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Viscous synergy and isentropic compressibility of some monoalkanols and cyclic ethers in water at 298.15 K

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Abstract

Pure or aqueous alcohols are most widely used in industry, including in the manufacture of pharmaceuticals and cosmetic products. However, in the case of insolubility of some solutes in water, non-water solvents may be used possessing the common characteristic of being soluble in water; as a result, such solvents may be used with different purposes, such as increasing water solubility, or modifying the viscosity or absorption of the dissolved substance. Also, the nature of intermolecular forces between the solvents brings a marked effect on the thermodynamic properties such as density, viscosity and surface tension etc. The present study investigates viscous synergy and isentropic compressibility in the systems comprising some monoalkanols (C_1–C_4) and cyclic ethers (1,4-dioxane and tetrahydrofuran) in the proportion $w/w=1{:}1$, in water at different concentrations (w/w) at 298.15 K to determine the proportion of monoalkanol + cyclic ether + water, at which maximum synergy occurs. The density and viscosity data have been analyzed using the equation developed by Kaletunc–Gencer and Peleg. Also a correlation between the density and viscosity increment for all the systems has been attempted. The ratio between maximum viscosity reached by the mixtures and pure state viscosity is expressed by the enhancement index defined as $E_n=\eta_{max}/\eta_0$.

Keywords: Viscous synergy; Isentropic compressibility; 1,4-dioxane; Tetrahydrofuran

1. Introduction

The increasing use of cyclic ether, monoalkanols and their aqueous mixtures in many industrial processes such as pharmaceutical and cosmetics has greatly stimulated the need for extensive information on their properties. 1,4-dioxane (DO), tetrahydrofuran (THF) and their aqueous mixtures are very important solvents that are widely used in various industries. They figure prominently in the high-energy battery technology and have also found application in organic synthesis as manifested from the physico-chemical studies in these media [1–7]. The thermodynamic properties of various alkanols have been studied in numerous solvents [8–14]. In our systematic study of the thermodynamic properties, we have reported densities, viscosities and speeds of sound of different solvents and their mixtures in the previous papers [15–22] from our laboratory. In this paper we extend our studies to the aqueous mixtures of 1,4-dioxane (DO) and tetrahydrofuran (THF) with some monoalkanols where water is represented as A, cyclic ether (DO or THF) is represented as B, and monoalkanol, represented as C. The monoalkanols include methanol (MeOH),

Table 1
Comparison of density, $\rho\times10^3$/kg m^{-3} and viscosity, η of the pure liquids with literature data at 298.15 K

Solvent	$\rho\times10^3$/kg m^{-3}		η/mPa s	
	Expt.	Lit.	Expt.	Lit.
Water	0.9971	0.9971 [25]	0.8904	0.8904 [25]
Tetrahydrofuran	0.8807	0.8807 [15]	0.4630	0.4630 [15]
1,4-Dioxane	1.0305	1.0305 [26]	1.2000	1.2000 [26]
Methanol	0.7869	0.7869 [12]	0.5470	0.5470 [12]
Ethanol	0.7850	0.7850 [12]	1.0760	1.0760 [12]
1-Propanol	0.8025	0.8025 [12]	1.9460	1.9460 [12]
2-Propanol	0.7825	0.7825 [12]	2.0314	2.0314 [12]
1-Butanol	0.8060	0.8060 [12]	2.5420	2.5420 [12]
2-Butanol	0.8035	0.8035 [12]	2.8230	2.8230 [12]

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Table 2
Comparison of the theoretical and experimental viscosities for the indicated water-soluble mixtures of tetrahydrofuran (THF), 1,4-dioxane (DO) and different monoalkanols as a function of (*w*/*w*) concentration

Mass % of H_2O	Pure THF		THF + MeOH ($w/w = 1:1$)		THF + EtOH ($w/w = 1:1$)		THF + 1-PrOH ($w/w = 1:1$)	
	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s
0	0.4630	0.4630	0.5050	0.4761	0.7695	0.6728	1.2045	0.7603
10	0.5057	0.6564	0.5435	0.7377	0.7816	1.0009	1.1731	1.1857
20	0.5485	0.9237	0.5821	1.0404	0.7937	1.3311	1.1417	1.5186
30	0.5912	1.2238	0.6206	1.3114	0.8058	1.6325	1.1103	1.8789
35	0.6126	1.3994	0.6399	1.4428	0.8118	1.7806	1.0946	1.9117
40	0.6340	1.4904	0.6596	1.5381	0.8179	1.8862	1.0789	2.0208
45	0.6553	1.5817	0.6784	1.6474	0.8239	1.9729	1.0632	2.0917
50	0.6767	1.6776	0.6977	1.7686	0.8299	2.0332	1.0475	2.1581
55	0.6981	1.7013	0.7169	1.7698	0.8360	2.0907	1.0317	2.2296
60	0.7199	1.7321	0.7362	1.7852	0.8420	2.0152	1.0160	2.1679
70	0.7622	1.6798	0.7748	1.7787	0.8541	1.8765	0.9846	2.0124
80	0.8049	1.4900	0.8133	1.5651	0.8662	1.6345	0.9532	1.6478
90	0.8477	1.2015	0.8519	1.2485	0.8783	1.2372	0.9218	1.2592
100	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904
Mass % of H_2O			THF + 2-PrOH ($w/w = 1:1$)		THF + 1-BuOH ($w/w = 1:1$)		THF + 2-BuOH ($w/w = 1:1$)	
			η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s
0			1.2472	0.6917	1.5025	0.8514	1.6430	0.8021
10			1.2115	1.1171	1.4413	1.2586	1.5677	1.2436
20			1.1758	1.4952	1.3801	1.6069	1.4925	1.6700
30			1.1402	1.8652	1.3189	1.9206		
35			1.1223	2.0303	1.2883	2.1404		
40			1.1045	2.1759	1.2577	2.1910		
45			1.0866	2.2524				
50			1.0688	2.2905				
55			1.0509	2.3370				
60			1.0331	2.2876				
70			0.9974	2.1204			1.1162	2.0884
80			0.9618	1.7880			1.0409	1.7427
90			0.9261	1.3276	0.9516	1.3354	0.9657	1.3178
100			0.8904	0.8904	0.8904	0.8904	0.8904	0.8904
Mass % of H_2O	Pure DO		DO + MeOH ($w/w = 1:1$)		DO + EtOH ($w/w = 1:1$)		DO + 1-PrOH ($w/w = 1:1$)	
	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s	η_{mix}/mPa s	η_{exp}/mPa s
0	1.2000	1.2000	0.8735	0.6148	1.1380	0.9243	1.5730	1.1309
10	1.1690	1.4419	0.8752	0.9069	1.1132	1.3182	1.5047	1.6458
20	1.1381	1.7859	0.8769	1.2053	1.0885	1.7779	1.4365	2.0743
30	1.1071	1.9762	0.8786	1.4429	1.0637	2.0719	1.3682	2.3439
35	1.0916	2.0230	0.8794	1.5471	1.0513	2.1364	1.3341	2.3963
40	1.0762	1.9871	0.8803	1.6171	1.0389	2.1975	1.2999	2.4199
45	1.0607	1.9577	0.8811	1.6712	1.0266	2.2388	1.2658	2.4286
50	1.0452	1.9139	0.8819	1.7057	1.0142	2.2636	1.2317	2.4468
55	1.0297	1.8346	0.8828	1.6971	1.0018	2.2029	1.1976	2.3527
60	1.0142	1.6970	0.8836	1.6349	0.9894	2.1110	1.1634	2.2553
70	0.9833	1.5181	0.8853	1.5233	0.9647	1.8947	1.0952	2.0141
80	0.9523	1.2967	0.8870	1.3352	0.9399	1.5610	1.0269	1.6868
90	0.9214	1.0949	0.8887	1.1766	0.9153	1.2005	0.9587	1.2584
100	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904	0.8904
Mass % of H_2O	DO + 2-PrOH ($w/w = 1:1$)		DO + 1-BuOH ($w/w = 1:1$)		Do + 2-BuOH ($w/w = 1:1$)		DO + THF ($w/w = 1:1$)	
0	1.6157	1.0778	1.8710	1.2715	2.0115	1.1333	0.8315	0.6797
10	1.5432	1.6710	1.7729	1.7840	1.8994	1.8135	0.8374	0.9285
20	1.4706	2.2000	1.6749	2.1742	1.7873	3.0482	0.8433	1.2432
30	1.3981	2.5134	1.5768	2.2031			0.8492	1.5476
35	1.3618	2.5920	1.5278	2.2643			0.8521	1.6815
40	1.3256	2.6547	1.4788	2.4169			0.8551	1.7972
45	1.2893	2.6967					0.8580	1.8754
50	1.2530	2.6892					0.8609	1.8939
55	1.2168	2.6212					0.8639	1.9094