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Densities, viscosities and relative permittivities of some *n*-alkoxyethanols with sulfolane at $T = 303.15$ K

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Abstract

Densities, viscosities and relative permittivities, at $T = 303.15$ K, in the binary mixtures of sulfolane with 2-methoxyethanol, 2-ethoxyethanol, 2-propoxyethanol and 2-buthoxyethanol have been measured as a function of composition. From the experimental data excess molar volumes, deviations in the viscosity, and the deviations in the relative permittivity from a mole fraction average have been calculated. The viscosity data were correlated with equations of Hind et al., Grunberg and Nissan, Frenkel, and McAllister. The results are discussed in terms of intermolecular interactions and structure of studied binary mixtures.
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1. Introduction

This paper is a continuation of our studies on the thermodynamic and structural properties of some mixtures of alkoxyalcohols with different aprotic solvents [1–7]. In the present work, we have measured the density (ρ), viscosity (η), and relative permittivity (ε) over the entire composition range, at 303.15 K, for binary mixtures of sulfolane (SLF) with 2-methoxyethanol (ME), 2-ethoxyethanol (EE), propoxyethanol (PE) and 2-buthoxyethanol (BE). The experimental results for ρ, η, and ε were used to calculate the excess molar volumes (V^E) and deviations in viscosity ($\Delta\eta$), and relative permittivity ($\Delta\varepsilon$) for all studied binary mixtures.

Alkoxyethanols are very interesting class of solvents owing of the presence of the oxy and hydroxyl groups in the same molecule. Due to this the formation of intra-and intermolecular hydrogen bonds between the –O– and –OH groups of the same or different molecules have been observed. The formation of intermolecular hydrogen bonds is more favourable when the molecules are in the *gauche* conformations [8–12]. Sulfolane is a typical dipolar aprotic solvent with a low donor number of 14.81 and a large dipole moment and relative permittivity in the liquid phase ($\mu = 4.8$ D; $\varepsilon = 43.39$). The proton basicity of sulfolane is much lower than that of water or even acetonitrile, as shown by its pKa(SH^+) value of -12.9. This is a globular molecule in which only the negative end of its large dipole moment exposed and thus is cannot act as a proton acceptor-donor. Also, because of the steric hindrance of its globular shape, sulfolane does not easily interact with other molecules [13–19]. These solvents have found a wide variety of applications in the petroleum, cosmetics, textile, pharmaceutical, and the other industries.

2. Experimental section

2.1. Materials

The following materials with mole fraction purity as stated were used: 2-methoxyethanol (Merck-Schuchardt FRG, GC > 0.99 mole fraction), 2-ethoxyethanol (Merck–Schuchardt FRG, GC > 0.98 mole fraction), 2-propoxyethanol (Merck–Schuchardt FRG, GC > 0.99 mole fraction) and 2-butoxyethanol (Fluka, Switzerland, purum, GC ≥ 0.98 mole fraction). All

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Table 1
Densities, viscosities and relative permittivities of pure components, at T=(293.15, 298.15, and 303.15) K

Solvent	ρ $\mathrm{g \cdot cm^{-3}}$		η $\mathrm{mPa \cdot s}$		ε	
	This work	Literature	This work	Literature	This work	Literature
Sulfolane	1.26196	1.26140 [20] 1.26202 [25] 1.2619 [27]	10.121	10.052 [25] 10.356 [26] 10.284 [27]	43.33	43.39 [20] 43.40 [28]
ME	0.95577	0.95584 [21] 0.95576 [24]	1.404	1.476 [21]	16.56	16.59 [21] 16.54 [29]
EE	0.92050	0.92118 [21] 0.920537 [22]	1.646	1.646 [21]	13.76	13.98 [22]
PE	0.90311	0.93050 [23]	2.070	–	11.19	–
BE	0.89231	0.892172[23] 0.89231 [21] 0.89203 [30]	2.411	2.408 [21]	8.88	–

alkoxyethanols were further purified by the methods described by us previously [1–7]. Additionally sulfolane (Aldrich, purum, GC$\geq$0.98 mole fraction) was used. It was purified by the method described by Domańska et al. [13]. The mixtures were prepared just before use by mass on a Sartorius balance of the type ING1, operating in a dry box to avoid atmospheric moisture. Conversion to molar quantities was based on the relative atomic mass table published in1985, next issued by IUPAC in 1986. The uncertainty in the mole fraction sulfolane is estimated to be less than $\pm 1 \cdot 10^{-4}$. Liquids were stored in dry-box over phosphorus pentoxide and degassed by ultrasound just before the experiment. Experimental density, viscosity and relative permittivity for the pure solvents, at T=303.15 K, are compared with values available in the literature and listed in Table 1. The differences between the measured and literature values can be ascribed to different measurement methods used, and to the different purification procedures employed by other authors [31].

2.2. Measurements

Solvent densities were measured with a bicapillary type Lipkin pycnometer, with a capacity of ca. 90 $\mathrm{cm^3}$. The maximum error in the density measurements was $2 \cdot 10^{-5}$ g $\mathrm{cm^{-3}}$.

The flow times of the mixtures and the pure liquids were measured in a ViscoClock (made by Schott), equipped with an Ubbelohde capillary viscometer. Double distilled, deionized and degassed water with a specific conductance of $1 \cdot 10^{-9}$ S $\mathrm{m^{-1}}$ was used for the calibration. The time measurement tolerance was±0.005%, and the display accuracy was ±0.01 s. The uncertainty in the viscosity measurements was ±0.001 mPa s.

The relative permittivity measurements were carried out at 3 MHz, using a bridge of the type OH − 301 (made in Radelcis, Hungary). The thermostatic stainless steel measuring cell was of CIII ($1 < \varepsilon < 60$) type. The cell was calibrated with standard pure liquids, such as acetone, butan-1-ol, N,N-dimethylformamide, dichloromethane and water+dioxane binary mixtures (double distilled, deionized and degassed water with a specific conductance of $1 \cdot 10^{-9}$ S $\mathrm{m^{-1}}$ was used for these mixtures). All these pure solvent were of spectrograde quality or higher. The relative permittivities for the standards were taken from the literature [32]. The accuracy in the relative permittivity measurements was ±0.02.

In all measurements of the density, viscosity and relative permittivity a Haake model DC-30 thermostat was used at a constant digital temperature control of ±0.01 K.

3. Results and discussion

The experimental densities (ρ), viscosities (η) and relative permittivities (ε) obtained from the measurements of the pure solvents and for the studied binary mixtures, at T=303.15 K, are summarized in Tables 2, 3, and 4. Many investigations of the density, viscosity and relative permittivity behaviours of liquids have been reported in the literature and the best representation

Table 2
Densities (ρ) and excess molar volumes (V^E) for {SLF (1)+ME (2), SLF (1)+EE (2), SLF (1)+PE (2) and SLF (1)+BE (2)} binary mixtures at T=303.15 K

SLF (1)+ME (2)			SLF (1)+EE (2)		
x_1	ρ $\mathrm{g \cdot cm^{-3}}$	V^E $\mathrm{cm^3 \cdot mol^{-1}}$	x_1	ρ $\mathrm{g \cdot cm^{-3}}$	V^E $\mathrm{cm^3 \cdot mol^{-1}}$
0.0000	0.95577	0.000	0.0000	0.92050	0.000
0.0501	0.97526	−0.110	0.0500	0.93809	−0.103
0.0995	0.99393	−0.198	0.0999	0.95578	−0.209
0.1997	1.03010	−0.319	0.2000	0.99119	−0.386
0.3000	1.06415	−0.366	0.3003	1.02625	−0.493
0.4005	1.09646	−0.369	0.3972	1.05973	−0.537
0.5000	1.12702	−0.348	0.4985	1.09439	−0.533
0.5995	1.15638	−0.319	0.5996	1.12877	−0.496
0.6996	1.18465	−0.274	0.7001	1.16277	−0.432
0.7997	1.21178	−0.215	0.8001	1.19636	−0.335
0.9092	1.23987	−0.114	0.8985	1.22888	−0.190
0.9499	1.24985	−0.062	0.9498	1.24568	−0.103
1.0000	1.26196	0.000	1.0000	1.26196	0.000

SLF (1)+PE (2)			SLF (1)+BE (2)		
x_1	ρ $\mathrm{g \cdot cm^{-3}}$	V^E $\mathrm{cm^3 \cdot mol^{-1}}$	x_1	ρ $\mathrm{g \cdot cm^{-3}}$	V^E $\mathrm{cm^3 \cdot mol^{-1}}$
0.0000	0.90311	0.000	0.0000	0.89231	0.000
0.0498	0.91931	−0.164	0.0500	0.90710	−0.188
0.1001	0.93559	−0.278	0.0994	0.92173	−0.313
0.2000	0.96833	−0.439	0.1993	0.95211	−0.484
0.3000	1.00182	−0.536	0.2983	0.98348	−0.571
0.4000	1.03611	−0.579	0.4005	1.01753	−0.609
0.4998	1.07119	−0.575	0.4997	1.05242	−0.606
0.5996	1.10724	−0.535	0.6000	1.08970	−0.564
0.7000	1.14442	−0.449	0.7000	1.12903	−0.482
0.8001	1.18238	−0.317	0.8001	1.17078	−0.364
0.8999	1.22133	−0.157	0.9000	1.21503	−0.208
0.9500	1.24147	−0.079	0.9500	1.23822	−0.116
1.0000	1.26196	0.000	1.0000	1.26196	0.000

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