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Relative permittivity of the binary mixtures of 2-methoxyethanol with diethylene glycol, triethylene glycol, tetraethylene glycol, and polyethylene glycol 200 at various temperatures

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Abstract

Relative permittivities at $T = (293.15, 298.15, \text{and } 303.15)$ K in the binary liquid mixtures of 2-methoxyethanol with diethylene glycol, triethylene glycol, tetraethylene glycol, and polyethylene glycol 200 have been measured over the entire mixture compositions. The relative permittivity deviations ($\Delta\varepsilon$) were calculated from these experimental data. The results are discussed in terms of intermolecular interactions and structure of studied binary mixtures.

Keywords: Diethylene glycol; Triethylene glycol; Tetraethylene glycol; Polyethylene glycol 200; 2-Methoxyethanol; Relative permittivity; Intermolecular interactions

1. Introduction

In continuation of our program on the thermodynamic and structural properties of some mixtures of alkoxyalcohols with different solvents [1–6], the present paper reports the relative permittivity for binary mixtures containing 2-methoxyethanol (ME), diethylene glycol (DEG), triethylene glycol (TEG), tetraethylene glycol (TETRAEG), and polyethylene glycol 200 (PEG 200) at various temperatures. From these results, the deviations of the relative permittivity ($\Delta\varepsilon$) at $T = (293.15, 298.15, \text{and } 303.15)$ K have been calculated. These quantities have been fitted to the Redlich–Kister equation [7], to obtain the binary coefficients and standard deviations. Furthermore, the experimental results have been used to describe the nature of intermolecular interactions.

2. Experimental

2.1. Materials

The following materials with mole fraction purity as stated were used: 2-methoxyethanol (Merck–Schuchardt FRG, GC $\geqslant$ 0.99 mole fraction), diethylene glycol (Fluka, Swizerland, puriss. p.a., GC $\geqslant$ 0.995 mole fraction), triethylene glycol (Fluka, Swizerland, puriss. anhydrous, GC $\geqslant$ 0.99 mole fraction), tertraethylene glycol (Fluka, Switzerland, purum, GC $\geqslant$ 0.99 mole fraction), and polyethylene glycol 200 (Fluka, Switzerland). All glycols and 2-methoxyethanol were further purified by the methods described by Sastry [8], Iglesias [9] and Pal [10].

The mixtures were prepared using a Sartorius balance. Conversion to molar quantities was based on the relative atomic mass table of 1985, issued by IUPAC in 1986. The maximum estimated error in the mole fractions is $\pm 1 \cdot 10^{-4}$. Liquids were stored in dry-box over phosphorus pentoxide and degassed by ultrasound just before the

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experiment. Experimental relative permittivities for the pure solvents, at $T = 298.15$ K, are compared with values available in the literature and listed in table 1. The differences between the measured and the literature values can be ascribed to different measurement methods used, and to the different purification procedures employed by other authors [11].

2.2. Measurements

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 C4 ($1 < \varepsilon < 35$) type. The cell was calibrated with standard pure liquids, such as acetone, butan-1-ol, *N*,*N*-dimethylformamide, and dichloromethane. All these solvent were of spectrograde quality or higher. The relative permittivities for the standards were taken from the literature [12]. The accuracy in the relative permittivity measurements was ±0.02. In all the dielectric property measurements, an Haake model DC-30 thermostat was used at a constant digital temperature control of ±0.01 K.

3. Results and discussion

The experimental relative permittivities (ε) obtained from the measurements of the pure solvents and for the binary mixtures at all investigated temperatures are summarized in tables 2 to 5. The variation of relative permittivity with binary composition was studied by using the following equation:

$$\ln \varepsilon = \sum_{j=0}^{6} \beta_j \cdot x_1^j, \tag{1}$$

which could be fitted to the experimental data at each temperature using a least-squares method. The values of β_j coefficients and the standard deviations $\sigma(\ln \varepsilon)$ are summarized in table 6.

The goodness-of-fit of this procedure is ascertained by a mean deviation $\overline{\Delta\varepsilon} = \pm 0.03$ for (ME + DEG), $\overline{\Delta\varepsilon} = \pm 0.02$ for (ME + TEG), $\overline{\Delta\varepsilon} = \pm 0.02$ for (ME + TETRAEG), and $\overline{\Delta\varepsilon} = \pm 0.01$ for (ME + PEG 200) binary liquid mixtures.

From the measured relative permittivities the deviation of the relative permittivities ($\Delta\varepsilon$), at $T = (293.15, 298.15,$ and $303.15)$ K, were fitted to the following equation:

TABLE 1
Relative permittivities of pure components, at $T = (293.15, 298.15,$ and $303.15)$ K

Solvent	ε					
	293.15 K		298.15 K		303.15 K	
	This work	Literature	This work	Literature	This work	Literature
2-Methoxyethanol	17.38	17.35 [13]	16.95	16.94 [13]	16.56	16.54 [13]
Diethylene glycol	31.81		30.95	30.92 [8] 30.93 [16]	30.03	29.11 [17]
Triethylene glycol	23.69		23.07	23.05 [8] 23.05 [16]	22.43	
Tetraethylene glycol	20.44		19.91		19.35	
Polyethylene glycol 200	19.95		19.14		18.41	18.43 [19]

TABLE 2
Relative permittivities (ε) and relative permittivity deviations ($\Delta\varepsilon$) or {2-methoxyethanol (1) + diethylene glycol (2)} binary mixtures at $T = (293.15,$ 298.15, and 303.15) K

x_1	ε			$\Delta\varepsilon$		
	293.15 K	298.15 K	303.15 K	293.15 K	298.15 K	303.15 K
			ME (1) + DEG (2)			
0.0000	31.81	30.95	30.03			
0.0414	31.69	30.71	29.85	0.48	0.38	0.34
0.0999	31.49	30.39	29.49	1.12	0.84	0.81
0.2077	31.23	29.85	29.01	2.42	1.81	1.78
0.3001	31.03	29.41	28.45	3.55	2.66	2.46
0.4094	30.32	28.67	27.49	4.42	3.45	2.97
0.4998	29.56	27.81	26.61	4.96	3.86	3.31
0.5994	28.32	26.68	25.36	5.16	4.12	3.40
0.6996	26.65	24.99	23.55	4.94	3.83	2.94
0.7996	24.25	22.78	21.64	3.98	3.02	2.38
0.9018	21.43	20.27	19.39	2.63	1.95	1.51
0.9463	19.98	18.88	18.25	1.83	1.18	0.97
1.0000	17.38	16.95	16.56			