Viscosities, Densities, and Speeds of Sound of Binary Mixtures of *o*-Xylene, *m*-Xylene, *p*-Xylene, and Isopropylbenzene with 2-Butanone at 298.15 K

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The viscosities, densities, and speeds of sound of binary mixtures of 2-butanone with *o*-xylene, *m*-xylene, *p*-xylene, and isopropylbenzene have been determined at 298.15 K over the whole composition range. Deviations in viscosity ($\Delta\eta$) and excess compressibility (K_s^E) were calculated.

Introduction

Studies of liquid mixture behavior have generated considerable interest in recent years. The viscosity, density, and speeds of sound are important properties of pure components, and measurements on mixtures are useful for design.

As part of the experimental investigation of the excess thermodynamic properties of liquid mixtures, in the present study, measurements of densities, viscosities, and speeds of sound of four binary mixtures of 2-butanone with *o*-, *m*-, *p*-xylene and isopropylbenzene have been made at 298.15 K. This forms part of a program to study the properties of liquid mixtures with a C_8 or C_9 aromatic hydrocarbon as one of the components, where similar studies were reported with 3-pentanone.[1]

Experimental Section

2-Butanone (Glaxo Labs, India), *o*-xylene, *m*-xylene, *p*-xylene (Riedel; Germany), and isopropylbenzene (BDH; Poole, England) were purified by standard procedures[2] and stored over molecular sieves. The purity of the samples was checked by comparing measured densities and viscosities with those reported in the literature as shown in Table 1. Densities were measured with Anton Paar densimeter DMA 60/602 with an uncertainty of $\pm 1.0 \times 10^{-4}$ g·cm^{-3}. The mole fraction of each mixture was obtained to an uncertainty of $\pm 1.0 \times 10^{-4}$.

Viscosities were measured by using a modified Ubbelhode viscometer, as described earlier.[3] From the measured values of density ρ and efflux time t, we calculated the viscosity using the relation

$$\frac{\eta}{\rho} = At + \frac{B}{t} \tag{1}$$

where A and B are viscometer constants. The values of these constants A and B were obtained by measuring the flow time with triply distilled water and doubly distilled benzene. The flow measurements were made with an electronic stopwatch with a precision of ±0.01 s. The uncertainty in the viscosity estimates was found to be within ±0.003 mPa·s.

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Table 1. Physical Properties of the Pure Components at 298.15 K

	ρ/g·cm^{-3}		η/mPa·s	
component	expt	lit	expt	lit
2-butanone	0.7996	0.7997[2]	0.376	0.378[2]
isopropylbenzene	0.8571	0.85743[2]	0.739	0.739[2]
o-xylene	0.8752	0.87594[2] 0.8744[8] 0.87563[10]	0.768	0.760[11] 0.756[2] 0.758[9]
m-xylene	0.8594	0.8599[2] 0.8597[8]	0.587	0.588[9] 0.581[2]
p-xylene	0.8561	0.85661[2] 0.8558[8]	0.609	0.605[2] 0.614[8]

Speeds of sound were determined by using an interferometer (Belen model UI-751) with an uncertainty of ±1.0 m·s^{-1}. All of the measurements were made at constant temperature with the help of a circulating-type cryostat (MK70-MLW) where the uncertainty in temperature was ±0.02 K.

Results and Discussion

The experimental values of viscosity η, density ρ, and speed of sound u are reported in Table 2. Deviations in viscosity $\Delta\eta$ were obtained by using the relation

$$\Delta\eta = \eta_m - (x_1\eta_1 + x_2\eta_2) \tag{2}$$

where η_m is the viscosity of the mixture and η_1 and η_2 are the viscosities of pure components 1 and 2, respectively. The molar volume V_m was calculated by using the relation

$$V_m = \frac{x_1M_1 + x_2M_2}{\rho_m} \tag{3}$$

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

The values of the speeds of sound u and mixture density ρ_m were used to calculate the isentropic compressibility K_s by using the relation

$$K_s = u^{-2}\rho_m^{-1} \tag{4}$$

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Table 2. Density, ρ, Speed of Sound, u, Viscosity, η, and Compressibility, K_s, for the Binary Systems of *o*-Xylene, *m*-Xylene, *p*-Xylene, and Isopropylbenzene with 2-Butanone at 298.15 K

x_1	ρ / g·cm^{-3}	u / m·s^{-1}	η / mPa·s	$10^{12}K_s$ / Pa^{-1}
		o-Xylene (1) + 2-Butanone (2)		
0.0000	0.7996	1195	0.376	875.8
0.0437	0.8056	1208	0.390	850.5
0.1095	0.8137	1222	0.412	822.9
0.2288	0.8257	1244	0.451	782.5
0.3564	0.8362	1266	0.493	746.1
0.4969	0.8461	1288	0.542	712.3
0.6500	0.8560	1310	0.601	680.7
0.8165	0.8659	1331	0.673	651.8
0.9244	0.8717	1339	0.727	639.8
1.0000	0.8752	1349	0.768	627.8
		m-Xylene (1) + 2-Butanone (2)		
0.0000	0.7996	1195	0.376	875.8
0.0428	0.8035	1204	0.384	858.4
0.1084	0.8092	1218	0.398	832.9
0.2261	0.8183	1240	0.422	794.6
0.3524	0.8270	1256	0.448	766.4
0.4941	0.8357	1273	0.478	738.3
0.6460	0.8441	1293	0.510	708.5
0.8137	0.8520	1312	0.546	681.8
0.9235	0.8567	1320	0.570	669.9
1.0000	0.8594	1323	0.587	664.8
		p-Xylene (1) + 2-Butanone (2)		
0.0000	0.7996	1195	0.376	875.8
0.0429	0.8060	1218	0.392	836.2
0.1074	0.8138	1237	0.414	803.0
0.2235	0.8235	1257	0.444	768.5
0.3501	0.8304	1272	0.471	744.2
0.4895	0.8366	1289	0.500	719.4
0.6419	0.8429	1299	0.533	703.0
0.8117	0.8496	1308	0.572	687.9
0.9213	0.8532	1313	0.596	679.8
1.0000	0.8561	1316	0.609	674.4
		Isopropylbenzene (1) + 2-Butanone (2)		
0.0000	0.7996	1195	0.376	875.8
0.0377	0.8050	1204	0.388	856.8
0.0964	0.8122	1217	0.408	831.2
0.2025	0.8217	1240	0.445	791.4
0.3251	0.8295	1262	0.486	756.8
0.4599	0.8354	1279	0.535	731.7
0.6150	0.8420	1290	0.592	713.6
0.7937	0.8492	1298	0.660	698.9
0.9123	0.8539	1308	0.705	684.4
1.000	0.8571	1338	0.739	651.7

The excess isentropic compressibility K_s^E was obtained from the relation

$$K_s^E = K_s - K_s^{id} \tag{5}$$

where K_s is the experimental compressibility and K_s^{id} is the isentropic compressibility of an ideal mixture of the components.

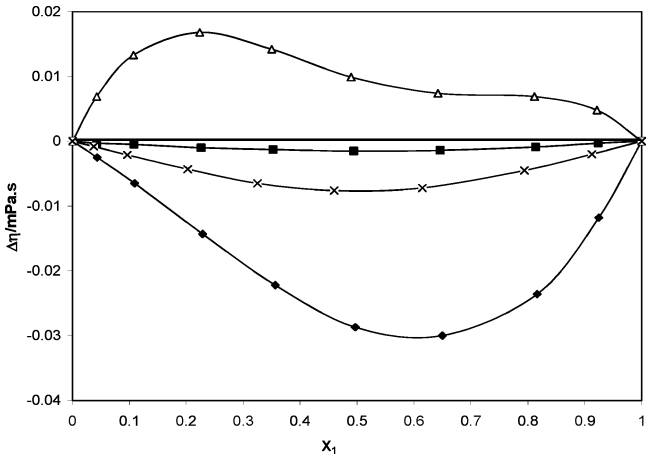

Figure 1. Viscosity deviations $\Delta\eta$ for the following systems: ◆, *o*-xylene; ■, *m*-xylene; △, *p*-xylene; and ×, isopropylbenzene with 2-butanone at 298.15 K.

K_s^{id} was determined by using the Kiyohara and Benson equation[4]

$$K_s^{id} = \sum \phi_i \left[k_{s,i}^o + \frac{TV_i^0(\alpha_i^0)^2}{C_{Pi}^o} \right] - \frac{T(\sum x_i V_i^0)(\sum \phi_i \alpha_i^0)^2}{\sum x_i C_{Pi}^o} \tag{6}$$

where ϕ_i is the volume fraction of component i in the mixture stated in terms of the unmixed components, T is the temperature, and $k_{s,i}^o$, V_i^0, α_i^0, and C_{Pi}^o are the isentropic compressibility, molar volume, coefficient of thermal expansion, and molar heat capacity, respectively, for pure component i. The values of α_i^0 were obtained from the density values at two different temperatures. The values of the molar heat capacity were taken from the literature.[2,5,6] The values of K_s^E and deviations in viscosity ($\Delta\eta$) were fit to a Redlich−Kister[7]-type equation

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

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

The standard deviation in each case is calculated using the relation

$$\sigma(X) = \left[\frac{\sum (X_{\exp t} - X_{\text{calcd}})^2}{N - n} \right]^{1/2} \tag{8}$$

where N is the number of data points and n is the number of coefficients. The values of the coefficients of eq 7 as

Table 3. Values of the Coefficients of the Redlich−Kister Equation (Eq 7) and Standard Deviations (Eq 8) at 298.15 K

	A_0	A_1	A_2	A_3	A_4	A_5	σ
			o-Xylene (1) + 2-Butanone (2)				
$10^{12}K_s^E$/Pa^{-1}	−86.6042	47.5003	−57.9245	−89.4501	9.5669	241.4153	0.3284
$\Delta\eta$/mPa·s	−0.1142	−0.0630	−0.0039				0.0002
			m-Xylene (1) + 2-Butanone (2)				
$10^{12}K_s^E$/Pa^{-1}	−67.1039	−16.9555	−9.2239	−13.7568	−12.7092	7.6913	0.2087
$\Delta\eta$/mPa·s	−0.0061	−0.0001	0.0009				0.0001
			p-Xylene (1) + 2-Butanone (2)				
$10^{12}K_s^E$/Pa^{-1}	−166.3837	159.0951	−28.4630	−114.0092	−226.6264	418.4860	0.4129
$\Delta\eta$/mPa·s	0.0384	−0.0505	0.0986				0.0001
			Isopropylbenzene (1) + 2-Butanone (2)				
$10^{12}K_s^E$/Pa^{-1}	−51.6052	172.5840	51.160	−29.4449	145.6436	191.1078	0.1073
$\Delta\eta$/mPa·s	−0.0309	−0.0004	0.0102				0.0001

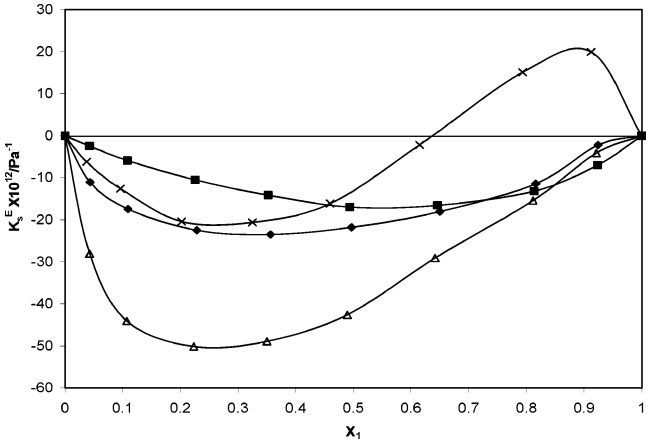

Figure 2. Excess compressibility K_s^E for the following systems: ◆, *o*-xylene; ■, *m*-xylene; △, *p*-xylene; and ×, isopropylbenzene with 2-butanone at 298.15 K.

determined by the method of least squares along with the standard deviations for all four systems are reported in Table 3.

The deviations in viscosity $\Delta\eta$ (Figure 1) are negative for the systems containing *o*-xylene, *m*-xylene, and isopropylbenzene, but for *p*-xylene, the deviation is positive. However, the deviations vary from more negative for *o*-xylene to less negative for *m*-xylene and then to positive for *p*-xylene. The excess compressibility K_s^E (Figure 2) for all of the systems is negative except for the isopropylbenzene, for which it changes from negative to positive.

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