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Speed of sound and Viscosity theories of benzoate liquid mixtures

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ABSTRACT:

Density (ρ), viscosity (η) and speed of sound (U) values of various mole fractions of **System I:** Ethyl-4- hydroxy benzoate (E4HB) with aniline (AN), o- chloroaniline (OCA) and **System II:** P-methoxy benzoic acid (PMBA) with formamide (FA), D-methyl formamide (DMF) were measured using the accepted methods at 303.15, 308.15, and 313.15K. Measured values of speed of sound and viscosity have been correlate using the empirical relations Nomoto's relation, Ideal mixture relation, Junjie's method and Rao's relation for speed of sound and various relations due to Gruenberg-Nissan model, Hind rule, Arrhenius equation, Wijk and Kendall- Monroe relation for viscosity. The validity of these theories will check the goodness of fit from chi square test, average percentage error (APE) for speed of sound and interaction parameter, standard deviation(σ) for viscositywere calculated.

Key words: Mole fraction, accepted methods, empirical relations, speed of sound, viscosity

INTRODUCTION:

Measurement of speed of sound gives the valuable information about the physicochemical behavior of the fluid and fluid mixtures. Several empirical relations and theories are available for the theoretical computation of speed of sound and viscosity in fluid and fluid mixtures. They are broadly used in perfumery and pesticides. The benzenes are a widely used industrial chemical. Benzene is found in crude oil and is a major part of gasoline. It's used to make metabolites, plastics, resins, synthetic fibers, rubber lubricants, dyes, detergents and pharmacy. The amides of commercial importance are acetamide, also called formamide and dimethylformamide, which are used as solvents, sulfa drugs and nylons and amines play important roles in many drugs, cosmetics, detergents, plastics, and antimicrobials. In present study the authors want to observe the molecular interactions between the similar featuredfluids using speed of sound and viscosity theories. [1, 3]

EXPERIMENTAL SECTION:

The binary liquid mixes were created using mass variation for several samples just before began the experiment began. Measurements of the speed of sound ranged from 303.15 K to 313.15K by using ultrasonic interferometer(M/s Mittal Enterprises, India) operating at a fixed frequency of 2 MHz with an accuracy of ±0.1m/s.

The density of pure component and its multiple components was determined with an accuracy of ± 0.02mg using 10ml specific gravity bottles on a high-precision electronic digital balance (Baijnath Premnath SF

400A, Kanpur, USA). Viscosity was measure with Viscometer by Ostwald regarding E-4-HB and P-MBA binary systems. Varioustemperatures were used to calibrate the viscometer, by using double-distiller water. The experimentally measured data of density, viscosity, and sound velocity were compared with theoretical relations.

RESULTS AND DISCUSSION

Speed of sound theories: The prognostic artistries of speeds of sound theories based upon the brawn of interactivity persuading in a framework. The deviation in upshots may be ascribed to the précised made in these theories for theodd-odd speaks interactivities between the motes in the whole captivation. This implies the impedance relation (U_{IMP}) and Nomoto (U_{NMR}) and reveals merit of concurrence among theoretical to measured data. The measured values of speed of sound along with their theoretically determined values of Nomoto's, Ideal mixing, Junjie's, Vandael & Vangel and Rao's [4-7] with mole fraction in the twofold fluid blends of p-MBA /E-4-HB at three different temperatures were noticed at table 1 & 2 The APE and chi square test (χ) is also included for the individual twofold blends. *U* for both real and framework increases/decreases with ρ and *z* compliance with mole fraction. This drift is due to own alliance of solvent molecules have more strong dipole- induced interactions between the molecules. For sound procreation Eyring and Kincaid [14] was proposed that *U* should increase/decrease with alteration of L_f decreases in mixing of speaks**.**

On other side, slight changes in Junjie U_{JN}, Rao's (U_R) and Vandael & Vangel (U_{VDV}) relations. This type of alterations are presumed in the blends due to volume variation after fluid mixing, also there is much deviation in theoretical prediction of U with measured data recommend the exits of solid inclination for the relationship between the segment atoms because of hydrogen bond in the mix.

The Chi-square and APE values are less for all these theories. These upshots are used to judge non-idealitybehavior in the fluid blends and it can also perceive the mote ally with positive/negative alteration in '*U*' specifies atomic dissociation/ association of species by heap of solvent. Regarding this behavior of twofold blendsimpliespositive digression in'*U'* accredits elastic nature of spherical motes is liable for the atomic coalition. [2,15] **Viscosity theories**: The standard deviation is small in all systems where the interactions are less there exists stronginteractions between mixes. This shows that, the envisage flair of various viscosity theories depend upon the strength interplay prevailing in a system. The experimental and theoretical viscosity values of Gruenberg-Nissan model, Hind rule, Arrhenius equation, Wijk and Kendall-Monroe relations [9-13] for pMBA /E-4-HB systems are presented in table 3&4 along with interaction parameters and standard deviations. On all of these models fairlypredicted viscosity theories, they are reasonably close to the measured values for the twofold mix reported in this work, this showing the validity of studied theoretic models for twofold mix. Out of all equations used to correlate measured data of mix viscosity standard deviation calculated using Wijk and Hind is lower than other theories. Hence, Hind and Wijk theories are more convenient and fit well for this mix. [8,16]

CONCLUSION

The deliberated values of speed of sound and viscosity from several theories have been correlated with the measured values. Speed of sound values obtained from Nomoto's and Vandael & Vangel relations are in good concurrence with the measured values. The Chi square values also support these upshots and the observed deviationof theoretical values of speed of sound from the experimental values is attributed to the presence of intermolecular interactions. The experimental values of viscosity are also correlated with the empirical relations of viscosity and these are in good agreement with the experimental values. It may be concluded that out of these theories, Nomoto'srelation in the speed of sound Hind is in the viscosity were the best suited relation for the fluid mixtures.

Table 1: Speed of sound theories for the binary system of E -4-HB with aniline/o-Chloroaniline at T= 303.15 K, 308.15K and 313.15K

X_1	U_{EXP} m.s^{-1}	U_{NOM} m.s^{-1}	U_{IMR} m.s^{-1}	U_{JM} m.s^{-1}	U_{VDV} m.s^{-1}	U_R m.s^{-1}
E-4-HB + Aniline						
303.15 K						
0.0000	1224.4	1224.4	1224.4	1224.4	1224.4	1224.4
0.2136	1318.2	1318.2	1314.0	1316.6	1318.8	1312.2
0.4547	1398.6	1394.0	1397.4	1391.2	1396.6	1389.2
0.6493	1454.6	1454.2	1452.6	1451.8	1458.4	1456.0
0.8753	1507.4	1507.8	1504.6	1507.4	1507.4	1507.4
1.0000	1524.6	1524.6	1524.6	1524.6	1524.6	1524.6
APE		0.0006	0.0052	0.0013	0.0058	0.0149
chi square(χ)		0.0046	0.0622	0.0038	0.0613	0.1714
308.15 K						
0.0000	1214.4	1214.4	1214.4	1214.4	1214.4	1214.4
0.2136	1286.2	1286.2	1286.2	1286.2	1286.2	1286.2
0.4547	1378.8	1378.8	1378.8	1378.8	1378.8	1378.8
0.6493	1484.4	1484.4	1484.4	1484.4	1484.4	1484.4
0.8753	1516.6	1516.6	1516.6	1516.6	1516.6	1516.6
1.0000	1542.6	1542.6	1542.6	1542.6	1542.6	1542.6
APE		0.0015	0.0057	0.0011	0.0050	0.0165
chi square(χ)		0.0054	0.0674	0.0035	0.0647	0.1239
313.15K						
0.0000	1192.4	1192.4	1192.4	1192.4	1192.4	1192.4
0.2136	1248.8	1248.2	1241.8	1240.8	1239.6	1249.6
0.4547	1378.2	1378.6	1373.4	1371.6	1381.0	1376.8
0.6493	1464.6	1464.0	1462.8	1468.0	1470.8	1461.4
0.8753	1544.2	1544.8	1541.6	1547.4	1539.4	1549.0
1.0000	1571.6	1571.6	1571.6	1571.6	1571.6	1571.6

APE		0.0004	0.0032	0.0007	0.0039	0.0032
chi square(χ)		0.0046	0.0374	0.0086	0.0329	0.0272
		E-4-HB +O-Chloroaniline				
		303.15K				
0.0000	1464.4	1464.4	1464.4	1464.4	1464.4	1464.4
0.2367	1488.2	1488.6	1481.2	1484.6	1482.6	1486.6
0.4158	1492.6	1492.2	1494.6	1498.2	1494.2	1499.8
0.6304	1504.6	1504.0	1507.6	1506.0	1509.8	1505.2
0.8786	1517.4	1517.2	1519.4	1512.8	1511.4	1518.6
1.0000	1524.6	1524.6	1524.6	1524.6	1524.6	1524.6
APE		0.0006	0.0062	0.0005	0.0068	0.0132
Chi square(χ)		0.0056	0.0548	0.0048	0.0052	0.1434
			308.15K			
0.0000	1458.2	1458.2	1458.2	1458.2	1458.2	1458.2
0.2367	1474.2	1474.8	1478.2	1471.4	1474.6	1470.6
0.4158	1494.6	1494.2	1492.4	1494.0	1491.8	1496.8
0.6304	1518.8	1518.0	1512.6	1514.6	1516.2	1510.0
0.8786	1530.4	1530.6	1532.4	1536.4	1534.2	1538.4
1.0000	1542.6	1542.6	1542.6	1542.6	1542.6	1542.6
APE		0.0005	0.0027	0.0003	0.0036	0.0185
Chi square(χ)		0.0043	0.0416	0.0027	0.0549	0.1136
			313.15 K			
0.0000	1438.4	1438.4	1438.4	1438.4	1438.4	1438.4
0.2367	1467.2	1467.2	1467.2	1467.2	1467.2	1467.2
0.4158	1492.8	1492.8	1492.8	1492.8	1492.8	1492.8
0.6304	1524.2	1524.2	1524.2	1524.2	1524.2	1524.2
0.8786	1557.6	1557.6	1557.6	1557.6	1557.6	1557.6
1.0000	1571.6	1571.6	1571.6	1571.6	1571.6	1571.6
APE		0.0004	0.0039	0.0005	0.0026	0.0142
Chi square(χ)		0.0063	0.0439	0.0035	0.0506	0.1539

Table 2: Speed of sound theories for the binary system of p-MBA with formamide/DMF at T= 303.15 K, 308.15K and 313.15K

X_1	U_{EXP} $m.s^{-1}$	U_{NOM} $m.s^{-1}$	U_{IMR} $m.s^{-1}$	U_{JM} $m.s^{-1}$	U_{VDV} $m.s^{-1}$	U_R $m.s^{-1}$
			p-MBA +Formamide			
			303.15K			
0.0000	1583.4	1583.4	1583.4	1583.4	1583.4	1583.4
0.2032	1580.2	1580.2	1580.6	1581.4	1582.2	1581.6
0.4150	1574.6	1574.6	1574.2	1576.6	1574.0	1575.4

0.6344	1568.0	1568.0	1568.8	1568.4	1561.2	1567.2
0.8576	1562.8	1562.8	1562.4	1561.8	1560.6	1561.6
1.0000	1557.6	1557.6	1557.6	1557.6	1557.6	1557.6
APE		0.0001	0.0042	0.0002	0.0062	0.0105
chi square(χ)		0.0074	0.0546	0.0056	0.0457	0.1407
308.15K						
0.0000	1576.4	1576.4	1576.4	1576.4	1576.4	1576.4
0.2032	1570.2	1570.2	1570.2	1570.2	1570.2	1570.2
0.4150	1568.8	1568.8	1568.8	1568.8	1568.8	1568.8
0.6344	1554.6	1554.6	1554.6	1554.6	1554.6	1554.6
0.8576	1547.4	1547.4	1547.4	1547.4	1547.4	1547.4
1.0000	1533.6	1533.6	1533.6	1533.6	1533.6	1533.6
APE		0.0002	0.0069	0.0002	0.0072	0.0184
chi square(χ)		0.0061	0.0476	0.0046	0.0606	0.1871
313.15K						
0.0000	1572.4	1572.4	1572.4	1572.4	1572.4	1572.4
0.2032	1568.2	1568.2	1568.2	1568.2	1568.2	1568.2
0.4150	1545.6	1545.6	1545.6	1545.6	1545.6	1545.6
0.6344	1538.8	1538.8	1538.8	1538.8	1538.8	1538.8
0.8576	1530.2	1530.2	1530.2	1530.2	1530.2	1530.2
1.0000	1525.4	1525.4	1525.4	1525.4	1525.4	1525.4
APE		0.0004	0.0036	0.0008	0.0036	0.0022
chi square(χ)		0.0042	0.0397	0.0084	0.0397	0.0247
p-MBA+DMF						
303.15K						
0.0000	1458.4	1458.4	1458.4	1458.4	1458.4	1458.4
0.2731	1486.2	1486.2	1481.2	1485.2	1486.0	1480.2
0.4407	1508.6	1508.6	1506.6	1503.0	1501.2	1518.2
0.6993	1524.8	1524.8	1529.8	1527.2	1523.6	1531.8
0.8139	1541.4	1541.4	1540.4	1543.6	1544.8	1544.6
1.0000	1557.2	1557.2	1557.2	1557.2	1557.2	1557.2
APE		0.0006	0.0044	0.0004	0.0077	0.0167
Chi square(χ)		0.0059	0.0812	0.0052	0.0739	0.1296
308.15K						
0.0000	1434.4	1434.4	1434.4	1434.4	1434.4	1434.4
0.2731	1468.6	1468.2	1463.6	1464.6	1461.0	1466.2
0.4407	1494.8	1494.8	1492.2	1497.2	1495.6	1490.6
0.6993	1512.2	1512.0	1516.8	1511.8	1515.8	1520.4
0.8139	1522.4	1522.4	1521.4	1526.2	1502.4	1526.8
1.0000	1533.6	1533.6	1533.6	1533.6	1533.6	1533.6
APE		0.0008	0.0068	0.0006	0.0071	0.0137
Chi square(χ)		0.0050	0.0719	0.0021	0.0608	0.1449

			313.15 K			
0.0000	1422.4	1422.4	1422.4	1422.4	1422.4	1422.4
0.2731	1458.6	1458.2	1454.6	1451.0	1456.6	1450.6
0.4407	1482.2	1482.4	1483.4	1484.6	1487.0	1485.8
0.6993	1504.8	1504.0	1507.2	1506.2	1509.2	1505.2
0.8139	1514.6	1514.8	1511.8	1517.8	1518.8	1511.0
1.0000	1525.4	1525.4	1525.4	1525.4	1525.4	1525.4
APE		0.0007	0.0038	0.0005	0.0063	0.0286
Chi square(**χ**)		0.0049	0.0477	0.0029	0.0576	0.1568

Table 3 Viscosity theories for the binary system of E -4-HB with aniline/o-Chloroaniline at T= 303.15 K, 308.15K and 313.15K

x_1	η Exp (mPas)	**Hind** (mPas)	**Gruenberg -Nissan** (mPas)	**Wijk** (mPas)	**Arrhenius** (mPas)	**Kendall-Monroe equation** (mPas)
			E-4-HB + aniline			
			303.15 K			
0.0000	2.234	2.234	2.234	2.234	2.234	2.234
0.2136	2.106	2.106	2.104	2.108	2.105	2.107
0.4547	1.968	1.968	1.967	1.964	1.962	1.961
0.6493	1.663	1.663	1.665	1.667	1.666	1.668
0.8753	1.419	1.419	1.418	1.416	1.412	1.415
1.0000	1.286	1.286	1.286	1.286	1.286	1.286
Interaction parameter		1.114	0.434	1.163	2.209	2.064
Standard deviation(σ)		0.232	0.318	0.501	0.525	0.226
			308.15 K			
0.0000	1.943	1.943	1.943	1.943	1.943	1.943
0.2136	1.761	1.761	1.763	1.764	1.765	1.768
0.4547	1.594	1.594	1.597	1.596	1.598	1.595
0.6493	1.375	1.375	1.376	1.372	1.371	1.376
0.8753	1.258	1.258	1.251	1.256	1.257	1.252
1.0000	1.196	1.196	1.196	1.196	1.196	1.196
Interaction parameter		1.071	0.446	0.905	2.484	2.467
Standard deviation(σ)		0.162	0.204	0.416	0.878	0.621
			313.15 K			
0.0000	1.724	1.724	1.724	1.724	1.724	1.724
0.2136	1.587	1.587	1.584	1.588	1.582	1.586
0.4547	1.438	1.438	1.436	1.435	1.437	1.434
0.6493	1.391	1.391	1.397	1.394	1.396	1.398
0.8753	1.269	1.269	1.265	1.267	1.263	1.264
1.0000	1.172	1.172	1.172	1.172	1.172	1.172

Interaction parameter		0.962	0.207	0.715	2.250	2.234
Standard deviation(σ)		0.107	0.108	0.319	0.902	0.746
E-4-HB+Ocholoro aniline						
303.15 K						
0.0000	3.814	3.814	3.814	3.814	3.814	3.814
0.2367	3.426	3.426	3.423	3.427	3.425	3.422
0.4158	3.121	3.121	3.124	3.126	3.125	3.128
0.6304	2.843	2.843	2.842	2.845	2.848	2.847
0.8786	2.518	2.518	2.516	2.512	2.514	2.519
1.0000	1.286	1.286	1.286	1.286	1.286	1.286
Interaction parameter		2.124	2.364	2.823	1.323	1.163
Standard deviation(σ)		0.140	0.229	0.546	0.728	0.847
308.15 K						
0.0000	3.476	3.476	3.476	3.476	3.476	3.476
0.2367	3.266	3.266	3.264	3.268	3.265	3.269
0.4158	3.047	3.047	3.042	3.046	3.041	3.045
0.6304	2.784	2.784	2.786	2.788	2.789	2.782
0.8786	2.441	2.441	2.444	2.442	2.445	2.446
1.0000	1.196	1.196	1.196	1.196	1.196	1.196
Interaction parameter		2.043	2.145	2.362	1.351	0.987
Standard deviation(σ)		0.136	0.437	0.641	0.726	0.981
313.15 K						
0.0000	3.105	3.105	3.105	3.105	3.105	3.105
0.2367	2.962	2.962	2.967	2.969	2.961	2.963
0.4158	2.549	2.549	2.546	2.543	2.545	2.546
0.6304	1.954	1.954	1.955	1.958	1.956	1.957
0.8786	1.627	1.627	1.624	1.623	1.628	1.625
1.0000	1.172	1.172	1.172	1.172	1.172	1.172
Interaction parameter		2.046	2.214	2.410	1.839	1.256
Standard deviation(σ)		0.082	0.138	0.363	0.565	0.728

Table 4 Viscosity theories for the binary system of p-MBA with formamide/DMF at T= 303.15 K, 308.15K and 313.15K

x_1	η_{Exp} **(mPas)**	**Hind** (mPas)	**Gruenberg -Nissan** (mPas)	**Wijk** (mPas)	**Arrhenius** (mPas)	**Kendall-Monroe equation** (mPas)
p-MBA + Formamide						
303.15 K						
0.0000	2.782	2.782	2.782	2.782	2.782	2.782

0.2032	2.425	2.425	2.428	2.422	2.429	2.426
0.4150	2.193	2.193	2.196	2.195	2.198	2.197
0.6344	1.968	1.968	1.962	1.961	1.965	1.960
0.8576	1.749	1.747	1.742	1.741	1.740	1.746
1.0000	1.583	1.583	1.583	1.583	1.583	1.583
Interaction parameter		1.174	0.504	1.046	2.829	2.260
Standard deviation(σ)		0.263	0.358	0.651	0.725	0.462
308.15 K						
0.0000	2.465	2.465	2.465	2.465	2.465	2.465
0.2032	2.139	2.139	2.139	2.139	2.139	2.139
0.4150	1.965	1.965	1.965	1.965	1.965	1.965
0.6344	1.648	1.648	1.648	1.648	1.648	1.648
0.8576	1.672	1.672	1.675	1.677	1.676	1.670
1.0000	1.424	1.424	1.424	1.424	1.424	1.424
Interaction parameter		1.071	0.446	0.905	2.484	2.467
Standard deviation(σ)		0.162	0.204	0.416	0.878	0.621
313.15 K						
0.0000	2.254	2.254	2.254	2.254	2.254	2.254
0.2032	2.017	2.017	2.015	2.014	2.010	2.018
0.4150	1.872	1.872	1.874	1.877	1.879	1.876
0.6344	1.640	1.640	1.643	1.646	1.648	1.640
0.8576	1.526	1.526	1.522	1.527	1.524	1.525
1.0000	1.345	1.345	1.345	1.345	1.345	1.345
Interaction parameter		0.962	0.207	0.715	2.250	2.234
Standard deviation(σ)		0.107	0.108	0.319	0.902	0.746
p-MBA + DMF						
303.15 K						
0.0000	0.772	0.772	0.772	0.772	0.772	0.772
0.2731	0.923	0.923	0.926	0.925	0.928	0.924
0.4407	1.234	1.234	1.232	1.236	1.237	1.235
0.6993	1.412	1.412	1.414	1.418	1.416	1.417
0.8139	1.523	1.523	1.525	1.527	1.528	1.526
1.0000	1.583	1.583	1.583	1.583	1.583	1.583
Interaction parameter		1.082	1.004	0.972	0.875	0.807
Standard deviation(σ)		0.104	0.127	0.209	0.310	0.093
308.15 K						
0.0000	0.735	0.735	0.735	0.735	0.735	0.735
0.2731	0.893	0.893	0.895	0.897	0.896	0.898
0.4407	1.127	1.127	1.124	1.126	1.125	1.129
0.6993	1.262	1.262	1.267	1.264	1.268	1.269
0.8139	1.356	1.356	1.353	1.358	1.351	1.357
1.0000	1.424	1.424	1.424	1.424	1.424	1.424

Interaction parameter		1.043	1.155	1.669	1.351	0.973
Standard deviation(σ)		0.083	0.039	0.014	0.120	0.140
			313.15 K			
0.0000	0.682	0.682	0.682	0.682	0.682	0.682
0.2731	0.812	0.812	0.814	0.815	0.816	0.817
0.4407	0.966	0.966	0.967	0.965	0.968	0.963
0.6993	1.121	1.121	1.124	1.126	1.127	1.125
0.8139	1.249	1.249	1.247	1.245	1.246	1.248
1.0000	1.345	1.345	1.345	1.345	1.345	1.345
Interaction parameter		1.017	0.994	0.817	0.639	0.560
Standard deviation(σ)		0.016	0.008	0.063	0.015	0.007

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