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Excess molar volumes, viscosity deviations and ultrasonic speeds of sound of binary mixtures of 2-butanone with some alkoxyethanols and amines at 298.15 K

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Abstract

Densities, viscosities and ultrasonic speeds were measured for the binary mixtures of 2-butanone (BU), +2-methoxy ethanol (ME), +2-ethoxy ethanol (EE), +2-butoxy ethanol (BE), +isopropylamine (IPA), +cyclohexylamine (CHA) and +diethylamine (DEA) over the entire range of composition at 298.15 K. From the experimental values of density, viscosity and ultrasonic speed, excess molar volumes (V^E), viscosity deviations ($\Delta\eta$) and deviations in isentropic compressibility (ΔK_S) have been calculated. The excess or deviation properties were fitted to the Redlich–Kister polynomial equation to obtain their coefficients and standard deviations. To explore the nature of the interactions various thermodynamic parameters, e.g., intermolecular free length (L_f), specific acoustic impedance (Z) etc. have also been derived from the density and ultrasonic speed data. McAllister's multibody interaction model along with the Heric–Brewer model has been used to correlate kinematic viscosities (υ) of the binary mixtures. Also, the experimental values of density, viscosity and ultrasonic speeds of the mixtures at 298.15 K were fitted to a polynomial of the type: $y = \sum_{j=0}^{3} a_j x_1^j$ by the method of least-squares with each point weighed equally. The excess or deviation properties were found to be either negative or positive depending on the molecular interactions and the nature of liquid mixtures and have been discussed in terms of molecular interactions and structural changes.

Keywords: Excess molar volumes; Viscosity deviations; Ultrasonic speeds; 2-butanone; Alkoxyethanols; Amines

1. Introduction

Properties such as density and viscosity of pure chemicals and of their binary mixtures over the whole composition range at a particular temperature or several temperatures, are useful for a full understanding of their thermodynamic and transport properties as well as for practical chemical engineering purposes. On the other hand, excess thermodynamic functions and deviations of nonthermodynamic ones of binary liquid mixtures are fundamental for understanding the interactions between molecules in these types of binary mixtures. So in recent years, there has been considerable interest in theoretical and experimental investigations of the excess thermodynamic properties of binary mixtures. The present work is a continuation of our systematic study [1–3] of the physicochemical properties of nonaqueous binary liquid mixtures and it reports density (ρ), viscosity (η) and ultrasonic speeds (u) for the binary mixtures of 2-butanone (BU)+alkoxyethanols (2-methoxy-, 2-ethoxy-, 2-butoxyethanol), and 2-butanone+amines (isopropyl-, cyclohexyl-,

Table 1
Physical properties of pure components at 298.15 K

Pure components	$\rho\times10^{-3}$/kg m^{-3}		η/mPa s		u/m s^{-1}
	Expt.	Lit.	Expt.	Lit.	
2-butanone	0.7981	0.7981 [2]	0.373	0.373 [2]	1195.4
2-methoxyethanol	0.9603	0.9602 [7]	1.540	1.5414 [7]	1340.2
2-ethoxyethanol	0.9250	0.9256 [8]	1.850	1.850 [8]	1302.8
2-butoxyethanol	0.8965	0.8966 [5]	2.792	2.795 [5]	1303.2
Isopropylamine	0.6815		0.278		1075.6
Cyclohexylamine	0.8668		1.753		1416.4
Diethylamine	0.6984		0.265		1130.6

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diethylamine) over the entire range of composition at 298.15 K and at atmospheric pressure. It is well known that 2-butanone has numerous applications both in pure chemistry and industry. Also, alkoxyethanols have wide use as monomers in the production of polymers and emulsion formulations. They are also of considerable interest for studying the heteroproximity effects of the etheric oxygen on the –O–H bond and, hence, their influence on the associated nature of the species in these molecules. Isopropylamine, cyclohexylamine and diethylamine are also important in characterizing the associated nature of the liquids in mixtures, because of the presence of both a proton donor and a proton acceptor and they form water insoluble compounds of medical importance [4].

To explore the nature of the interactions various thermodynamic parameters, e.g., intermolecular free length, specific acoustic impedance etc. and their deviations have been derived from the density and ultrasonic speed data. The excess or deviation properties were fitted to the Redlich–Kister polynomial equation to obtain their coefficients and standard deviations and have been interpreted in terms of molecular interactions and structural effects. This work provides a test of various empirical equations to correlate viscosity and acoustic data of binary mixtures in terms of pure component properties.

2. Experimental section

2.1. Chemicals

2-methoxy-, 2-ethoxy- and 2-butoxyethanol (S. D. Fine Chemicals, AR, India) were purified as described in the literature [5]. 2-butanone, isopropylamine, cyclohexylamine

Table 2
Correlation coefficients of density, viscosity and ultrasonic speed of the binary mixtures from Eq. (1) at 298.15 K

System	a_0	a_1	a_2	a_3	σ
$\rho \times 10^{-3}$/kg m^{-3}					
BU (1)+ME (2)	0.9603	−0.1758	0.0219	−0.0074	0.0008
BU (1)+EE (2)	0.9250	−0.1118	−0.0079	−0.0072	0.0007
BU (1)+BE (2)	0.8965	−0.0663	−0.0121	−0.0200	0.0006
BU (1)+IPA (2)	0.6815	0.1569	0.0328	−0.0728	0.0006
BU(1)+CHA (2)	0.8664	−0.0237	0.0287	−0.0739	0.0007
BU (1)+DEA (2)	0.6982	0.1012	0.0070	−0.0086	0.0006
η/mPa s					
BU (1)+ME (2)	1.547	−2.311	1.024	0.129	0.002
BU (1)+EE (2)	1.853	−3.353	2.288	−0.409	0.001
BU (1)+BE (2)	2.785	−4.886	2.708	−0.227	0.002
BU (1)+IPA (2)	0.277	0.132	0.098	−0.136	0.003
BU (1)+CHA (2)	1.752	1.345	0.070	−0.106	0.003
BU (1)+DEA (2)	0.266	0.077	−0.117	0.150	0.002
u/m s^{-1}					
BU (1)+ME (2)	1340.1	−99.8	−31.9	−13.4	0.1
BU (1)+EE (2)	1304.0	−214.9	103.2	4.3	0.2
BU (1)+BE (2)	1304.5	−264.3	177.0	−19.9	0.3
BU (1)+IPA (2)	1072.9	374.5	−358.9	104.9	0.7
BU (1)+CHA (2)	1410.1	−108.7	−88.7	−25.9	1.5
BU (1)+DEA (2)	1128.4	129.1	−22.9	−41.5	0.5

Table 3
Experimental values of density, $\rho \times 10^{-3}$/kg m^{-3}; viscosity, η/mPa s; excess molar volume, $V^E \times 10^6$/m^3 mol^{-1}; and deviations in viscosity, $\Delta\eta$/mPa s for the binary mixtures under investigation at 298.15 K

Mole fraction of BU (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
BU (1)+ME (2)				
0	0.9603	1.540	0	0
0.1049	0.9420	1.321	−0.071	−0.097
0.2087	0.9245	1.113	−0.150	−0.184
0.3115	0.9074	0.937	−0.210	−0.240
0.4130	0.8908	0.780	−0.253	−0.278
0.5135	0.8746	0.640	−0.277	−0.301
0.6128	0.8588	0.525	−0.282	−0.300
0.7112	0.8433	0.464	−0.264	−0.246
0.8085	0.8281	0.430	−0.223	−0.166
0.9047	0.8131	0.410	−0.137	−0.074
1	0.7981	0.373	0	0
BU (1)+EE (2)				
0	0.9250	1.850	0	0
0.1219	0.9111	1.479	−0.065	−0.191
0.2381	0.8978	1.178	−0.139	−0.320
0.3488	0.8847	0.948	−0.197	−0.387
0.4545	0.8719	0.767	−0.234	−0.411
0.5555	0.8593	0.609	−0.257	−0.420
0.6521	0.8467	0.524	−0.248	−0.363
0.7446	0.8344	0.457	−0.222	−0.293
0.8333	0.8221	0.419	−0.167	−0.200
0.9183	0.8101	0.387	−0.094	−0.106
1	0.7981	0.373	0	0
BU (1)+BE (2)				
0	0.8965	2.792	0	0
0.1540	0.8860	2.106	−0.052	−0.313
0.2906	0.8758	1.609	−0.110	−0.480
0.4126	0.8657	1.234	−0.156	−0.560
0.5221	0.8558	0.939	−0.181	−0.590
0.6211	0.8458	0.727	−0.171	−0.562
0.7108	0.8361	0.607	−0.161	−0.466
0.7927	0.8265	0.519	−0.140	−0.355
0.8676	0.8169	0.466	−0.101	−0.227
0.9365	0.8075	0.416	−0.054	−0.110
1	0.7981	0.373	0	0
BU (1)+IPA (2)				
0	0.6815	0.278	0	0
0.0835	0.6946	0.288	−0.371	0.002
0.1701	0.7089	0.300	−0.845	0.005
0.2600	0.7236	0.314	−1.318	0.011
0.3534	0.7381	0.330	−1.700	0.018
0.4505	0.7522	0.345	−1.993	0.024
0.5515	0.7652	0.358	−2.106	0.028
0.6567	0.7781	0.370	−2.165	0.030
0.7663	0.7884	0.371	−1.890	0.020
0.8806	0.7962	0.372	−1.299	0.010
1	0.7981	0.373	0	0
BU (1)+CHA (2)				
0	0.8668	1.753	0	0
0.1326	0.8630	1.574	−0.463	0.004
0.2559	0.8609	1.409	−1.100	0.009
0.3708	0.8580	1.257	−1.606	0.016
0.4783	0.8540	1.115	−1.937	0.022
0.5790	0.8482	0.978	−2.034	0.025
0.6735	0.8409	0.846	−1.949	0.022

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