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Density, Viscosity and Speed of Sound for Benzaldehyde with Isopropylbenzene System at 298.15, 303.15, 308.15, 313.15 K

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The densities, viscosities and speeds of sound for binary mixture of benzaldehyde with isopropylbenzene at 298.15, 303.15, 308.15 and 313.15 K have been measured over the whole compositional range. The excess thermodynamic properties such as excess volume (V^E), deviations in viscosity ($\Delta\eta$) and excess isentropic compressibility (K_S^E) are calculated. All of the excess properties have been fitted to Redlich-Kister equation.

Key Words: Excess volume, Deviations in viscosity, Excess compressibility, Binary mixture.

INTRODUCTION

Excess properties and deviations of properties for liquids can reveal the existence of specific molecular interactions. Therefore, the systematic study of these properties has great importance in gaining a better knowledge of these interactions. Moreover, knowledge of thermodynamic and transport properties is essential for the proper design of industrial processes. We report in this work measurements of densities, viscosities and speeds of sound for the binary mixture benzaldehyde with isopropylbenzene at 298.15, 303.15, 308.15 and 313.15 K. We have also calculated excess volumes, deviations in viscosity and excess isentropic compressibilities for the binary mixture.

EXPERIMENTAL

Benzaldehyde (S.D. Fine Chem., Mumbai, India) and isopropylbenzene (Riedel, Germany), AR grade, were purified using standard procedures[1] and stored over molecular sieves. The purity of the chemicals was checked by comparing the measured densities and viscosities with those reported in literature as shown in Table-1.

The densities were measured using a calibrated bicapillary pycnometer having an uncertainty of $\pm 1 \times 10^{-4}$ g.cm^{-3}. Viscosities were measured with the help of a modified Ubbelohde viscometer as described earlier[2]. At each temperature, the viscometer was calibrated so as to determine the two constants A and B in the equation:

$$\eta/\rho = At + B/t \qquad (1)$$

TABLE-1
PHYSICAL PROPERTIES OF THE PURE COMPONENTS AT 298.15 K

Component	T (K)	ρ (g.cm^{-3})		η (mPa.s)	
		Expt.	Lit.	Expt.	Lit.
Benzaldehyde	298.15	1.0434	1.0434[1]	1.321	1.321[1]
Isopropylbenzene	298.15	0.8575	0.85751[1] 0.85743[7]	0.739	0.739[1] 0.739[7]

The values of constants were obtained by measuring the flow time, *t*, with triply distilled water and double distilled benzene. The flow measurements were made with an electronic stop watch with precision of ±0.01 s. The uncertainty in the viscosity values is within ±0.003 mPa.s. Speeds of sound were measured with the help of interferometer (UTI-101) with a reproducibility of 0.1 m.s^{-1}. All the measurements were made at constant temperature with the help of a circulating type cryostat where the temperature was controlled to ±0.02 K.

RESULTS AND DISCUSSION

The experimental values of density, ρ, viscosity, η, and speed of sound, u, measured at different temperatures for the system are given in Table-2.

The molar volume, V_m, was calculated by using the relation:

$$V_m = (x_1M_1 + x_2M_2)/\rho_m \quad (2)$$

where x_1 and x_2 are the mole fractions and M_1 and M_2 are molecular weights of components 1 and 2 respectively and ρ_m is the mixture density.

The excess volume (V^E) for the binary mixture was obtained from the following relation:

$$V^E = x_1M_1(1/\rho_m - 1/\rho_1) + x_2M_2(1/\rho_m - 1/\rho_2) \quad (3)$$

where ρ_1 and ρ_2 are the densities of pure components 1 and 2 respectively.

The deviations in viscosity, $\Delta\eta$, were calculated by using the equation:

$$\Delta\eta = \eta_m - (x_1\eta_1 + x_2\eta_2) \quad (4)$$

where η_1 and η_2 are the viscosities of pure components 1 and 2 respectively and η_m is the mixture viscosity.

The values of mixture density, ρ_m, and speed of sound, u, are used to calculate the isentropic compressibility, K_s, by using the relation:

$$K_S = u^{-2} \cdot \rho_m^{-1} \quad (5)$$

The excess isentropic compressibility, K_S^E, was obtained from the relation:

$$K_S^E = K_S - (x_1K_{S_1} + x_2K_{S_2}) \quad (6)$$

where K_{S_1} and K_{S_2} are isentropic compressibilities of pure components 1 and 2 respectively. The values of K_S are given in Table-2.

TABLE-2
DENSITY, ρ, SPEED OF SOUND, u, VISCOSITY, η, COMPRESSIBILITY, K_S, FOR BENZALDEHYDE (1) + ISOPROPYLBENZENE (2) SYSTEM AT DIFFERENT TEMPERATURES

x_1	ρ ($g.cm^{-3}$)	u ($m.s^{-1}$)	η (mPa.s)	$10^{12} K_S$ (Pa^{-1})
		298.15 K		
1.0000	1.0434	1452.5	1.321	454.3
0.9500	1.0425	1452.3	1.287	454.8
0.8500	1.0331	1446.8	1.219	462.4
0.7720	1.0220	1437.0	1.168	473.9
0.6680	1.0043	1422.3	1.102	492.2
0.5485	0.9826	1404.8	1.031	515.8
0.4380	0.9619	1387.0	0.968	540.5
0.3289	0.9406	1368.8	0.907	567.4
0.2460	0.9235	1353.3	0.862	591.2
0.1530	0.9020	1334.0	0.813	623.0
0.0702	0.8799	1316.0	0.772	656.2
0.0000	0.8575	1296.2	0.739	694.1
		303.15 K		
1.0000	1.0421	1432.7	1.245	467.5
0.9500	1.0389	1428.5	1.215	471.7
0.8500	1.0277	1424.4	1.152	479.6
0.7720	1.0155	1416.0	1.103	491.1
0.6680	0.9973	1402.4	1.040	509.9
0.5485	0.9753	1385.1	0.971	534.4
0.4380	0.9545	1368.0	0.911	559.8
0.3289	0.9335	1350.1	0.854	587.7
0.2460	0.9165	1335.5	0.811	611.7
0.1530	0.8950	1317.3	0.765	643.9
0.0702	0.8734	1299.6	0.725	677.9
0.0000	0.8532	1282.0	0.693	713.2

(Contd.)

x_1	ρ ($g.cm^{-3}$)	u ($m.s^{-1}$)	η (mPa.s)	$10^{12} K_S$ (Pa^{-1})
		308.15 K		
1.0000	1.0408	1419.9	1.175	476.6
0.9500	1.0343	1414.0	1.147	483.6
0.8500	1.0207	1409.5	1.089	493.1
0.7720	1.0088	1400.6	1.043	505.3
0.6680	0.9906	1385.6	0.983	525.8
0.5485	0.9681	1368.2	0.917	551.8
0.4380	0.9468	1351.5	0.860	578.3
0.3289	0.9255	1333.5	0.806	607.7
0.2460	0.9085	1318.3	0.766	633.4
0.1530	0.8874	1300.4	0.722	666.4
0.0702	0.8670	1281.9	0.684	701.9
0.0000	0.8489	1265.9	0.652	735.1
		313.15 K		
1.0000	1.0395	1400.9	1.111	490.2
0.9500	1.0301	1394.5	1.085	499.2
0.8500	1.0150	1387.1	1.031	512.0
0.7720	1.0025	1377.9	0.988	525.4
0.6680	0.9842	1364.2	0.931	546.0
0.5485	0.9613	1346.6	0.868	573.6
0.4380	0.9394	1329.6	0.814	602.2
0.3289	0.9176	1311.9	0.763	633.2
0.2460	0.9006	1296.7	0.725	660.4
0.1530	0.8802	1278.3	0.683	695.2
0.0702	0.8611	1260.5	0.645	730.9
0.0000	0.8447	1246.0	0.614	762.5

The excess volume, V^E, excess isentropic compressibility, K_S^E, and deviations in viscosity, $\Delta\eta$, were fitted to a Redlich-Kister[3] type equation:

$$A = x_1 x_2 \sum_{i=1}^{n} A_{j-1}(x_1 - x_2)^{(j-1)} \qquad (7)$$

where A is the property under consideration, A_{j-1} is the polynomial coefficient and n is the polynomial degree.

The standard deviation in each case is calculated using the equation:

$$\sigma(X) = \left[\frac{\Sigma(X_{expt} - X_{calcd})^2}{N - n}\right]^{1/2} \quad (8)$$

where N is the number of data points and n is the number of coefficients.

The values of coefficients of eqn. (7) as determined by the method of least squares along with the standard deviations at different temperatures for the system are reported in Table-3.

TABLE-3
VALUES OF COEFFICIENTS OF REDLICH-KISTER EQUATION (7) AND STANDARD DEVIATION EQUATION (8).

T (K)	A_0	A_1	A_2	A_3	σ
		V^E (cm^3 mol^{-1})			
298.15	–18.7421	3.3151	–10.6458	0.9053	0 01958
303.15	–17.0068	3.8807	–8.0187	–1.0499	0.02077
308.15	–15.1775	2.7890	–3.8732	1.0480	0.04622
313.15	–13.3636	1.4681	–0.5792	3.0126	0.05320
		$\Delta\eta$ (mPa s)			
298.15	–0.1079	–0.0144	–0.0134	0.0279	0.00026
303.15	–0.0993	–0.0128	0.0207	0.0522	0.00017
308.15	–0.0867	–0.0079	0.0359	0.0421	0.00021
313.15	–0.0728	–0.0102	0.0473	0.0388	0.00019
		10^{12} K_S^E (Pa^{-1})			
298.15	–190.2884	37.3331	–108.7304	6.4216	0.50988
303.15	–80.9980	31.9062	–75.5940	21.0694	0.58630
308.15	–172.9454	2.83203	–46.8274	15.3356	0.99474
313.15	–165.0751	31.4671	–1.16021	12.5788	0.94375

The negative values of V^E suggest the existence of specific interactions between the molecules[4]. The curves at different temperatures are characterized by the presence of well defined minima occurring at around $x_1 = 0.438$. This minima indicates the presence of complex formation at this composition. With increase in temperature, the values of V^E become less negative.

The negative values of V^E and $\Delta\eta$ show that one type of molecules are interstitially accommodated into clusters of other molecules resulting in negative V^E and negative $\Delta\eta$.[5]

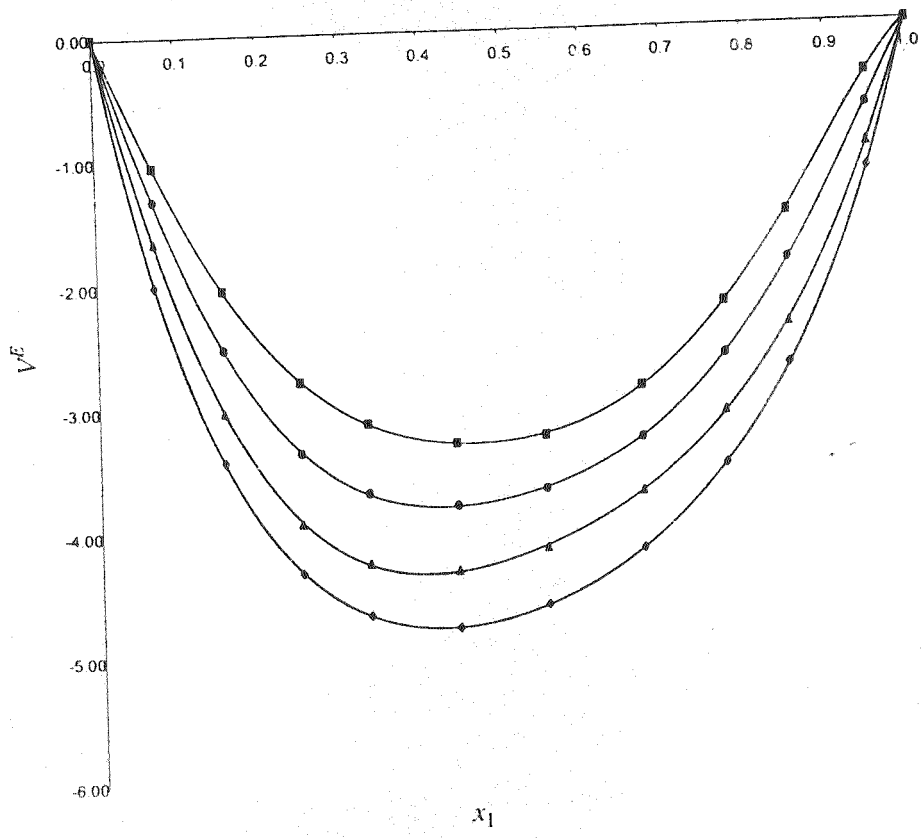

Fig. 1. Excess molar volume, V^E ($cm^3.mol^{-1}$) for the system benzaldehyde (1) + isopropylbenzene (2) at 298.15 K (◆), 303.15 K (▲), 308.15 (●) and 313.15 K (■)

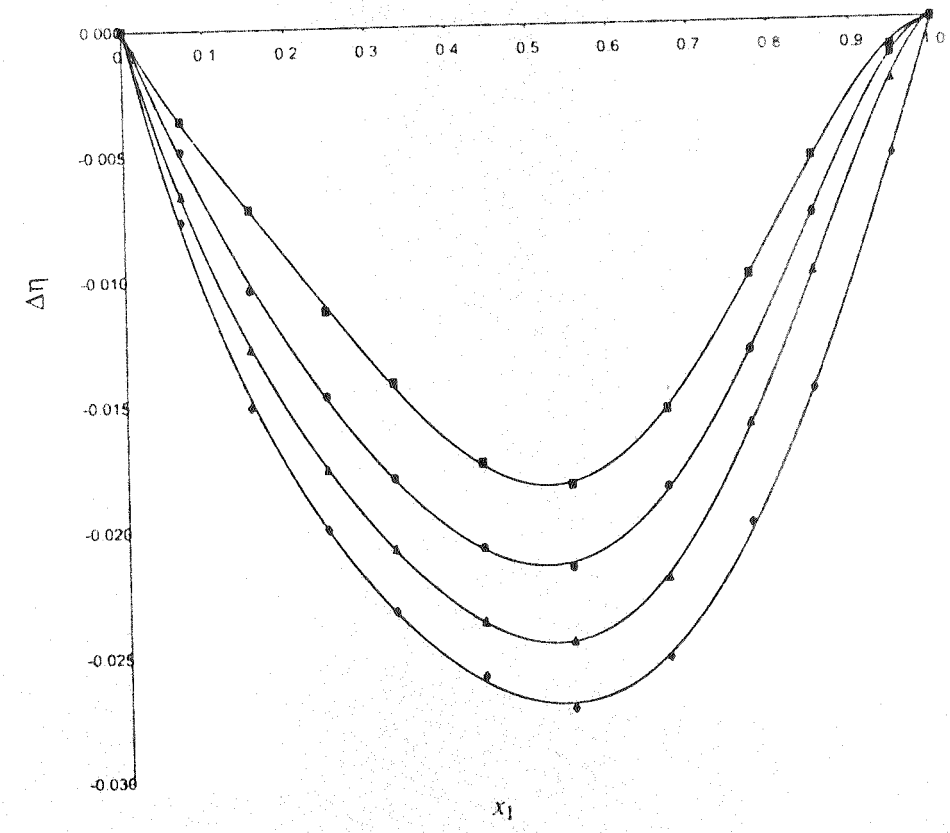

Fig. 2. Viscosity deviations, Δη (mPa s) for the system benzaldehyde (1) + isopropylbenzene (2) at 298.15 K (◆), 303.15 K (▲), 308.15 (●) and 313.15 K (■)

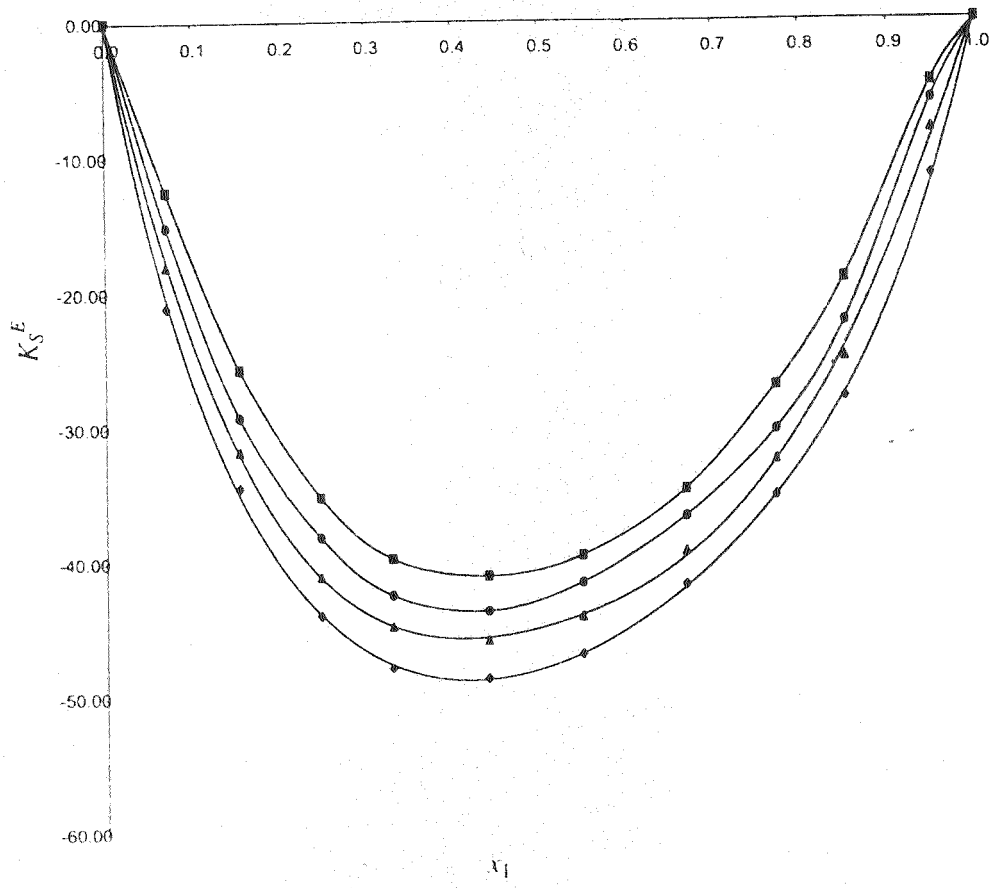

Fig. 3. Excess compressibility, $10^{12}\ K_S^E$ (Pa^{-1}) for the system benzaldehyde (1) + isopropylbenzene (2) at 298.15 K (◆), 303.15 K (▲), 308.15 (●) and 313.15 K (■)

The values of K_S^E are also negative at all the temperatures and the values of K_S^E become less negative as temperature is increased[6]. This may be attributed to the weakening of structure making interactions at elevated temperatures due to enhanced thermal motion.

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