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Research Article

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Sound Speeds and Excess Isentropic Compressibilities of Binary Liquid Mixtures of *m*-Xylene with Nitrotoluenes

P Nagaraja[1], C Narasimha Rao[1], S Ramanaiah[2] and P Venkateswarlu[1]*

[1]*Department of Chemistry, S.V. University, Tirupati, Andhra Pradesh, India*
[2]*Department of Chemistry, Rayalaseema University, Kurnool, Andhra Pradesh, India*

ABSTRACT

Sound speeds (u) were measured and excess isentropic compressibilities (K_S^E) were computed from the measured sound speed (u) and density (ρ) data for the binary liquid mixtures of m-xylene with o- and m- nitrotoluenes at T= (298.15 K, 303.15 K, 308.15 K and 313.15 K). These values are negative for the studied binary liquid mixtures. The excess isentropic compressibilitiy (K_S^E) values are analysed on the basis of molecular interactions between unlike non-electrolyte molecules.

Keywords: *m*-xylene; Molecular interactions; non-electrolytes; Isentropic compressibilities

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INTRODUCTION

Excess thermodynamic properties of liquid mixtures provide important information for the design of industrial processes and also give information about inter molecular interactions in binary liquid mixtures [1]. A fundamental understanding of the behaviour of binary liquid mixtures of *m*-xylene with nitrotoluenes is useful in many industrial processes. To the best of our knowledge, excess isentropic compressibility data for the liquid mixtures of *m*-xylene with nitrotoluenes is not available in the literature. Recently, thermodynamic properties of isomeric nitrotoluenes with organic liquids [2,3] were reported. In the present work, new experimental data for the excess isentropic compressibilities of two binary liquid mixtures namely *m*-xylene with *o*- and *m*- nitrotoluenes are reported.

EXPERIMENTAL SECTION

m-Xylene was obtained from S.D. Fine Chemicals Ltd, India was used as supplied. *o*-Nitrotoluene and *m*-nitrotoluene were also obtained from S.D. Fine Chemicals Ltd., India and were purified as described in the literature [4,5]. All the binary liquid mixtures were prepared in glass bottles with air tight stoppers. Adequate precautions were taken to minimize evaporation losses. Weights of solutions were measured using digital electronic balance (Acculab, ALC-210-4, India). The uncertainty in mole fraction of solution was found to be less than $\pm 2 \times 10^{-4}$. Densities of binary liquid mixtures were measured by using Rudolph Research Analytical digital densimeter (DDH-2911 model). Densimeter was calibrated with doubly distilled, deionized water and with air as standards.

RESULTS AND DICUSSION

In the present study, speed of sound (u) data of pure liquids and their binary mixtures of *m*-xylene with *o*-nitrotoluene and *m*-nitrotoluene were measured over the entire composition range at 298.15 K, 303.15 K, 308.15 K and 313.15 K. The measured speed of sound (u), and density (ρ) data were used to compute isentropic compressibilities (K_S), and excess isentropic compressibilities (K_S^E) by the following equations:

$$K_S = u^{-2}\rho^{-1} \qquad (1)$$

The corresponding excess isentropic compressibilities (k_s^E) were obtained from the relation.

$$K_S^E = K_S - K_S^{id} \qquad (2)$$

where K_S^{id} is the ideal value of the isentropic compressibility and was calculated from the following equation [6].

$$k_s^{id} = \sum_{i=1}^{2} \emptyset_i \left[k_{s,i} + TV_i \ (\alpha_i^2)/C_{p,i}\right] - \left\{T \left[\sum_{i=1}^{2} x_i V_i\right] \left[\sum_{i=1}^{2} \emptyset_i \alpha_i\right] / \sum_{i=1}^{2} x_i C_{p,i}\right\} \qquad (3)$$

where C_{pi} and α_i are the molar heat capacity and the thermal expansion coefficient of the i th component respectively.

The mole fraction of *m*-xylene (x_1), density (ρ) of the mixture, speed of sound (u), isentropic compressibility (K_S), and excess isentropic compressibility (K_S) are included in Tables 1 and 2 and also the K_S^E data are graphically presented in Figures 1 and 2.

Table 1: Molefraction of *m*-xylene (x_1), densities (ρ), speed of sound (u), isentropic compressibilities (k_s), excess isentropic compressibilities (k_s^E) of m-xylene (1) with *o*-nitrotoluene (2) at 298.15 K to 313.15 K

x_1	ρ (γ χμ–3)	u (ms-1)	K_S	K_S^E (Experimental)	K_S^E Redlich-kister	K_S^E Hwang et al.
***m*-xylene (1) + *o*-nitrotoluene (2)**						
T = 298.15 K						
0.09651	1.13457	1440.7	406.9	-6.368	-6.368	-6.314
0.19377	1.10651	1427.6	424.6	-11.636	-11.641	-11.641
0.29179	1.07832	1416	443.4	-15.731	-15.73	-15.78
0.39057	1.05001	1400.3	463.5	-18.541	-18.533	-18.587
0.49014	1.02157	1388.3	484.9	-19.941	-19.927	-19.949
0.5905	0.99296	1378.1	507.8	-19.768	-19.768	-19.761
0.69165	0.96424	1365.7	532.3	-17.884	-17.894	-17.899
0.79362	0.93541	1348.9	558.6	-14.109	-14.119	-14.184
0.89639	0.90646	1335.7	586.9	-8.239	-8.233	-8.35
T = 303.15 K						
0.09651	1.12906	1425.2	417.6	-6.813	-6.813	-6.754
0.19377	1.10143	1411.6	436	-12.451	-12.455	-12.455
0.29179	1.07365	1399.5	455.6	-16.834	-16.833	-16.886
0.39057	1.04574	1383.4	476.5	-19.841	-19.833	-19.891
0.49014	1.01769	1370.9	498.8	-21.339	-21.325	-21.349
0.5905	0.98946	1360.2	522.7	-21.156	-21.156	-21.149
0.69165	0.96111	1347.3	548.3	-19.14	-19.15	-19.156
0.79362	0.93263	1330.1	575.8	-15.1	-15.11	-15.18
0.89639	0.90403	1316.4	605.4	-8.816	-8.81	-8.935
T = 308.15 K						
0.09651	1.12293	1404.5	432.3	-7.551	-7.551	-7.49
0.19377	1.09514	1391.2	451.4	-13.786	-13.791	-13.791
0.29179	1.06723	1379.4	471.8	-18.618	-18.617	-18.673
0.39057	1.03919	1363.6	493.5	-21.918	-21.91	-21.971
0.49014	1.01103	1351.3	516.8	-23.543	-23.529	-23.555
0.5905	0.98272	1340.8	541.6	-23.313	-23.313	-23.305
0.69165	0.9543	1328.3	568.2	-21.065	-21.075	-21.081
0.79362	0.92577	1311.4	596.8	-16.596	-16.606	-16.679
0.89639	0.89713	1297.9	627.5	-9.676	-9.669	-9.801
T = 313.15 K						
0.09651	1.12021	1389.1	442.6	-8.677	-8.677	-8.611
0.19377	1.09242	1375.3	462.6	-15.83	-15.834	-15.834
0.29179	1.06451	1362.9	484	-21.356	-21.354	-21.415
0.39057	1.03647	1346.7	506.8	-25.114	-25.105	-25.171
0.49014	1.00833	1334	531.2	-26.945	-26.931	-26.958
0.5905	0.98004	1323	557.3	-26.652	-26.652	-26.644
0.69165	0.95164	1309.9	585.3	-24.054	-24.063	-24.07
0.79362	0.92314	1292.6	615.4	-18.927	-18.936	-19.016
0.89639	0.89454	1278.7	647.7	-11.018	-11.011	-11.155

Table 2: Molefraction of m-xylene (x1), densities (□), speed of sound (u), isentropic compressibilities (ks), excess isentropic compressibilities (ksE) of m-xylene (1) with m-nitrotoluene (2) at 298.15 K to 313.15 K

x_1	ρ (γ χμ–3)	u (ms-1)	K_S	K_S^E (Experimental)	K_S^E	
					Redlich-kister	Hwang et al.
***m*-xylene (1) + *m*-nitrotoluene (2)**						
T = 298.15 K						
0.09693	1.12893	1448.8	404	-8.144	-8.138	-8.072
0.19452	1.1012	1434.8	422	-14.859	-14.85	-14.85
0.29278	1.07335	1422.3	441.2	-20.049	-20.031	-20.09
0.39173	1.0454	1405.7	461.6	-23.58	-23.552	-23.615
0.49135	1.01733	1392.8	483.4	-25.301	-25.267	-25.291
0.59167	0.98912	1381.7	506.7	-25.027	-25.007	-24.994
0.69268	0.96081	1368.4	531.7	-22.587	-22.58	-22.578
0.79441	0.93241	1350.7	558.5	-17.773	-17.769	-17.838
0.89684	0.90391	1336.6	587.3	-10.347	-10.332	-10.464
T = 303.15 K						
0.09693	1.12891	1427.9	415.8	-8.55	-8.55	-8.48
0.19452	1.10118	1414	434.4	-15.599	-15.602	-15.602
0.29278	1.07332	1401.6	454.2	-21.046	-21.043	-21.105
0.39173	1.04536	1385.2	475.3	-24.75	-24.74	-24.807
0.49135	1.0173	1372.4	497.8	-26.553	-26.539	-26.564
0.59167	0.98909	1361.4	521.9	-26.263	-26.263	-26.249
0.69268	0.96079	1348.2	547.7	-23.701	-23.71	-23.709
0.79441	0.93239	1330.7	575.4	-18.646	-18.656	-18.728
0.89684	0.90389	1316.7	605.1	-10.853	-10.846	-10.984
T = 308.15 K						
0.09693	1.12008	1412.6	427.8	-9.277	-9.27	-9.197
0.19452	1.09218	1398.4	447.4	-16.922	-16.912	-16.912
0.29278	1.06419	1385.7	468.3	-22.823	-22.802	-22.868
0.39173	1.03612	1369	490.6	-26.828	-26.798	-26.869
0.49135	1.00795	1355.8	514.4	-28.77	-28.735	-28.762
0.59167	0.97968	1344.4	539.9	-28.445	-28.424	-28.409
0.69268	0.95133	1331	567.2	-25.659	-25.649	-25.648
0.79441	0.9229	1313.1	596.5	-20.177	-20.172	-20.249
0.89684	0.89441	1298.8	627.9	-11.737	-11.722	-11.868
T = 313.15 K						
0.09693	1.12007	1394.5	438.8	-9.784	-9.779	-9.702
0.19452	1.09216	1380	459.2	-17.847	-17.84	-17.84
0.29278	1.06417	1367.2	480.9	-24.069	-24.052	-24.122
0.39173	1.03609	1350.3	504.1	-28.291	-28.266	-28.34
0.49135	1.00793	1337	528.8	-30.336	-30.307	-30.335
0.59167	0.97966	1325.4	555.3	-29.991	-29.976	-29.961
0.69268	0.95131	1311.7	583.7	-27.051	-27.047	-27.046
0.79441	0.92289	1293.8	614.1	-21.271	-21.268	-21.349
0.89684	0.8944	1279.3	646.9	-12.37	-12.357	-12.511

A perusal of K_S^E data in Figures 1 and 2 suggest that, the property was negative for the binary mixtures of *m*-xylene with *o*-nitrotoluene and *m*-nitrotoluene at all the temperatures. The K_S^E values were attributed to the change in intermolecular free-spaces defined by Jacobson [7,8].

These changes occur due to structure-breaking and structure-making effects of the components and the consequent change in geometrical factors. Structure-breaking effect contributes to an increase in free-space between the molecules and this result in the sound waves covering shorter distance in the mixtures.

This leads to positive deviation in excess isentropic compressibility. On the other hand, structure-making effects would contribute to decrease in free space and a negative deviation in isentropic compressibility.

The actual deviation would depend upon the balance between the two opposing effects. The experimental k_s^E data in the present investigation results indicate that the structure – making effect was dominant in the binary mixtures of *m*-xylene with *o*-nitrotoluene and *m*-nitrotoluene.

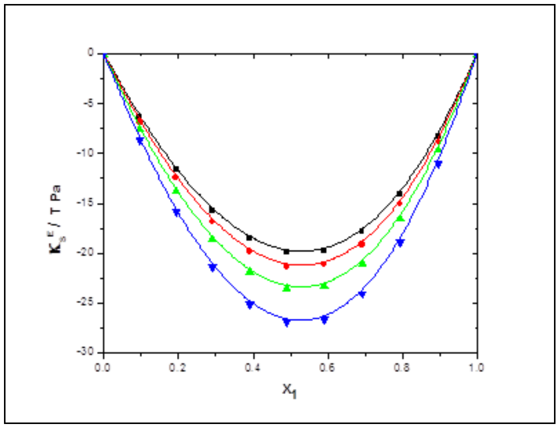

Figure 1: Variation of excess isentropic compressibility (k_s^E) of the binary liquid mixture of *m*-xylene (1) with *o*-nitrotoluene (2) at 298.15 K (▪), 303.15 K (●), 308.15 K (Δ) and 313.15 K (∇)

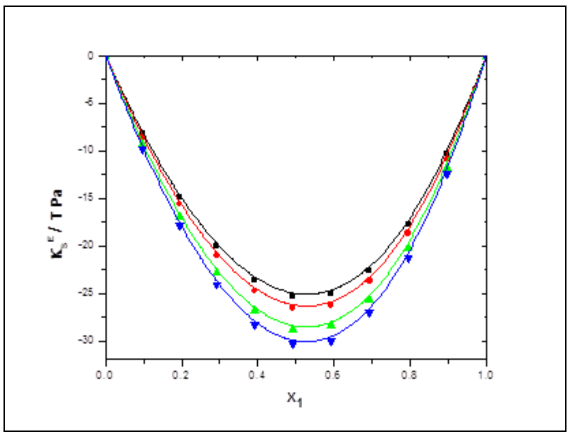

Figure 2: Variation of excess isentropic compressibility (ksE) of the binary liquid mixture of m-xylene (1) with m-nitrotoluene (2) at 298.15 K (▪), 303.15 K (●), 308.15 K (Δ) and 313.15 K (∇)

CONCLUSIONS

Experimental density and sound speed data were utilized to compute excess isentropic compressibilities of binary liquid mixtures of *m*-xylene with nitrotoluenes. The results indicate that a negative deviation of excess isentropic compressibilities is observed for the studied binary liquid mixtures. The results were interpreted interms of intermolecular interactions between component liquids.

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