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Excess Volumes of Density, Viscosity and Speed of Sound Studies of Binary Mixture of o-xylene, m-xylene and p- xylene with T-Butanol at 298.15K



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ABSTRACT

The density, viscosity and speed of sound studies of binary mixture of o-xylene, m-xylene and p-xylene with t-butanol at 298.15K using these parameters the excess volume (V^E), Deviation in viscosity ($\Delta\eta$), isentropic compressibility (K_S^E), have been evaluated. The recently proposed jouyban – Acree model is used to correlate the experimental values of density, viscosity and speed of sound at 298.15 K.



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1. INTRODUCTION

Binary mixture of t-butanol with aromatic hydrocarbons is of great interest due to their extremely non-ideal behaviour and practical importance to the chemical industry. A lot of work has been reported in the literature (1-4). The studies of viscosity, density and ultrasonic velocity are being increasingly used as tools for investigation of the properties of pure components and the nature of intermolecular interaction between the liquid mixture constituents.

2. MATERIALS AND METHODS

Experimental

o-xylene, m-xylene and p-xylene were of high grade and were distilled under reduced pressure before use t-butanol were analytical grade and purified by distillation and then drying. All the mixture Adair Dutt were prepared by mass using a balance with an accuracy of ± 0.01 mg.

Care was taken to avoid evaporation and contamination during mixing. The estimated uncertainty in 1 mole fraction was less than 1×10^{-4} .

The purity of this solvent was checked by comparing their density (ρ) and viscosity (η) value with compared well with literature data (Table-1). Binary mixture was prepared by knowing masses of each liquid in airtight stoppered glass bottles.

The densities of pure liquid and their mixture were determined in 15 cm^3 double arm pycnometer (5-8). The pycnometer was calibrated using conductivity water (conductivity less than $1.0 \times 10^{-6} \Omega^{-1}$) with 0.99705 cm^{-3} as its density (5) at $T = 298.15\text{K}$. The pycnometer filled with air bubble free experimental liquid was kept in a transparent walled water bath in which the temperature was maintained constant to $\pm 0.01\text{K}$ for 10-15 minutes to attain thermal equilibrium. The position of the liquid levels in the two arms were recorded with traveling microscope which read correctly to $\pm 0.01 \text{ mm}$. The density values were reproducible within $5 \times 10^{-5} \text{ g cm}^{-3}$.

The dynamic viscosities were measured using an Ubbelohde suspended level viscometer (9-11) calibrated with conductivity water having a conductivity of $1 \times 10^{-6} \Omega^{-1} \text{ cm}^{-1}$. An electronic

digital stopwatch with readability of ± 0.01 s was used for flow time measurement. At least three repetitions of each data reproducible to ± 0.05 s were obtained and result were averaged. Because all flow time greater than 200 s. The uncertainties in dynamic viscosities are of the order of ± 0.003 mpas.

The sound speed u , was measured at a frequency of 2 MHz in these solution through the interferometric method (using mettall's F-81 model at 298.15 K. No attempt was made to correct sound speed obtained at a frequency to the zero frequency thermodynamic value. The estimated error in sound speed measurement is $\pm 1\text{ms}^{-1}$. The other experimental details are the same as those reported earlier (5-6)

3. RESULTS AND DISCUSSION

Experimental values of densities (ρ), viscosity (η) and ultrasonic velocities (u) of mixtures at 298.15K are listed as a function of mole fraction in Table2. The density values have been used to calculate excess molar volumes (V_m^E) using the following equation

$$V_m^E = (x_1M_1+x_2M_2)/\rho_{12} - (x_1M_1/\rho_1)-(x_2M_2/\rho_2) \quad (1)$$

Where ρ_{12} is the density of the mixture and x_1, M_1, ρ_1 , and x_2, M_2, ρ_2 are the mole fraction, the molecular weights, and the densities of pure components 1 and 2, respectively.

The viscosity deviation $\Delta\eta$ was calculated using

$$\Delta\eta = \eta_{12} - x_1\eta_1 - x_2\eta_2 \quad (2)$$

The excess isentropic compressibility, κ_s^E , was calculated using Laplace relation, that is

$$\kappa_s = (1/ u^2\rho) \quad (3)$$

Deviation in isentropic compressibility, (ΔK_s) calculated using the equation

$$\Delta K_s = K_{s12} - \phi_1K_{s1} - \phi_2K_{s2} \quad (4)$$

Where K_{s12} is the experimental isentropic compressibility of the mixture ϕ_1, ϕ_2 and K_{s1}, K_{s2} are volume fraction and isentropic compressibility of pure components.

Recently, Jouyban et al. (21-22) proposed a model for correlating the density and viscosity of liquid mixture at various temperature (the Jouyban-Acree model). The proposed equation is

$$\ln u_{m,T} = f_1 \ln u_{1,T} + f_2 \ln u_{2,T} + f_1 f_2 \sum [A_j (f_1 - f_2)^j / T] \quad (5)$$

Where $u_{m,T}$, $u_{1,T}$ and $u_{2,T}$ is speed of sound of the mixture and solvents 1 and 2 at temperature T, respectively, f_1 and f_2 are the mole fraction and A_j are the model constants.

The correlating ability of the Jouyban - Acree model was tested by calculating the average percentage deviation (APD) between the experimental and calculated speed of sound as

$$APD = (100/N) \sum [(|u_{\text{exptl}} - u_{\text{calcd}}|) / u_{\text{exptl}}] \quad (6)$$

Where N is the number of data points in each set. Optimum numbers of constants A_j , in each case, were determined from the examination of the average percentage deviation value.

The Jouyban-Acree model was not previously applied to ultrasonic velocity measurements. We extend the Jouyban-Acree model (eq 5) to the ultrasonic velocity of the liquid mixtures with f as the mole fraction and again apply eq 6 for the correlating ability of the model.

The constants A_j calculated from the least-squares analysis are presented in Table 3 along with the average percentage deviation (APD). The proposed model provides reasonably accurate calculations for the density, viscosity and ultrasonic velocity of binary liquid mixtures at various temperatures, and the model could be used for data modeling.

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Table 1: Comparison of experimental density (ρ) and viscosities (η) and ultrasonic velocities (u) of pure liquid with literature values at 298.15 K.

Liquid	$\rho/(\text{g} \cdot \text{cm}^{-3})$		$\eta/(\text{mPa} \cdot \text{s})$		$u/(\text{m} \cdot \text{s}^{-1})$	
	Expt.	Lit.	Expt.	Lit.	Expt.	Lit.
t-butanol	0.7810	0.7812 ¹²	4.445	4.444 ¹²	1125	1123.5 ¹³
o-xylene	0.8756	0.8759 ¹⁴	0.755	0.754 ¹⁵	1345	1348 ¹⁶
m-xylene	0.8601	0.8599 ¹⁷	0.585	0.582 ¹⁷	1320	1324 ¹⁸
p-xylene	0.8562	0.8565 ¹⁹	0.602	0.605 ²⁰	1315	1314 ¹⁸

Table 2: Density (ρ), viscosity (η), Ultrasonic velocity (u), Isentropic compressibility (K_s), Excess molar volume, (V^E), Deviation in viscosity ($\Delta\eta$), and Deviation in Isentropic compressibility (ΔK_s) for t-butanol (1) + xylenes (2) at 298.15 K.

t-butanol (1) + o-xylene (2) at 298.15 K.

x_1	$\rho \times 10^{-3}$ kg.m ⁻³	η mPa.s	$V^E \times 10^6$ m ³ .mol ⁻¹	$\Delta\eta$ mPa.s	u ms ⁻¹	K_s Tpa ⁻¹	ΔK_s Tpa ⁻¹
0.0000	0.8756	0.755	0.000	0.000	1345	631	0
0.1003	0.8666	1.004	0.193	-0.121	1317	665	3
0.2009	0.8576	1.297	0.331	-0.199	1291	700	6
0.3016	0.8485	1.607	0.428	-0.261	1265	736	9
0.3990	0.8396	1.925	0.482	-0.302	1242	773	12
0.4999	0.8302	2.282	0.505	-0.318	1219	811	13
0.5998	0.8208	2.659	0.480	-0.309	1198	849	12
0.6988	0.8112	3.056	0.430	-0.278	1178	889	12
0.7997	0.8013	3.493	0.329	-0.213	1159	929	9
0.9003	0.7911	3.952	0.200	-0.125	1141	970	5
1.0000	0.7810	4.445	0.000	0.000	1125	1012	0

t-butanol (1) + m-xylene (2) at 298.15 K.

x_1	$\rho \times 10^{-3}$ kg.m ⁻³	η mPa.s	$V^E \times 10^6$ m ³ .mol ⁻¹	$\Delta\eta$ mPa.s	u ms ⁻¹	K_s Tpa ⁻¹	ΔK_s Tpa ⁻¹
0.0000	0.8601	0.585	0.000	0.000	1320	667	0
0.0957	0.8524	0.807	0.248	-0.147	1296	699	6
0.1947	0.8447	1.079	0.419	-0.258	1272	732	11
0.2956	0.8369	1.395	0.537	-0.331	1249	765	14
0.4002	0.8287	1.757	0.619	-0.373	1227	801	17
0.5001	0.8210	2.131	0.626	-0.384	1208	835	18
0.6001	0.8131	2.539	0.605	-0.362	1189	870	18
0.7003	0.8052	2.973	0.525	-0.315	1171	906	17
0.7994	0.7972	3.437	0.412	-0.234	1155	940	13
0.8995	0.7891	3.922	0.240	-0.135	1139	976	8
1.0000	0.7810	4.445	0.000	0.000	1125	1012	0

t-butanol (1) + p-xylene (2) at 298.15 K.

x_1	$\rho \times 10^{-3}$ kg.m ⁻³	η mPa.s	$V^E \times 10^6$ m ³ .mol ⁻¹	$\Delta\eta$ mPa.s	u ms ⁻¹	K_s Tpa ⁻¹	ΔK_s Tpa ⁻¹
0.0000	0.8562	0.602	0.000	0.000	1315	675	0
0.0994	0.8487	0.835	0.234	-0.149	1293	705	3
0.1972	0.8415	1.123	0.393	-0.237	1271	736	7
0.2992	0.8340	1.443	0.509	-0.309	1249	769	11
0.4004	0.8265	1.798	0.580	-0.343	1228	802	13
0.4976	0.8193	2.162	0.598	-0.352	1209	835	15
0.6002	0.8117	2.575	0.564	-0.334	1190	870	15
0.6968	0.8044	2.991	0.497	-0.289	1172	904	14
0.7993	0.7966	3.455	0.376	-0.219	1155	941	12
0.8980	0.7889	3.924	0.226	-0.129	1140	976	8
1.0000	0.7810	4.445	0.000	0.000	1125	1012	0

Table 3: Parameters of Jouyban-Acree Model and Average Percentage Deviation for Density for Density, Viscosity and Ultrasonic Velocity.

For Density

System t-Butanol +	A ₀	A ₁	A ₂	A ₃	A ₄	APD
o-Xylene	6.5692	1.4566	0.2419	2.3019	2.8063	0.0424
m-Xylene	3.8135	1.2853	0.6602	2.6245	2.0321	0.0443
p-Xylene	3.9481	1.4487	0.2635	2.5147	2.7710	0.0439

For Viscosity

System t-Butanol +	A ₀	A ₁	A ₂	A ₃	A ₄	APD
o-Xylene	147.3911	-26.1343	-2.0584	-	-	2.0186
m-Xylene	168.3289	21.4135	-23.2300	-	-	2.6183
p-Xylene	187.0899	12.6179	-36.7927	-	-	2.8323

For Ultrasonic Velocity

System t-Butanol +	A ₀	A ₁	A ₂	A ₃	A ₄	APD
o-Xylene	-13.2801	-1.9633	-0.1140	2.5749	-0.0626	0.0426
m-Xylene	-12.4121	-0.7519	-1.5978	1.3999	-	0.0310
p-Xylene	-9.2513	-1.6985	-1.0146	0.0289	-	0.0289

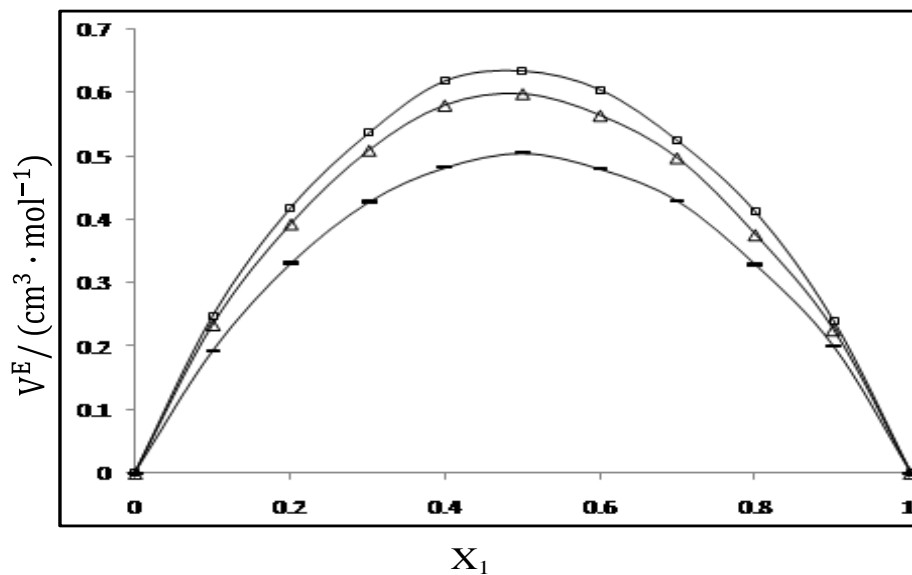


Figure 1: V^E values at 298.15 K for (x_1) t-Butanol + ($1-x_1$) o-Xylene (-), m-Xylene (\square), p-Xylene (Δ),

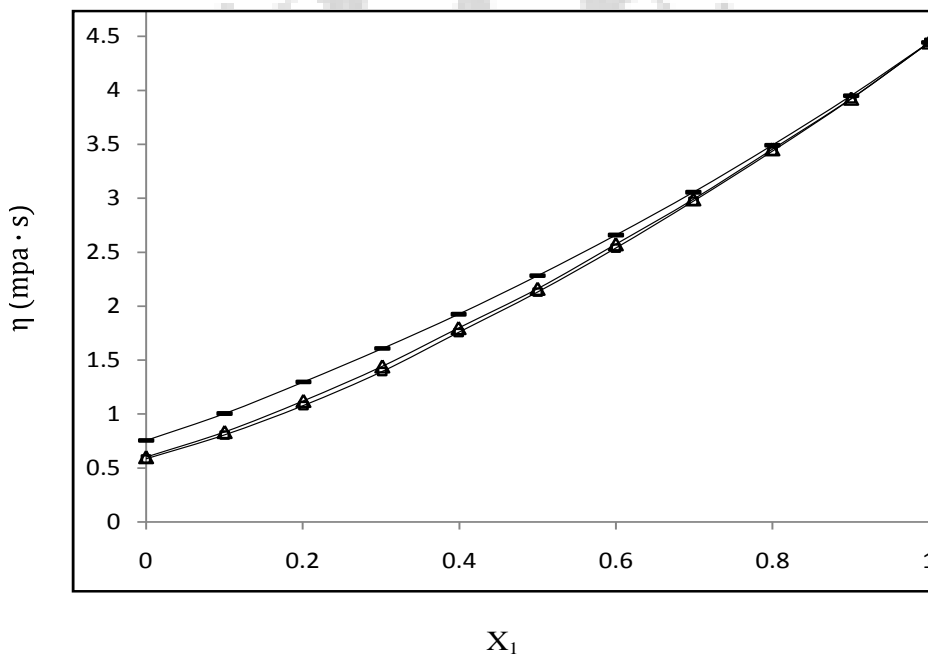


Figure 2: η values at 298.15 K for (x_1) t-Butanol + ($1-x_1$) o- Xylene (-), m-Xylene (\square), p-Xylene (Δ),

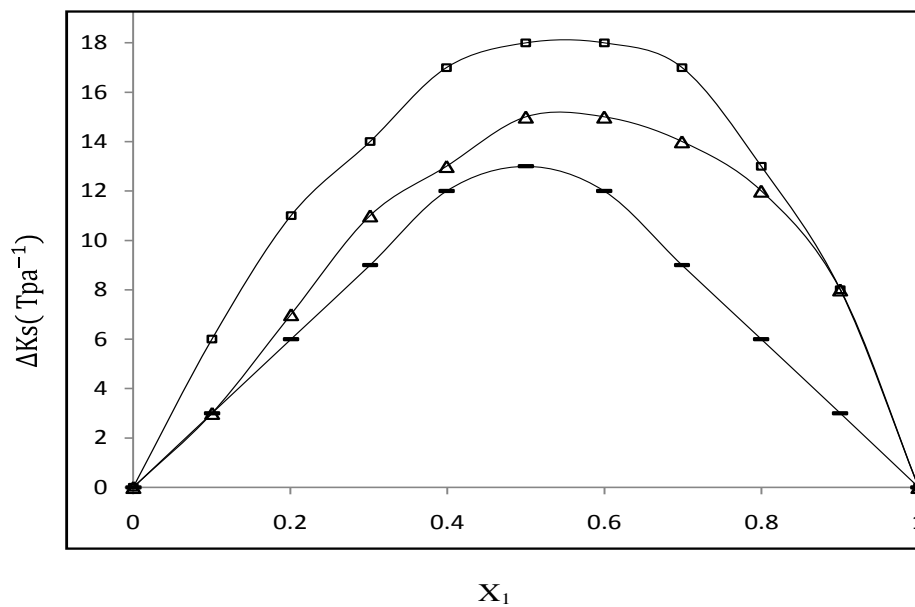


Figure 3: ΔK_s values at 298.15 K for (x_1) t-Butanol + $(1-x_1)$ o-Xylene (-), m-Xylene (\square), p-Xylene (Δ),

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