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FT-IR studies and excess thermodynamic properties of binary liquid mixtures 2-(2-butoxyethoxy) ethanol with 1-hexanol, 1-octanol and 1-decanol at different temperatures

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A B S T R A C T

In continuation to our prior investigational studies on the interactions between binary mixtures of alkoxy alkanols and alcohols, here, we report the thermo-physical properties and spectra analysis of 2-(2-butoxyethoxy) ethanol with $CH_3(CH_2)_3OC_2H_4O(CH_2)_2OH$, viz., 1-hexanol $CH_3(CH_2)_5OH$, 1-octanol $CH_3(CH_2)_7OH$ and 1-decanol $CH_3(CH_2)_9OH$ over the entire composition range at T = (293.15, 298.15, 303.15, 308.15 and 313.15) K. The experimental data of densities and speeds of sound were used to calculate the values of excess functions and deviations in properties. The evaluated properties from experimental data have been construed in terms of the difference in the size of the molecule as well as the strength of specific and non-specific interactions between components of the mixture. The excess functions and their deviations have also been correlated using Redlich-Kister type polynomial equation by the method of least-squares for the estimation of the binary coefficients and the standard deviations. The FT-IR technique has been used to scrutinize the –OH interactions between the binary mixtures and inestimable to spot the influence on the structural variation in the alcohols.

1. Introduction

The binary liquid mixtures due to their unusual behaviour have been attracted considerable attention because they exhibit various phenomena that cannot be found in pure substance. Upon mixing the liquid mixtures might produce fascinating properties due to specific interaction, H-bond effects [1–3]. Thermo physical properties plays a significant role to study the molecular interactions and arrangements through the mixing deviation from ideality [4]. The dual functionality present in alkoxy alkanols make them account for their unique solvency properties [5–7]. 2-(2-Butoxyethoxy) ethanol is an important organic solvent with extensive use as additive for jet fuel to prevent ice build-up fixative for perfumes, germicides, bactericides, insects repellent and antiseptic [8–10]. Alcohols also play an important role in industry and laboratory as reagents and attract great attention as useful solvents in the green technology. The binary mixtures containing 2-(2-butoxyethanol) ethanol are interesting because they find applications in many biological, environmental and industrial fields [11–13]. The present work is a continuation of systematic studies on thermo physical and spectroscopic properties of binary liquid mixtures of alkoxy alkanols and alcohols.In an effort to make a comprehensive study, we measure the density ρ and speed of sound u for the binary liquid mixtures containing 2-(2-butoxyethoxy) ethanol with alcohols at temperatures of (293.15, 298.15, 303.15, 308.15 and 313.15) K over the entire composition range. The evaluated properties from experimental data have been construed in terms of the difference in the size of the molecule as well as the strength of specific and non-specific interactions between components of the mixture. Further, measurements of excess thermodynamic properties are found to be greatly significant in studying the structural changes associated with the liquids. They also provide important information about molecular packing, molecular motion, various types of intermolecular interactions and their strength influenced by the size, shape and the chemical nature of component molecules [14]. The excess functions and their deviations have also been correlated using Redlich-Kister type polynomial equation by the method of least-squares for the estimation of the binary coefficients and the standard deviations. The FT-IR technique has been used to scrutinize the –OH interactions between the binary mixtures and inestimable to spot the influence on the structural variation in the alcohols.

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2. Experimental

2.1. Materials

2-(2-Butoxyethoxy) ethanol was obtained from Sigma Aldrich, USA. All alcohols i.e. 1-hexanol (Analytical reagent grade), 1-octanol (Analytical reagent grade), 1-decanol (Laboratory reagent grade) were procured from SD Fine Chemicals, India. All the chemicals were fractionally distilled and dried over 0.4 nm molecular sieves. The provenance and mass fraction purities tested by gas chromatography were reported in Table 1. The purities of solvents were further ascertained by comparing their densities, speeds of sound and viscosities at different temperatures with values reported in the literature [15–25] as shown in Table 2 and also given in the Figures S1 and S2 of Supplementary information.

2.2. Methods

Each binary mixture were prepared by weighing appropriate amounts of 2-(2-butoxyethoxy) ethanol and each alcohol mentioned above on an A&D Company limited electronic balance (Japan, Model GR-202) electronic balance, with a precision of ±0.01 mg, by syringing each component into airtight narrow mouthed stoppered bottles to minimize evaporation losses. The pure components were separately degassed shortly before sample preparation. The probable error in mole fraction was estimated to be less than $\pm 1 \times 10^{-4}$.

2.3. Density and speed of sound measurements

Densities ρ and speeds of sound u were measured by using a digital vibrating tube density and speed of sound analyser

Table 1
Specification of chemical samples.

Chemical name	CAS No.	Provenance	Initial mass fraction purity	Purification method	Final mass fraction purity	Analysis method	Water content[*]/(mass%)
2-(2-butoxyethoxy) ethanol	112–34-5	Sigma Aldrich, USA	0.995	–	0.995	–	–
1-hexanol	111–27-3	S.D. Fine Chemicals, India	0.989	Distillation	0.995	GC[a]	0.043
1-octanol	111–87-5	S.D. Fine Chemicals, India	0.987	Distillation	0.998	GC[a]	0.027
1-decanol	112–30-1	S.D. Fine Chemicals, India	0.987	Distillation	0.995	GC[a]	0.031

[a] GC Gas Chromatography.
[*] By Karl Fischer titration (data provided by the supplier).

Table 2
Comparison of experimental values of density (ρ) and speed of sound (u) of pure liquids with the corresponding literature values at different temperatures (T) and at pressure p = 0.1 MPa.

Compound	T/K	ρx10^{-3}/(kg·m^{-3})		u/(m·s^{-1})	
		Exp.	Lit.	Exp.	Lit.
2-(2-Butoxyethoxy) ethanol	293.15	0.952288	0.9524[b]	1378.20	1374.28[d]
	298.15	0.947980	0.9481[c]	1361.31	1358.9[c]
	303.15	0.943909	0.9438[b]	1344.53	1339.95[d]
	308.15	0.939704	–	1326.36	–
	313.15	0.935503	0.9355[d]	1307.74	–
1-Hexanol	293.15	0.819239[a]	0.81874[e]	1320.38[a]	1319.37[e]
	298.15	0.815652[a]	0.81565[f]	1303.54[a]	1303.3[l]
	303.15	0.812043[a]	0.8120[g]	1286.68[a]	1285.46[e]
	308.15	0.808402[a]	0.8085[g]	1270.00[a]	1268.46[e]
	313.15	0.804743[a]	0.8049[g]	1253.54[a]	1251.83[e]
1-Octanol	293.15	0.825337[a]	0.82512[e]	1364.08[a]	1364.23[e]
	298.15	0.821877[a]	0.82187[h]	1347.32[a]	1347.24[e]
	303.15	0.818400[a]	0.8183[g]	1330.99[a]	1330.29[e]
	308.15	0.814903[a]	0.8149[g]	1314.28[a]	1313.50[e]
	313.15	0.811385[a]	0.8115[g]	1297.72[a]	1296.46[e]
1-Decanol	293.15	0.829898[a]	0.82975[i]	1396.65[a]	1397.23[i]
	298.15	0.826489[a]	0.82647[j]	1379.43[a]	1379.96[i]
	303.15	0.823069[a]	0.8231[g]	1362.40[a]	1362.82[i]
	308.15	0.819635[a]	0.8192[g]	1345.62[a]	1345.62[i]
	313.15	0.816188[a]	0.8160[k]	1329.07[a]	1329.03[i]

Standard uncertainties are u (T) = $\pm 1 \times 10^{-2}$ K, u (P) = ±2 kPa, u (x) = 1×10^{-4} and a combined expanded uncertainty (level of confidence = 0.95, k = 2) U (ρ) = 0.4 kg·m^{-3}, U (u) = ±2.4 m ·s^{-1}.
[a] Dubey et al. [15].
[b] Kang et al. [16].
[c] Pal et al. [17].
[d] Mozo et al. [5].
[e] Zorebski et al. [18].
[f] Pena et al. [19].
[g] Saleh et al. [20].
[h] Iloukhani et al. [21].
[i] Dziada et al. [22].
[j] Dubey et al. [23].
[k] Marks et al. [24].
[l] Lobe et al. [25].