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Excess molar volume and viscosity deviation for binary mixtures of polyethylene glycol dimethyl ether 250 with 1,2-alkanediols (C_3–C_6) at $T = (293.15$ to $323.15)$ K

Jalal Basiri Parsa *, Mahdieh Farshbaf Haghro

Faculty of Chemistry, Bu-Ali Sina University, Hamedan 65178, Iran

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Abstract

In this work, density and viscosity have been determined for (polyethylene glycol dimethyl ether 250 + 1,2-propanediol, or 1,2-butanediol, or 1,2-pentanediol, or 1,2-hexanediol) binary systems over the whole concentration range at temperatures of (293.15, 303.15, 313.15, 323.15) K and atmospheric pressure. Experimental data of mixtures were used to calculate the excess molar volumes V^E, and viscosity deviations $\Delta\eta$. These results were fitted by the Redlich–Kister polynomial relation to obtain the coefficients and standard deviations.

Keywords: Polyethylene glycol dimethyl ether 250; 1,2-Alkanediol; Excess molar volume; Viscosity deviation

1. Introduction

A full understanding of thermodynamic and transport properties of binary liquid systems is essential in many chemical engineering processes such as design calculation, heat transfer, mass transfer, fluid flow, and so forth [1]. We have started a research program on the excess properties of mixtures containing (polyethylene glycol dimethyl ether 250 + alkanediols). In this work we have reported experimental data such as density (ρ) and viscosity (η) at several temperatures over the whole range of composition for binary liquid mixtures. From the experimental density and viscosity values, excess molar volumes and viscosity deviations have been calculated, respectively.

Polyethylene glycol dimethyl ether 250, $CH_3O((CH_2)_2O)_n$–CH_3, also denominated PEGDME 250, is a mixture of Glymes which have been studied extensively in recent years [2–5]. The aims of this work are (i) to report experimental data of density and viscosity for {PEGDME 250 + 1,2-propanediol or 1,2-butanediol or 1,2-heptanediol or 1,2-hexanediol} binary systems at $T = (293.15$ to $323.15)$ K, (ii) to use the data of the mixtures to calculate the excess molar volumes and viscosity deviation, and (iii) to fit these results using Redlich–Kister [6] polynomial relation to obtain the coefficients and the standard deviations. Finally, the results are discussed in terms of the intermolecular interactions.

Pereira *et al.* [2] have published data for (PEGDME 250 + methanol) binary systems at $T = (293.15$ to $333.15)$ K. This system has been studied by Esteve *et al.* [7,8] too at $T = (283.15$ to $323.15)$ K. Conesa *et al.* [9] also studied densities, kinematic viscosities, and heat capacities of some ethylene glycol dimethyl ethers at $T = (283.15$ to $423.15)$ K. In our knowledge, no more experimental density and viscosity measurements have been reported in the literature for the {1,2-(C_3–C_6)–alkanediols + PEGDME 250} systems.

There were agreement between our data for pure materials and those were reported in the above references.

* Corresponding author. Tel.: +98 811 8282807; fax: +98 811 8257407.
E-mail address: parssa@basu.ac.ir (J.B. Parsa).

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2. Experimental

2.1. Materials

Polyethylene glycol dimethyl ether 250 (Merck) CAS-No. 24991-55-7 for synthesis, 1,2-propanediol (Merck, GC > 0.99), 1,2-butanediol (Aldrich, GC > 0.99), 1,2-pentanediol (Fluka, GC > 0.95), and 1,2-hexanediol (Fluka, GC > 0.97). All chemicals were used as received without further purification.

2.2. Methods

The solutions for the measurements of densities and viscosities were prepared fresh, and all the properties were measured the same time. The mass measurements were made using an electronic balance (AB 204-N Mettler) accurate to ±0.1 mg. The uncertainty in mole fractions is estimated to be lower than $\pm 2 \times 10^{-4}$. Densities of the pure liquids and their mixtures were measured with a high precision vibrating tube density meter (Anton Paar, DMA 4500). The instrument had a built-in thermostat for maintaining the desired temperatures in the range (0 to 90) °C. The temperature in the cell was regulated to ±0.01 °C with solid state thermostat, thus accuracy of the temperature during the measurements, however, is ±0.01 °C. The instrument operated in the static mode and capable of a precision better than 10^{-5} g · cm^{-3}. Before each series of measurements, the densimeter was calibrated with bidistilled water and dry air at atmospheric pressure, the uncertainty of density measurements is ±0.0002.

Viscosities of the pure liquids and selected mixtures were measured with a modified suspended level Ubbelohde viscometer consisting of basic control unit, measuring stand, thermostat, and calibrated Ubbelohde viscometer [10]. The viscometer and thermometer was submerged in a thermostatic bath at temperatures of (293.15, 303.15, 313.15 and 323.15) K with a resolution of ±0.01 K. The time given to attain thermal equilibrium for the content of viscometer was 15 min. The flow time was measured with an accurate electronic timer that is capable of measuring time to within ±0.01 s. Three to four sets of readings for the flow times were taken for each pure liquid or liquid mixture and arithmetic mean was considered for the calculations with accuracy of ±0.01 s.

The equation for viscosity, according to the corrected Hagen–Poiseuille law [10], is

TABLE 1
Data for the pure liquid at several temperatures

Component	T/K	ρ/(g · cm)$^{-3}$		η/(mPa · s)		ν/(mm^2 · s^{-1})	
		Experimental	Literature	Experimental	Literature	Experimental	Literature
PEGDME 250	293.15	1.03890	1.0354 [2]	7.85		7.56	7.1153 [8]
				1.03538 [8]			7.215 [9]
				1.0355 [9]			
	303.15	1.02987	1.0264 [2]	5.63	5.4895 [7]	5.47	5.3495 [7]
			1.02617 [7]				5.457 [9]
			1.0264 [9]				
	313.15	1.02088	1.0172 [2]	4.05		3.97	4.3025 [8]
			1.01705 [8]				4.290 [9]
			1.0174 [9]				
	323.15	1.01191	1.0085 [2]	2.92		2.89	3.4224 [8]
			1.00836 [8]				3.464 [9]
			1.0084 [9]				
1,2-Propanediol	293.15	1.03630	1.03638 [16]	56.21			
	303.15	1.02892	1.028939 [5]	32.63	33.902 [5]		
			1.02914 [16]				
	313.15	1.02139	1.021399 [5]	19.58	19.47 [5]		
			1.0219 [16]				
	323.15	1.01370		12.79			
1,2-Butanediol	293.15	1.00243		71.87			
	303.15	0.99498		37.86			
	313.15	0.98739		21.49			
	323.15	0.97964		13.12			
1,2-Pentanediol	293.15	0.97035		76.96			
	303.15	0.96307		39.16			
	313.15	0.95565		22.52			
	323.15	0.94812		13.66			
1,2-Hexanediol	293.15	0.95186		83.41			
	303.15	0.94466	0.94454 [17]	42.25			
	313.15	0.93734		24.12			
	323.15	0.92990		14.79			