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Theoretical calculations of ideal speeds of sound of dipropylene glycol monobutyl ether with methanol, 1-propanol, 1-pentanol and 1-heptanol at 298.15k and atmospheric pressure

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Abstract
Theoretical ideal speeds of sound have been calculated at 298.15K and atmospheric pressure in binary mixture of dipropylene glycol monobutyl ether with methanol, 1-propanol, 1-pentanol and 1-heptanol. Results of calculation of ideal speed of sound u^{id} at 298.15 K for the mixtures at various mole fraction are summarized and compared with the literature values[1] of ultrasonic speed of sound u^*.

Keywords: Ideal speed of sound u^{id} ; isentropic compressibility κ_s^* ; densities ρ^* ; isobaric thermal expansivities α_p^* and molar isobaric heat capacities $C_{p,m}^*$.

Introduction
A number of approximate ideal mixing rules have been made to estimate ideal speed of sound u^{id}. These approximate equations are still all too frequently used. As a result different values of excess speed of sound are obtained. Here the author tried to accumulate the different approaches used to calculated u^{id}. For example, the ultrasonic speed in ideal liquid mixtures was considered to be the mass fraction w_i weighted average of the speed in the pure components U_i. This can be expressed as

$$u^{id} = \Sigma w_i u_i \quad (1.1)$$

In literature the expression Eq. (1.2) was proposed for the speed of sound in ideal mixtures

$$u^{id} = [\Sigma w_i (u_i)^2]^{½} \quad (1.2)$$

In another instance the modified equation for the ideal ultrasonic speed. The expression is

$$u^{id} = (\Sigma \phi_i u_i)^{-1} \quad (1.3)$$

A equation for ideal mixtures based on the Newton Laplace equation and from the thermodynamic definition of the isentropic compressibility of solutions and liquid mixtures. According to this treatment a similar thermodynamic approach was used to evaluate the ultrasonic speed in binary liquid mixtures of aromatic hydrocarbons.

$$u^{id} = (\Sigma \phi_i / w_i (u_i)^2]^{-½} \quad (1.4)$$

Another promising approach was used to calculate u^{id} using volume fraction averaging of the pure component properties. The 'excess' means that, for a binary liquid mixture having ideal thermodynamic properties, thermodynamics does not require the ultrasonic speed to be a linear function of the mole fraction composition.

$$u^{id} = v_m^{id} [M_m K_{s,m}^{id}]^{-1/2} \quad (1.5)$$

The calculated theoretical value of ideal speed of sound and excess speed of sound as a function of x at 298.15 K and atmospheric pressure for diethylene glycol monobutyl ether with methanol, 1-propanol, 1-pentanol and 1-heptanol are calculated from data given by Pal *et al.* [1]

Table 1: Different values of Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with methanol at 298.15K and atmospheric pressure.

				u^{id}/ms^{-1}			
X	**u/ ms^{-1} (from ref. 1)**	$K_{s,m}^{id}$ / **TPa^{-1}**	κ_s^{id} / **TPa^{-1}**	u_1^{id} **from equation (1.1)**	u_2^{id} **from equation (1.2)**	u_3^{id} **from equation (1.3)**	u_4^{id} **from equation (1.4)**
dipropyleneglycol monobutyl ether (1) + methanol (2)							
0.0022	1107.5	42.600	1039.43	1105.98	1107.55	1107.61	1106.82
0.0072	1111.7	43.100	1037.59	1106.85	1111.84	1112.07	1109.49
0.0139	1117.5	43.768	1035.13	1108.01	1117.33	1117.84	1112.99
0.0233	1125.0	44.706	1031.67	1109.65	1124.57	1125.55	1117.76
0.0317	1131.4	45.543	1028.58	1111.11	1130.62	1132.09	1121.89
0.0396	1137.1	46.330	1025.68	1112.48	1135.97	1137.95	1125.65
0.0492	1143.9	47.285	1022.14	1114.15	1142.09	1144.73	1130.08
0.0604	1151.6	48.398	1018.03	1116.09	1148.74	1152.19	1135.06
0.0810	1164.0	50.442	1010.45	1119.67	1159.76	1164.78	1143.70
0.0910	1169.1	51.434	1006.77	1121.41	1164.61	1170.41	1147.67
0.1274	1186.3	55.038	993.38	1127.73	1180.07	1188.60	1161.00
0.1690	1206.6	59.150	978.08	1134.96	1194.37	1205.72	1174.34
0.2375	1222.5	65.909	952.89	1146.85	1212.52	1227.50	1192.80
0.2887	1234.4	70.953	934.06	1155.75	1223.02	1239.87	1204.33
0.3289	1241.7	74.911	919.27	1162.73	1229.94	1247.79	1212.31
0.3799	1249.3	79.929	900.52	1171.59	1237.43	1256.00	1221.30
0.4213	1254.4	84.000	885.29	1178.78	1242.67	1261.42	1227.81
0.4739	1259.8	89.171	865.94	1187.92	1248.45	1266.99	1235.22
0.5091	1262.9	92.669	853.00	1194.03	1251.86	1270.01	1239.45
0.5514	1266.0	96.786	837.44	1201.38	1255.56	1273.01	1244.69
0.5932	1268.3	100.649	822.07	1208.64	1258.85	1275.38	1250.70
0.6290	1269.0	104.407	808.90	1214.86	1261.42	1277.00	1252.78
0.6736	1271.8	108.787	792.50	1222.60	1264.34	1278.56	1256.91
0.7249	1273.4	113.823	773.63	1231.52	1267.36	1279.80	1261.27
0.7817	1273.4	119.398	752.74	1241.38	1270.35	1280.58	1265.66
0.8302	1276.6	124.159	734.90	1249.81	1272.65	1280.82	1269.10
0.8963	1277.9	130.645	710.59	1261.29	1275.48	1280.63	1273.37
0.9288	1278.0	133.834	698.64	1266.93	1276.75	1280.33	1275.32
0.9590	1278.8	136.797	687.53	1272.18	1277.87	1279.96	1277.05
0.9786	1279.2	138.720	680.32	1275.58	1278.56	1279.66	1278.13
0.9924	1279.1	140.686	675.25	1277.98	1279.04	1279.43	1276.09

Table 2: Different values of Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-propanol at 298.15K and atmospheric pressure.

				u^{id}/ms^{-1}			
x	**u/ ms^{-1} (from ref. 1)**	$K_{s,m}^{id}$ / **TPa^{-1}**	κ_s^{id} / **TPa^{-1}**	u_1^{id} **from equation (1.1)**	u_2^{id} **from equation (1.2)**	u_3^{id} **from equation (1.3)**	u_4^{id} **from equation (1.4)**
dipropyleneglycol monobutyl ether (1) + 1-propanol (2)							
0.0060	1210.1	64.691	853.37	1210.12	1210.85	1211.45	1210.46
0.0118	1211.1	65.136	852.31	1210.52	1211.94	1213.00	1211.19
0.0215	1212.5	65.880	850.55	1211.20	1213.72	1215.53	1212.41
0.0347	1215.8	66.893	848.14	1212.12	1216.04	1218.83	1214.04
0.0568	1222.3	-68.395	844.12	1213.65	1219.70	1224.02	+NAN
0.0783	1226.6	70.237	840.21	1215.15	1223.02	1228.70	1219.25
0.1043	1231.3	72.231	835.48	1216.96	1226.75	1233.92	1222.21
0.1464	1237.9	75.459	827.81	1219.89	1232.21	1241.42	1226.78
0.2038	1245.6	79.867	817.37	1223.88	1238.67	1250.05	1232.49
0.2710	1252.4	85.007	805.14	1228.56	1245.11	1258.19	1238.73
0.3082	1255.7	87.857	798.36	1231.15	1248.25	1261.93	1241.90
0.3582	1259.6	91.687	789.26	1234.63	1252.06	1266.22	1245.88
0.4276	1263.9	97.003	776.63	1239.46	1256.71	1270.99	1250.96
0.4821	1266.8	101.176	766.71	1243.25	1259.93	1273.90	1254.62
0.5284	1268.9	104.721	758.29	1246.48	1262.41	1275.89	1257.53
0.5778	1270.8	108.504	749.29	1249.91	1264.84	1277.56	1260.43
0.6370	1272.8	113.036	738.52	1254.04	1267.48	1279.05	1263.68
0.6904	1274.4	117.124	728.80	1257.75	1269.65	1279.95	1266.41
0.7351	1277.3	120.545	720.66	1260.86	1271.33	1280.44	1268.56
0.7784	1276.4	123.947	712.78	1263.88	1272.85	1280.69	1270.09
0.8214	1277.2	127.151	704.96	1266.87	1274.26	1280.75	1272.41
0.8617	1277.8	130.235	697.62	1269.67	1275.51	1280.64	1274.08
0.9007	1278.4	133.220	690.52	1272.39	1276.65	1280.41	1275.62
0.9174	1278.5	134.498	678.48	1273.55	1277.12	1280.27	1276.27
0.9446	1278.9	136.580	682.53	1275.44	1277.87	1280.01	1277.29
0.9719	1278.9	138.669	677.56	1277.34	1278.59	1279.68	1278.28
0.9968	1279.2	140.575	673.03	1279.08	1279.22	1279.34	1279.17

Table 3: Different values of Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-pentanol at 298.15K and atmospheric pressure.

				u^{id}/ms^{-1}			
x	**u/ ms^{-1} (from ref. 1)**	$K_{s,m}^{id}$ / **TPa^{-1}**	κ_s^{id} / **TPa^{-1}**	u_1^{id} **from equation (1.1)**	u_2^{id} **from equation (1.2)**	u_3^{id} **from equation (1.3)**	u_4^{id} **from equation (1.4)**
dipropyleneglycol monobutyl ether (1) + 1-pentanol (2)							
0.0039	1275.1	82.648	758.05	1275.02	1275.03	1275.25	1275.04
0.0110	1275.2	83.063	757.44	1275.05	1275.09	1275.68	1274.98
0.0219	1275.3	83.116	756.51	1275.09	1275.18	1276.32	1279.37
0.0311	1275.7	84.238	755.72	1275.13	1275.25	1276.85	1274.83
0.0430	1276.1	84.933	754.69	1275.18	1275.34	1277.50	1274.76
0.0552	1276.5	85.646	753.65	1275.24	1275.44	1278.14	1274.69
0.0661	1276.8	86.283	752.71	1275.28	1275.52	1278.69	1274.64
0.0773	1277.3	86.937	751.75	1275.33	1275.60	1279.23	1274.60
0.0977	1277.9	88.129	749.99	1275.42	1275.74	1280.16	1274.53
0.1470	1278.6	91.010	745.76	1275.63	1276.07	1282.12	1274.46
0.1852	1279.2	93.242	742.47	1275.80	1276.31	1283.38	1274.47
0.2145	1276.7	94.953	739.96	1275.92	1276.48	1284.21	1274.51
0.2668	1280.5	98.008	735.46	1276.15	1276.77	1285.41	1274.65
0.3067	1280.9	100.339	732.03	1276.32	1276.98	1286.10	1274.80
0.3709	1281.4	104.089	726.51	1276.59	1277.29	1286.87	1274.09
0.4208	1281.6	107.003	722.23	1276.81	1277.51	1287.19	1275.36
0.4680	1281.9	109.777	718.17	1277.01	1277.70	1287.30	1275.53
0.5205	1281.9	112.825	713.66	1277.24	1277.91	1287.21	1275.96
0.5672	1281.9	115.552	709.64	1277.44	1278.08	1286.97	1276.27
0.6216	1281.9	118.729	704.97	1277.67	1278.27	1286.51	1276.64
0.6874	1281.7	122.570	699.31	1277.96	1278.48	1285.72	1276.09
0.7248	1281.5	124.754	696.10	1278.12	1278.59	1285.17	1277.35
0.7751	1281.1	127.691	691.78	1278.33	1278.74	1284.33	1277.71
0.8312	1280.3	130.966	686.96	1278.57	1278.89	1283.25	1278.10
0.8765	1280.3	133.611	683.06	1278.77	1279.01	1282.29	1278.42
0.9048	1280.1	135.263	680.63	1278.89	1279.08	1281.65	1278.62
0.9363	1276.8	137.101	677.92	1279.03	1279.15	1280.91	1278.84
0.9497	1276.5	137.884	676.77	1279.08	1279.18	1280.98	1278.93
0.9768	1279.4	139.466	674.44	1279.20	1279.25	1279.90	1279.12
0.9967	1279.3	140.627	672.73	1279.29	1279.29	1279.38	1279.26

Table 4: Different values of Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-heptanol at 298.15K and atmospheric pressure.

				u^{id}/ms^{-1}			
x	**u/ ms^{-1} (from ref. 1)**	$K_{s,m}^{id}$ / **TPa^{-1}**	κ_s^{id} / **TPa^{-1}**	u_1^{id} **from equation (1.1)**	u_2^{id} **from equation (1.2)**	u_3^{id} **from equation (1.3)**	u_4^{id} **from equation (1.4)**
dipropyleneglycol monobutyl ether (1) + 1-heptanol (2)							
0.0060	1327.5	98.487	692.36	1327.41	1327.27	1327.43	1327.20
0.0142	1327.1	98.838	692.20	1327.01	1326.69	1327.07	1326.55
0.0234	1236.4	99.232	692.01	1326.57	1326.05	1326.66	1325.83
0.0363	1325.5	99.784	691.75	1325.94	1325.15	1326.08	1324.83
0.0494	1324.6	100.344	691.49	1325.31	1324.25	1325.50	1323.84
0.0638	1323.6	100.960	691.20	1324.61	1323.28	1324.85	1322.76
0.0807	1322.4	101.683	690.86	1323.79	1322.15	1324.08	1321.53
0.1003	1321.1	102.522	690.47	1322.85	1320.86	1323.19	1320.13
0.1471	1318.1	104.522	689.53	1320.58	1317.88	1321.04	1316.91
0.1991	1315.1	106.743	688.49	1318.06	1314.71	1318.63	1313.54
0.2308	1313.1	108.097	687.86	1316.53	1312.84	1317.14	1311.58
0.2788	1310.7	110.145	686.90	1314.21	1310.11	1314.87	1308.75
0.3287	1308.0	112.274	685.90	1311.79	1307.39	1312.48	1305.97
0.3973	1304.8	115.198	684.52	1308.47	1303.83	1309.18	1302.37
0.4394	1302.9	116.992	683.68	1306.43	1301.74	1307.13	1300.29
0.4784	1301.0	118.653	682.90	1304.55	1299.86	1305.23	1298.44
0.5432	1298.0	121.411	681.60	1301.41	1296.86	1302.05	1295.53
0.5831	1296.1	123.109	680.80	1299.48	1295.09	1300.08	1293.82
0.6404	1293.7	125.546	679.65	1296.70	1292.64	1297.25	1291.49
0.6817	1291.5	127.302	678.83	1294.71	1290.93	1295.20	1279.88
0.7304	1289.6	129.372	677.85	1252.35	1288.98	1292.77	1288.06
0.7746	1287.8	131.250	676.96	1290.21	1287.27	1290.57	1286.46
0.8145	1286.0	132.945	676.17	1288.28	1285.77	1288.58	1285.10
0.8813	1283.6	135.782	674.83	1285.05	1283.35	1285.24	1285.90
0.9125	1282.2	135.782	674.20	1283.53	1282.25	1283.68	1288.15
0.9125	1282.2	137.107	674.20	1283.53	1282.25	1283.88	1281.91
0.9425	1281.2	138.380	673.60	1282.08	1281.22	1282.18	1280.99
0.9634	1280.5	139.267	673.18	1281.07	1280.91	1281.13	1280.36
0.9827	1279.5	140.086	672.80	1280.14	1279.87	1280.16	1279.78

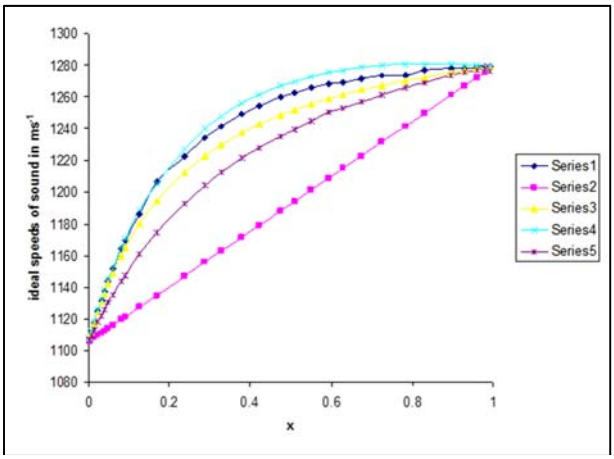

Fig 1: Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with methanol amine at 298.15K and atmospheric pressure. Series 1 for u, Series 2 for u_1^{id}, Series 3 for u_2^{id}, Series 4 for u_3^{id}, Series 5 for u_4^{id}.

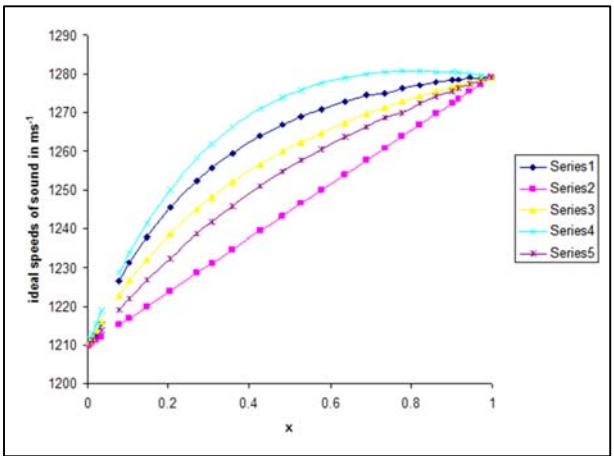

Fig 2: Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-propanol at 298.15K and atmospheric pressure. Series 1 for u, Series 2 for u_1^{id}, Series 3 for u_2^{id}, Series 4 for u_3^{id}, Series 5 for u_4^{id}.

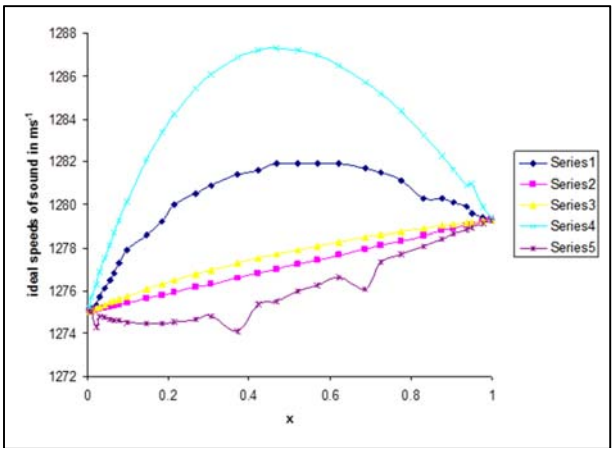

Fig 3: Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-pentanol at 298.15K and atmospheric pressure. Series 1 for u, Series 2 for u_1^{id}, Series 3 for u_2^{id}, Series 4 for u_3^{id}, Series 5 for u_4^{id}.

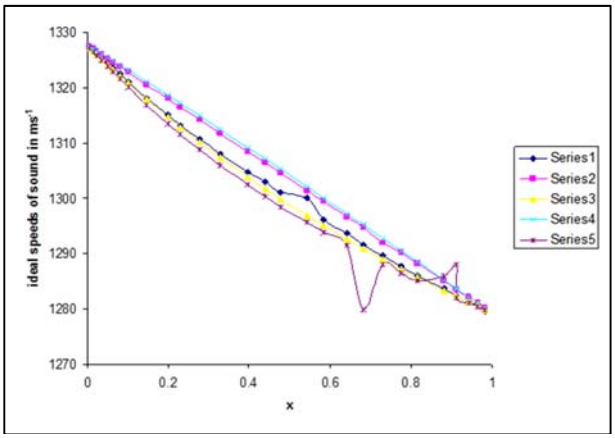

Fig 4: Ideal Speed of Sound for binary mixtures of dipropyleneglycol monobutyl ether with 1-heptanol at 298.15K and atmospheric pressure. Series 1 for u, Series 2 for u_1^{id}, Series 3 for u_2^{id}, Series 4 for u_3^{id}, Series 5 for u_4^{id}.

Conclusion

An examination has been made of some of graphical and analytic perspective of the thermodynamic data that have been accumulated for the non-aqueous mixtures. In conclusion, it is fair to ask whether we are any closer to an understanding of the nature of the patterns of molecular aggregation which exist within such mixtures. Our studies indicate that we are still in the dark regarding the proper elucidation of different types of interactions that occur in solution. As our few theoretical calculations are closer to the experimental values [1].

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