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Densities and volumetric properties of (*N*-(2-hydroxyethyl)morpholine + ethanol, + 1-propanol, + 2-propanol, + 1-butanol, and + 2-butanol) at (293.15, 298.15, 303.15, 313.15, and 323.15) K

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Abstract

Densities of binary mixtures of *N*-(2-hydroxyethyl)morpholine with ethanol, 1-propanol, 2-propanol, 1-butanol, and 2-butanol were measured over the entire composition range at temperatures from (293.15 to 323.15) K and atmospheric pressure using a vibrating-tube densimeter. The excess molar volumes, V^E were calculated from density data and fitted to the Redlich–Kister polynomial equation. Apparent molar volumes, partial molar volume at infinite dilution and the thermal expansion coefficient of the mixtures were also calculated. The V^E values were found to be negative over the entire composition range and at all temperatures studied and become less negative with increasing carbon chain length of the alkanols.

Keywords: Density; Excess molar volumes; *N*-(2-hydroxyethyl)morpholine; Alkanols

1. Introduction

The thermodynamic and transport properties of liquids and liquid mixtures have been used to understand the molecular interactions between the components of the mixture and also for engineering applications. In our preceding papers [1–5], the experimental values of density, sound velocity, refractive index, permittivity, and viscosity have been reported for the binary mixtures containing morpholine, *N*-formylmorpholine, *N*-methylmorpholine, *N*-(2-hydroxyethyl)morpholine as one component. As a part of our experimental programme on the physicochemical properties of binary liquid mixtures containing morpholines, we report here the experimental results of the density for thy binary mixtures of {*N*-(2-hydroxyethyl)morpholine (1) + ethanol (2), + 1-propanol (2), + 2-propanol (2), + 1-butanol (2), and + 2-butanol (2)} at temperatures from (293.15 to 323.15) K and at atmospheric pressure over the entire composition range. From these results, the excess molar volumes, apparent and partial molar volumes at infinite dilution, and thermal expansion coefficient have been calculated.

A detailed search in the literature shows no measurements have been made on the densities, and their excess properties for *N*-(2-hydroxyethyl)morpholine with ethanol, 1-propanol, 2-propanol, 1-butanol, and 2-butanol.

The aim of this work is to provide a set of data in order to asses the influence of the temperature on the molecular interactions between alkanols and *N*-(2-hydroxyethyl)-morpholine, and to determine the difference of molecular interaction between these solvents and *N*-(2-hydroxyethyl)-morpholine.

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2. Experimental

2.1. Materials

The *N*-(2-hydroxyethyl)morpholine (NHEM) (stated purity 99 mol%), obtained from E. Aldrich. Alkanols: ethanol, 1-propanol, 2-propanol, 1-butanol, and 2-butanol (stated mol. purity ⩾99.5%) were obtained from Fluka AG. All solvents were kept over activated molecular sieves of type 4 nm (4 Å) (Union Carbide) and filtered before use. The purity of all liquids was confirmed by gas liquid chromatographic analysis. The measured densities of the pure solvents at $T = (293.15, 298.15, 303.15, 313.15,$ and $323.15)$ K are given in table 1 together with the literature data [4,6–10]. All binary mixtures were prepared on a mass basis using a mettler balance, model AE-240 with a precision of ±0.01 mg.

2.2. Apparatus and procedure

The densities of the pure liquids and their binary mixtures were measured with a digital densimeter DMA 60/602 (Anton Paar) whose measurement cell temperature was controlled automatically within ±0.01 K of the selected value. Before each series of measurements, the densimeter was calibrated at atmospheric pressure with double distilled water and dry air. Densities, both water and dry air, at the various working temperatures were given by the manufacturer in the instruction manual. The reproducibility of the density measurement was $\pm 2 \cdot 10^{-5}$ g · cm^{-3}.

3. Results and discussion

The experimental values of density for binary mixtures at different temperatures from (293.15 to 323.15) K and at atmospheric pressure are listed in table 2. Excess molar volumes were calculated from density measurements according to the following equation:

$$V^{E}/(\mathrm{cm}^3 \cdot \mathrm{mol}^{-1}) = (x_1 M_1 + x_2 M_2)/\rho - x_1 M_1/\rho_1 - x_2 M_2/\rho_2, \quad (1)$$

where x_i, M_i, ρ_i are the mole fraction, the molar mass and the density of component i and ρ is the density of the mixture, respectively. The experimental V^E data of {NHEM (1) + alkanol (2)} mixtures at temperatures from (293.15 to 323.15) K are presented in table 2.

The values of V^E for each mixture were fitted to the Redlich–Kister polynomial equation [11]

$$V^{E} = x(1-x)\sum_{j=0}^{m} A_j (1-2x), \quad (2)$$

where x is the mole fraction of NHEM and A_j refer to the adjustable parameters. For each mixture, the optimum number of adjustable parameters was ascertained from an examination of the variation in the standard deviation σ

$$\sigma = \left[\sum \left(V^{E}_{\mathrm{obs}} - V^{E}_{\mathrm{cal}}\right)^2/(n-m)\right]^{1/2}, \quad (3)$$

where n is the total number of experimental points and m is the number of parameters. The values of A_i and the standard deviations σ are reported in table 3.

It can be observed from the experimental results in table 2 and figure 1 that the excess molar volume values V^E are negative over the entire mole fraction range and at all temperatures from (293.15 to 323.15) K for all binary mixtures of {NHEM (1) + ethanol (2), + 1-propanol (2), + 2-propanol (2), + 1-butanol (2), and + 2-butanol (2)} and become less negative with increasing carbon chain length in the alkanols. Figure 2 shows that V^E values become large and negative as the temperature increases.

In a binary mixture, the apparent molar volume $V\phi_1$ and $V\phi_2$ of NHEM (1) and alkanol (2) are defined by the following equations [12,13]:

TABLE 1
Densities (ρ) of pure component liquids at different temperatures

Liquid	T/K	ρ/(g · cm^{-3})		Liquid	T/K	ρ/(g · cm^{-3})	
		Expt.	Lit.			Expt.	Lit.
Ethanol	293.15	0.78833	0.78824	1-Propanol	293.15	0.80356	0.80361
	298.15	0.78497	0.78497		298.15	0.79971	0.79958
	303.15	0.78072	0.78073		303.15	0.79558	0.79548
	313.15	0.77261	0.77213		313.15	0.78734	0.78702
	323.15	0.76414			323.15	0.77897	0.77902
2-Propanol	293.15	0.78518	0.78542	1-Butanol	293.15	0.80952	
	298.15	0.78131	0.78123		298.15	0.80588	0.80576
	303.15	0.77666	0.77716		303.15	0.80199	0.80201
	313.15	0.76783	0.76798		313.15	0.79434	0.79432
	323.15	0.75871	0.75868		323.15	0.78667	
2-Butanol	293.15	0.80556		NHEM	293.15	1.07658	
	298.15	0.80243	0.80245		298.15	1.01730	1.01732
	303.15	0.79776			303.15	1.06651	
	313.15	0.79011	0.78954		313.15	1.05919	
	323.15	0.78492			323.15	1.05264	