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Density and surface tension variation with temperature for *n*-nonane + 1-hexanol

Manuel M. Piñeiro, Josefa García, Beatriz E. de Cominges,
Javier Vijande, José Luis Valencia, José Luis Legido *

Departamento de Física Aplicada, Facultade de Ciencias, Universidade de Vigo, 36310 Vigo, Spain

Abstract

New experimental densities and surface tensions for *n*-nonane + 1-hexanol at 288.15, 298.15 and 308.15 K are reported. Densities were measured with an Anton Paar DMA 4500 densimeter, and surface tensions using a Lauda TVT2 automated tensiometer, which uses the principle of the pending drop volume. The experimental data of pure liquids and mixtures have been used to calculate excess molar volumes and surface tension deviations of *n*-nonane + 1-hexanol as a function of mole fractions. A comparative study of these properties together with those available in the literature for the *n*-alkane + 1-alkanol mixtures has been performed. In addition, the magnitude of these experimental quantities is discussed in terms of the nature and type of intermolecular interactions in binary mixtures.
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1. Introduction

The understanding of physical properties such as density or surface tension is of great utility for both fundamental research and engineering applications in the industry. Systematic investigations of intermolecular interactions and the internal structures of mixed binary liquid mixtures continue to be an area of interest in physical chemistry. For the structural studies, a review of the literature shows that for the analysis of this type of effect in liquid solvent mixtures it is possible to apply a wide range of spectral methods, thermochemical methods, as well as studies on intensive macroscopic properties of solutions (density, viscosity, surface tension, etc.) carried out at different temperatures. Thus, using this last method, the accurate measurement of experimental data of physical properties in mixtures of organic liquids is required for a better understanding of their thermodynamic behavior. Furthermore, in recent years, interest in surface tension and interfacial tension has increased a lot because this property plays an important role in the design of contacting equipment involved in several chemical processes, as for instance gas absorption distillation, extraction, etc.

Over the last years our research group has conducted a systematic study of the thermophysical properties of hydrogen bonded systems [1–9] with *n*-alkanes. In this work experimental density and surface tension data of *n*-nonane + 1-hexanol mixture at 288.15, 298.15 and 308.15 K and atmospheric pressure are reported. Up to our knowledge no data of density and surface tension are available in literature for this system. In addition, excess molar volumes and deviations of surface tension were calculated.

2. Experimental

2.1. Materials and methods

n-Nonane and 1-hexanol were supplied by Fluka. Their mole fraction purities were: >0.98% for *n*-nonane and >0.99% for 1-hexanol. Both chemicals were degassed and dried over molecular sieves (Union Carbide, type 0.4 nm). Precautions such as cooling chemicals before sample preparation and minimizing empty space in vessels were taken in order to avoid evaporation losses during manipulations and subsequent errors in calculations.

The samples were prepared by mass using a Mettler AE-240 balance, with a precision of 10^{-4} in mole fraction, covering

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* Corresponding author. Tel.: +34 986812295; fax: +34 986812295.
 E-mail address: xllegido@uvigo.es (J.L. Legido).

the whole composition range of the mixture. Densities of the pure liquids and their mixtures were measured with an Anton Paar DMA 4500 vibrating tube densimeter. The accuracy of this densimeter is 5×10^{-5} g cm^{-3}. The density measuring cell is thermostated with a temperature stability of 0.01 K. The apparatus calibration was performed periodically. Water and air were used for calibration.

Excess molar volumes were determined from the density data as follows:

$$V_m^E = \frac{M}{\rho} - x_1 \frac{M_1}{\rho_1} - x_2 \frac{M_2}{\rho_2} \qquad (1)$$

where M and M_i are the molar masses of the mixture and component i, respectively; ρ and ρ_i are the densities of the mixture and component i; x_i is the mole fraction of the component i.

Surface tension (σ) was measured using a Lauda TVT2 automated tensiometer with a precision of 10^{-2} mN m^{-1}, which is based on the principle of the pending drop volume. This technique consists of measuring the volume of a drop detaching from a capillar with circular cross-section. The surface tension can be determined as follows:

$$\sigma = \frac{\Delta \rho g V}{2\pi r_{cap} f(r_{cap}/a)} \qquad a = \left(\frac{2\sigma}{\Delta \rho g}\right)^{1/2} \qquad (2)$$

where $\Delta \rho$ stands for the density difference between liquid and vapour phase, g is the gravitational acceleration, V is the drop volume, $2r_{cap}$ is the outer diameter of the capillary and f is a correction function.

The surface tension deviations ($\Delta \sigma$) were calculated by:

$$\Delta \sigma = \sigma - x_1 \sigma_1 - x_2 \sigma_2 \qquad (3)$$

where σ and σ_i are the surface tensions of the mixture and the component i, and x_i is the mole fraction of the component i.

3. Results and discussion

3.1. Density and surface tension

The measured density and surface tension of the pure liquids (n-nonane and 1-hexanol) at 288.15, 298.15 and 308.15 K are

Table 2
Experimental densities, ρ (g cm^{-3}), of x n-nonane + $(1-x)$ 1-hexanol at several temperatures

x	ρ (g cm^{-3})		
	$T = 288.15$ K	$T = 298.15$ K	$T = 308.15$ K
0.0509	0.81513	0.80793	0.80064
0.1003	0.80846	0.80118	0.79382
0.2028	0.79535	0.78795	0.78043
0.3070	0.78301	0.77548	0.76786
0.4026	0.77251	0.76490	0.75719
0.5086	0.76175	0.75406	0.74628
0.6016	0.75302	0.74528	0.73744
0.7080	0.74374	0.73596	0.72809
0.8080	0.73570	0.72788	0.71998
0.9016	0.72872	0.72088	0.71297
0.9506	0.72526	0.71744	0.70952

Table 3
Experimental surface tension of x n-nonane + $(1-x)$ 1-hexanol at several temperatures

$T = 288.15$ K		$T = 298.15$ K		$T = 308.15$ K	
x	σ (mN m^{-1})	x	σ (mN m^{-1})	x	σ (mN m^{-1})
0.0500	25.77	0.0504	24.84	0.0511	23.81
0.1082	25.47	0.1004	24.54	0.1013	23.52
0.2075	25.06	0.2042	24.12	0.2059	23.08
0.3079	24.62	0.2998	23.69	0.3066	22.59
0.4075	24.31	0.3880	23.41	0.4040	22.27
0.5066	24.01	0.5011	23.07	0.5065	21.98
0.6024	23.81	0.6060	22.84	0.6028	21.77
0.7079	23.68	0.7086	22.66	0.7135	21.59
0.8081	23.57	0.8085	22.56	0.8059	21.47
0.9036	23.48	0.9007	22.48	0.9043	21.34
0.9554	23.44	0.9508	22.39	0.9519	21.27

listed in Table 1 together with those values found in the literature [10–20]. The agreement, within the experimental uncertainties for most values, ensures both the purity of the chemicals used and the experimental devices accuracy.

In Tables 2 and 3 experimental density and surface tension data of n-nonane + 1-hexanol at the temperatures cited are

Table 1
Surface tension and density of n-nonane and 1-hexanol at several temperatures

Compound	T (K)	ρ (g cm^{-3})		σ (mN m^{-1})	
		Experimental	Literature	Experimental	Literature
n-Nonane	288.15	0.72178		23.38	
	298.15	0.71402	0.71345 [10]	22.37	22.37 [11]
	308.15	0.70621		21.25	
1-Hexanol	288.15	0.82228		26.08	
	298.15	0.81523	0.81507 [12]	25.19	25.19 [15]
			0.81515 [13,14]		25.73 [13]
			0.81534 [10]		25.67 [16]
					25.69 [17]
					25.79 [12]
					25.81 [18,19]
					25.9 [15,20]
	308.15	0.80800		24.19	