction *X*	U_{EXP} ms^{-1}	U_{RAO} ms^{-1}	U_{NOM} ms^{-1}	U_{IDR} ms^{-1}	U_J ms^{-1}	U_{FLT} ms^{-1}	U_{IMR} ms^{-1}
303.15 K							
0.0000	1318.42	1318.42	1318.42	1318.42	1318.42	1318.42	1318.42
0.1574	1328.45	1328.35	1328.24	1327.95	1327.66	1326.22	1326.03
0.3184	1338.53	1338.28	1338.10	1337.63	1337.16	1334.74	1334.45
0.4830	1348.53	1348.27	1348.02	1347.48	1346.94	1344.16	1343.75
0.6514	1358.41	1358.20	1357.98	1357.50	1357.00	1354.39	1354.04
0.8237	1368.24	1368.13	1367.99	1367.69	1367.37	1365.65	1365.43
1.0000	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05
308.15 K							
0.0000	1294.28	1294.28	1294.28	1294.28	1294.28	1294.28	1294.28
0.1574	1306.31	1306.14	1306.17	1305.86	1305.36	1303.52	1303.54
0.3184	1318.44	1318.08	1318.13	1317.63	1316.81	1313.70	1313.77
0.4830	1330.54	1330.15	1330.17	1329.60	1328.65	1325.01	1325.06
0.6514	1342.58	1342.26	1342.28	1341.76	1340.90	1337.46	1337.55
0.8237	1354.61	1354.45	1354.46	1354.14	1353.58	1351.29	1351.38
1.0000	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72
313.15 K							
0.0000	1274.66	1274.66	1274.66	1274.66	1274.66	1274.66	1274.66
0.1574	1287.79	1287.69	1287.68	1287.41	1286.69	1284.73	1284.83
0.3184	1301.06	1300.81	1300.79	1300.36	1299.17	1295.85	1296.05
0.4830	1314.32	1313.97	1313.99	1313.50	1312.12	1308.10	1308.43
0.6514	1327.54	1327.27	1327.28	1326.83	1325.58	1321.78	1322.12
0.8237	1340.77	1340.66	1340.65	1340.37	1339.57	1337.05	1337.29
1.0000	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12
318.15 K							
0.0000	1252.72	1252.72	1252.72	1252.72	1252.72	1252.72	1252.72
0.1574	1267.47	1267.42	1267.37	1267.20	1266.09	1263.84	1264.19
0.3184	1282.4	1282.20	1282.14	1281.86	1280.03	1276.18	1276.83
0.4830	1297.34	1297.13	1297.01	1296.70	1294.58	1290.01	1290.78
0.6514	1312.27	1312.10	1312.01	1311.72	1309.78	1305.42	1306.21
0.8237	1327.23	1327.16	1327.12	1326.94	1325.69	1322.74	1323.32
1.0000	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34

Table 3: Experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Butoxyethanol*.

Mole Fraction X	U_{EXP} ms^{-1}	U_{NOM} ms^{-1}	U_J ms^{-1}	U_{RAO} ms^{-1}	U_{FLT} ms^{-1}	U_{IMR} ms^{-1}	U_{IDR} ms^{-1}
303.15 K							
0.0000	1312.24	1312.24	1312.24	1312.24	1312.24	1312.24	1312.24
0.2019	1322.41	1323.06	1321.91	1320.64	1322.29	1323.08	1326.06
0.3875	1332.88	1333.94	1332.06	1330.77	1333.60	1334.05	1338.52
0.5585	1343.75	1344.88	1342.72	1341.55	1344.53	1345.08	1349.80

0.7167	1354.91	1355.87	1353.91	1352.77	1354.92	1356.12	1360.06
0.8635	1366.48	1366.93	1365.68	1363.79	1363.53	1367.12	1369.44
1.0000	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05	1378.05
308.15 K							
0.0000	1276.83	1276.83	1276.83	1276.83	1276.83	1276.83	1276.83
0.2019	1291.68	1291.53	1289.83	1287.92	1285.77	1292.61	1295.67
0.3875	1306.59	1306.34	1303.54	1300.35	1296.02	1308.08	1312.66
0.5585	1321.56	1321.27	1318.03	1314.87	1309.35	1323.22	1328.07
0.7167	1336.56	1336.30	1333.34	1330.53	1324.69	1338.03	1342.10
0.8635	1351.68	1351.45	1349.55	1347.28	1342.48	1352.53	1354.94
1.0000	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72	1366.72
313.15 K							
0.0000	1262.91	1262.91	1262.91	1262.91	1262.91	1262.91	1262.91
0.2019	1277.94	1277.82	1276.03	1275.35	1274.09	1279.01	1282.09
0.3875	1293.01	1292.84	1289.90	1289.03	1286.56	1294.74	1299.36
0.5585	1308.19	1307.99	1304.58	1303.93	1300.66	1310.11	1315.00
0.7167	1323.42	1323.24	1320.13	1319.47	1315.83	1325.12	1329.22
0.8635	1338.82	1338.62	1336.61	1336.05	1333.18	1339.79	1342.21
1.0000	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12	1354.12
318.15 K							
0.0000	1241.80	1241.80	1241.80	1241.80	1241.80	1241.80	1241.80
0.2019	1258.56	1258.20	1256.12	1255.84	1253.79	1259.77	1262.97
0.3875	1275.31	1274.73	1271.31	1270.71	1266.73	1277.22	1282.03
0.5585	1292.07	1291.42	1287.44	1286.90	1281.69	1294.19	1299.26
0.7167	1308.83	1308.25	1304.59	1303.93	1298.39	1310.68	1314.93
0.8635	1325.58	1325.22	1322.86	1322.87	1319.16	1326.73	1329.23
1.0000	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34	1342.34

From the tables, the experimental velocities are increasing with increasing concentration of Cyclohexanone in all the three binary systems. The association between component molecules is responsible for the observed variation. In the three binary mixtures containing 2-alkoxyethanols, we can find a close relation in the variation of ultrasonic velocities calculated with the same theory. A closed observation of individual theories corresponding to three mixtures, in CH+ME it is found that Nomoto's relation shows less deviation, for CH+EE Rao's theory and in CH+BE, FLT shows very small deviations. The assumptions and limitations accompanied with these theories are responsible for the deviations observed between experimental ultrasound velocities and calculated velocities through mathematical models. The percentage of deviations are computed for all the theories with respect to the composition of increasing Cyclohexanone content in the mixture are displayed in Table 4, Table 5, and Table 6 for all the temperatures considered. In the three mixtures Van deal Vangeel method and Impedance dependent relation showing much more deviation suggest that these theories are less apt for the present component mixtures [19].

Table 4: Percentage deviation between experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Methoxyethanol*.

Mole Fraction X	$\%U_{NOM}$	$\%U_J$	$\%U_{FLT}$	$\%U_{IDR}$	$\%U_{RAO}$	$\%U_{IMR}$	U^2_{exp}/U^2_{imx}
303.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1320	0.0014	0.0045	0.0721	0.0676	0.2767	0.4877	1.0098
0.2754	0.0022	0.0072	0.1064	0.1128	0.4538	0.8446	1.0171
0.4319	0.0024	0.0080	0.1023	0.1326	0.5217	1.0349	1.0210
0.6033	0.0027	0.0077	0.0992	0.1240	0.4872	1.0100	1.0205
0.7917	0.0017	0.0048	0.0748	0.0814	0.3237	0.6988	1.0141
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
308.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1320	0.0011	0.0041	0.0135	0.0660	0.2555	0.4843	1.0097
0.2754	0.0016	0.0064	0.0126	0.1100	0.4211	0.8388	1.0170
0.4319	0.0023	0.0076	0.0005	0.1300	0.4881	1.0287	1.0209
0.6033	0.0023	0.0071	0.0018	0.1214	0.4555	1.0040	1.0204
0.7917	0.0018	0.0048	0.0110	0.0801	0.3040	0.6952	1.0140
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
313.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1320	0.0058	0.0082	0.0169	0.0635	0.2399	0.4772	1.0096
0.2754	0.0103	0.0142	0.0189	0.1067	0.3956	0.8268	1.0169
0.4319	0.0122	0.0165	0.0145	0.1256	0.4609	1.0127	1.0206
0.6033	0.0113	0.0151	-0.0029	0.1171	0.4208	0.9872	1.0202
0.7917	0.0085	0.0109	0.0180	0.0780	0.2869	0.6836	1.0138
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
318.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1320	-0.0005	0.0022	0.0263	0.0605	0.2209	0.4790	1.0095
0.2754	0.0022	0.0065	0.0771	0.1041	0.3881	0.8323	1.0167
0.4319	0.0028	0.0077	0.0821	0.1226	0.4509	1.0194	1.0205
0.6033	0.0022	0.0065	0.0575	0.1138	0.4087	0.9930	1.0200
0.7917	0.0017	0.0045	0.0455	0.0750	0.2723	0.6867	1.0137
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Table 5: Percentage deviation between experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Ethoxyethanol*.

Mole Fraction X	$\%U_{RAO}$	$\%U_{NOM}$	$\%U_{IDR}$	$\%U_{J}$	$\%U_{FLT}$	$\%U_{IMR}$	U^2_{exp}/U^2_{imx}
303.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1574	0.0077	0.0161	0.0378	0.0597	0.1682	0.1822	1.0052
0.3184	0.0183	0.0320	0.0670	0.1025	0.2829	0.3051	1.0088
0.4830	0.0196	0.0382	0.0777	0.1182	0.3241	0.3543	1.0102
0.6514	0.0155	0.0318	0.0671	0.1037	0.2956	0.3214	1.0093
0.8237	0.0081	0.0183	0.0404	0.0637	0.1895	0.2051	1.0059
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
308.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1574	0.0132	0.0106	0.0345	0.0727	0.2139	0.2117	1.0046
0.3184	0.0271	0.0232	0.0614	0.1237	0.3597	0.3542	1.0078
0.4830	0.0292	0.0277	0.0709	0.1421	0.4153	0.4115	1.0090
0.6514	0.0240	0.0223	0.0608	0.1253	0.3813	0.3744	1.0082
0.8237	0.0121	0.0108	0.0350	0.0760	0.2452	0.2384	1.0052
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
313.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1574	0.0080	0.0084	0.0292	0.0853	0.2380	0.2298	1.0042
0.3184	0.0195	0.0207	0.0540	0.1452	0.4005	0.3853	1.0071
0.4830	0.0265	0.0251	0.0628	0.1671	0.4735	0.4481	1.0083
0.6514	0.0204	0.0198	0.0533	0.1477	0.4336	0.4081	1.0075
0.8237	0.0085	0.0087	0.0297	0.0898	0.2776	0.2598	1.0048
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
318.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.1574	0.0039	0.0078	0.0212	0.1092	0.2867	0.2591	1.0037
0.3184	0.0152	0.0206	0.0421	0.1851	0.4852	0.4347	1.0061
0.4830	0.0165	0.0251	0.0494	0.2130	0.5651	0.5057	1.0071
0.6514	0.0131	0.0200	0.0416	0.1896	0.5220	0.4615	1.0065
0.8237	0.0050	0.0086	0.0221	0.1164	0.3381	0.2944	1.0041
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Table 6: Percentage deviation between experimental and theoretical values of ultrasonic velocity at temperatures 303.15 K, 308.15 K, 313.15 K and 318.15 K for mole fraction *Cyclohexanone* with *2-Butoxyethanol*.

Mole Fraction X	$\%U_{NOM}$	$\%U_J$	$\%U_{RAO}$	$\%U_{FLT}$	$\%U_{IMR}$	$\%U_{IDR}$	U^2_{exp}/U^2_{imx}
303.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2019	-0.0491	0.0379	0.1339	0.0089	-0.0506	-0.2761	1.0019
0.3875	-0.0794	0.0617	0.1580	-0.0540	-0.0878	-0.4228	1.0030
0.5585	-0.0838	0.0769	0.1638	-0.0581	-0.0990	-0.4499	1.0033
0.7167	-0.0712	0.0736	0.1579	-0.0006	-0.0890	-0.3802	1.0028
0.8635	-0.0331	0.0586	0.1972	0.0156	-0.0466	-0.2168	1.0017
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
308.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2019	0.0117	0.1434	0.2909	0.4578	-0.0722	-0.3087	1.0017
0.3875	0.0191	0.2333	0.4777	0.8086	-0.1137	-0.4646	1.0027
0.5585	0.0223	0.2673	0.5059	0.9238	-0.1253	-0.4925	1.0029
0.7167	0.0192	0.2409	0.4510	0.8881	-0.1103	-0.4146	1.0026
0.8635	0.0167	0.1578	0.3255	0.6809	-0.0632	-0.2409	1.0015
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
313.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2019	0.0095	0.1494	0.2029	0.3014	-0.0833	-0.3247	1.0014
0.3875	0.0129	0.2403	0.3076	0.4992	-0.1335	-0.4912	1.0023
0.5585	0.0157	0.2759	0.3253	0.5755	-0.1466	-0.5203	1.0025
0.7167	0.0132	0.2487	0.2987	0.5737	-0.1288	-0.4381	1.0022
0.8635	0.0147	0.1647	0.2069	0.4215	-0.0726	-0.2530	1.0013
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
318.15 K							
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
0.2019	0.0290	0.1940	0.2165	0.3793	-0.0961	-0.3507	1.0010
0.3875	0.0451	0.3139	0.3609	0.6730	-0.1501	-0.5267	1.0018
0.5585	0.0505	0.3586	0.4001	0.8030	-0.1640	-0.5567	1.0020
0.7167	0.0446	0.3240	0.3745	0.7976	-0.1416	-0.4660	1.0018
0.8635	0.0272	0.2055	0.2045	0.4839	-0.0865	-0.2754	1.0009
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

4.1 Molecular interaction studies

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Percentage deviation between theoretical and experimental ultrasonic velocity values clearly indicating the existence of specific interactions among dissimilar component molecules. Each theory shows similar variation of ultrasound velocity at all mole fractions. The best suited theory changes from one binary system to the other. Nomoto's relation the best suited theory of 2-Methoxyethanol mixture and second better one of 2- Ethoxyethanol system and third better one for 2-Butoxyethanol mixture. The aptness decreases with increasing chain length of 2-alkoxyethanol molecules. It is clearly suggesting that less fitting of long chained molecules causes greater change in total molar volume of the solution. Since the

Nomoto's theory does not considered the changes occur in the total volume of the mixture due to molecular interactions [20]. No single theory is giving complete analysis of molecular interaction for the three binaires but the similarities are found with Rao's theory and Junjie's relation for ME and BE binaries. Impedance relation and Van deal and Vangeel relation are showing larger deviations with all other theories for three mixtures. All the theories showing positive deviations for the two binary systems of ME and EE but negative deviations observed in 2-Butoxyethanol mixture. Positive and negative deviations of theoretical ultrasound velocities indicating the departure from the ideal behavior of pure liquids due to interactions among dissimilar molecules. Positive deviations indicating strong intermolecular interactions [21, 22] whereas negative percentage deviation proposes dispersion forces originate from the destruction of molecular association [23]. From the negative deviation of velocity values, less possibility of strong interactions between 2-Butoxyethanol and Cyclohexanone molecules can be estimated, the similar variation was proposed by the analysis of thermo acoustic parameters of 2-alkoxyethanol mixtures [24].

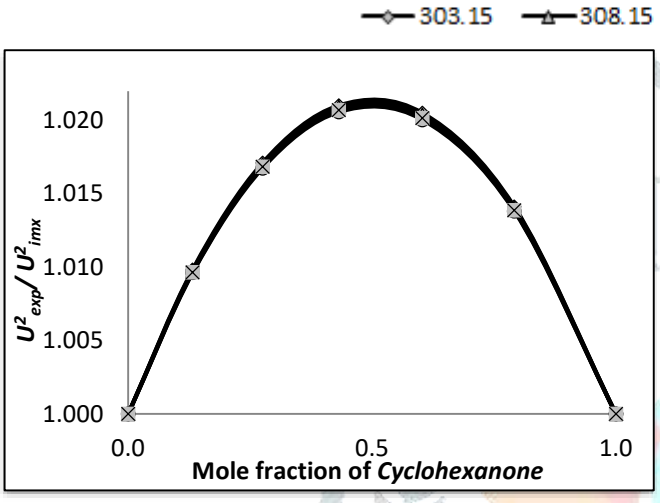

Fig a: Variation of U^2_{exp}/U^2_{imx} with mole fraction of *Cyclohexanone + 2-Methoxyethanol*

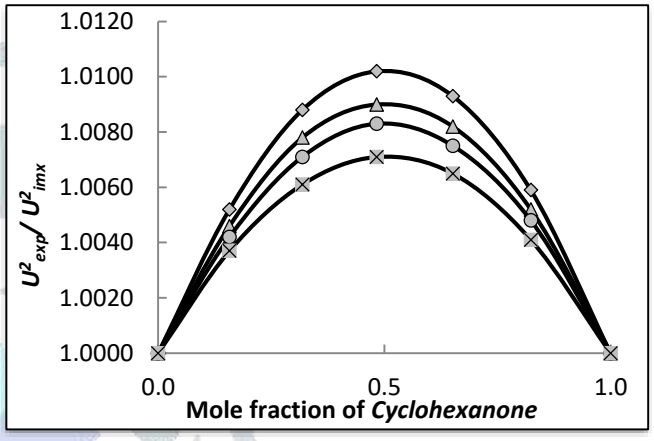

Fig b: Variation of U^2_{exp}/U^2_{imx} with mole fraction of *Cyclohexanone 2-Ethoxyethanol*

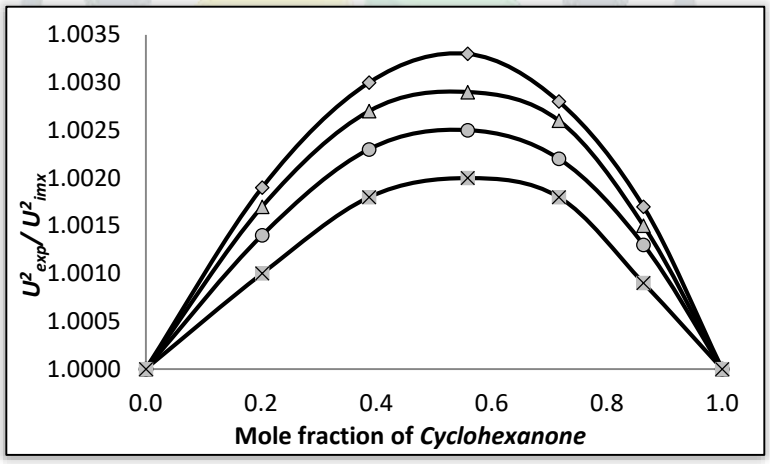

Fig c: Variation of U^2_{exp}/U^2_{imx} with mole fraction of *Cyclohexanone + 2-Butoxyethanol*

Figures a, b and c represent the variation of U^2_{exp}/U^2_{imx} with the mole fraction of Cyclohexanone for all three binary systems. The positive variation of the ratio U^2_{exp}/U^2_{imx} gives an idea of strong interactions between unlike component molecules [25] are getting maximum near equimolar compositions approximately. The proposed ratio values are 1.0210 for 2-Methoxyethanol mixture, 1.0102 for 2-Ethoxyethanol and 1.0033 for 2-Butoxyethanol systems and decreases for the binary systems in the order of ME > EE > BE clearly indicating decreasing inter-molecular interactions with increasing chain length [26]. Strong tendency of molecular association observed maximum near equal proportions of component liquids of 2-alkoxyethanols and Cyclohexanone. The negative deviation ultrasonic velocity values of BE binary mixtures are becoming positive with increasing temperature in Nomoto's and Free length theories are indicating the increasing association between unlike molecules by breaking self-association among like molecules.

V.CONCLUSIONS

From the experimental and mathematically computed values of ultrasound velocity, it can be concluded that, Nomoto's theory, Rao's specific velocity relation and Free length theory provide best results for three different binary mixtures. The fitting of different theories to the mixtures clearly defining the variation of molecular association depending on the molecules involved in the binary system. The change in volume due to increasing chain length of alkoxyethanol molecules, density and free length are reflecting in the fitting of molecules causes structural changes. Strong interactions proposed by the positive percentage deviation of theoretical velocities predicting the possibility of different association between dissimilar component molecules of binary mixtures.

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