Densities and Viscosities for Binary Mixtures of Benzonitrile with Methanol, Ethanol, Propan-1-ol, Butan-1-ol, Pentan-1-ol, and 2-Methylpropan-2-ol at (303.15, 308.15, and 313.15) K

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Experimental results of density and viscosity measurements at (303.15, 308.15, and 313.15) K of binary mixtures of benzonitrile with methanol, ethanol, propan-1-ol, butan-1-ol, pentan-1-ol, and 2-methylpropan-2-ol are presented over the whole range of composition. From these data, excess molar volumes V^E and deviations in viscosity $\Delta\eta$ have been computed. These quantities are fitted to a Redlich−Kister-type polynomial equation to derive the binary coefficients.

Introduction

Mixing properties such as excess molar volume, deviation in viscosity, and excess enthalpy have been used as a qualitative and quantitative guide to understand the molecular interactions between the components of the mixture and to carry out engineering applications in the process industry (Marsh, 1985; Aminabhavi et al., 1991; Francesconi and Comelli, 1996; Mather et al., 1997, 1999; Gmehling, 1993).

A perusal of the literature reveals that the thermodynamic studies on the binary mixture containing benzonitrile (most commonly used in pharmaceutical chemistry) are scant (Gmehling, 1999). Karunakar et al. (1982) reported experimental excess molar volume data of benzonitrile + alkanol (C_3−C_5) binary mixtures at 308.15 K. However, no viscosity data of these systems are available in the literature. Therefore, in the present paper we report density and viscosity data for the six binary systems formed by methanol, ethanol, propan-1-ol, butan-1-ol, pentan-1-ol, and 2-methylpropan-2-ol with benzonitrile at atmospheric pressure over the entire composition range at the temperatures (303.15, 308.15, and 313.15) K. These results are used to calculate excess volumes and deviations in viscosity.

Experimental Section

Benzonitrile (Merk Schuchrdt, purity >99%) was dried over anhydrous calcium chloride for 2 days and distilled at atmospheric pressure (Karunakar et al., 1982). Ethanol was refluxed over calcium oxide for 5 h and distilled subsequently at atmospheric pressure. The procedure was repeated two or three times (Riddick et al., 1986). Methanol (Quilignens Fine Chem, purity 99%), propan-1-ol (E. Merck, purity 99.5%), butan-1-ol (s. d. fine chem, purity 99%), and 2-methylpropan-2-ol (s. d. fine chem, purity 99.2%) were used after single distillation. The purity of the solvents after purification was ascertained by GLC and also by comparing their densities and viscosities with the corresponding literature values at 303.15 K (Table 1). Binary mixtures were prepared by mass in airtight stoppered glass bottles with a precision of 0.01 mg, and care was taken to avoid evaporation and contamination during the mixing process. The estimated error in the mole fraction is $<1 \times 10^{-4}$.

Densities of air bubble free pure liquids and binary mixtures were measured with the help of a bicapillary pycnometer having a bulb volume of 15 cm^3 and a capillary bore with an internal diameter of 1 mm, in a glass, transparent-walled water bath having a thermal stability of ±0.01 K (Nikam and Sawant, 1997, 1998). The pycnometer was calibrated by using water with conductivity $<1 \times 10^{-6}$ (Marsh, 1987). The density values were reproducible within $\pm 5 \times 10^{-5}$ g·cm^{-3}.

The dynamic viscosities were measured using an Ubbelohde suspended-level viscometer, calibrated with water (Marsh, 1987). An electronic digital stop watch with a readability of ±0.01 s was used for the flow time measurements. At least three repetitions of each data measurement reproducible to ±0.05 s were obtained, and the results were averaged. Since all flow times were >200 s and the capillary radius (0.5 mm) was far less than its length (50−60 mm), the kinetic energy and end corrections, respectively, were found to be negligible. The dynamic viscosity η of the liquids was calculated by

$$\eta/\eta_0 = (\rho t)/(\rho_0 t_0) \quad (1)$$

where ρ, ρ_0 and t, t_0 refer to the densities and flow times of the experimental liquids and water, respectively. The values of the dynamic viscosities η thus obtained are reproducible to ±0.003 mPa·s. The other experimental details of the measurements of density and viscosity are the same as those described previously (Nikam et al., 1998a,b).

Results and Discussion

The experimental values of the densities ρ and the viscosities η of the different binary mixtures at (303.15, 308.15, and 313.15) K are listed as a function of mole fraction of benzonitrile in Table 2. ρ values have been used to calculate the excess molar volumes V^E using the following equation

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Table 1. Comparison of Experimental Densities ρ and Viscosities η of Pure Liquids with Literature Values along with Deviations δ at 303.15 K

	ρ/(g·cm^{-3})				η/(mPa·s)			
liquid	expt	lit.		δ (%)	expt	lit.		δ (%)
benzonitrile	0.995 44	0.996 28[a]		0.08	1.148	1.161[a]		1.13
methanol	0.781 62	0.781 60[d]	0.781 70[a]	0.00	0.514	0.5146[a]	0.515[c]	0.12
ethanol	0.780 58	0.780 64[a]	0.780 5[d]	0.01	0.965	0.976[g]	0.987[a,c]	1.45
propan-1-ol	0.795 40	0.795 60[a]	0.795 48[c]	0.01	1.705	1.705[d]	1.725[a]	0.00
butan-1-ol	0.802 40	0.802 20[a]	0.802 01[c]	0.25	2.246	2.262[b]		0.71
pentan-1-ol	0.806 79	0.807 2[a]	0.806 8[f]	0.00	2.973	2.909[a]	2.961[f]	0.40
2-methylpropan-2-ol	0.775 02	0.775 46[a]	0.775 51[c]	0.06	3.359	3.378[a]	3.318[e]	0.56

[a] Riddick et al. (1986). [b] TRC Tables (1996). [c] Nikam et al. (1998a). [d] Zielkiewicz (1998). [e] Venkatesu and Rao (1996). [f] Nikam et al. (1998b). [g] Aminabhavi et al. (1993).

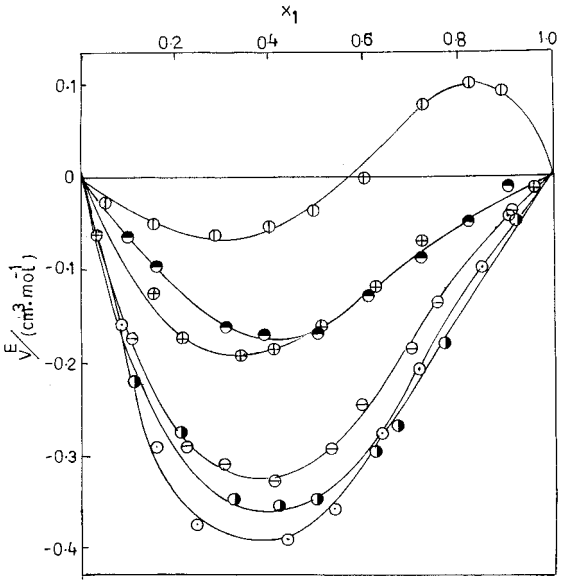

Figure 1. Excess molar volumes V^E at 303.15 K for (x_1)-benzonitrile + (1 − x_1)alkanols: (⊙) methanol; (◑) ethanol; (⊖) propan-1-ol; (⊕) butan-1-ol; (◓) pentan-1-ol; (⊕) 2-methylpropan-2-ol.

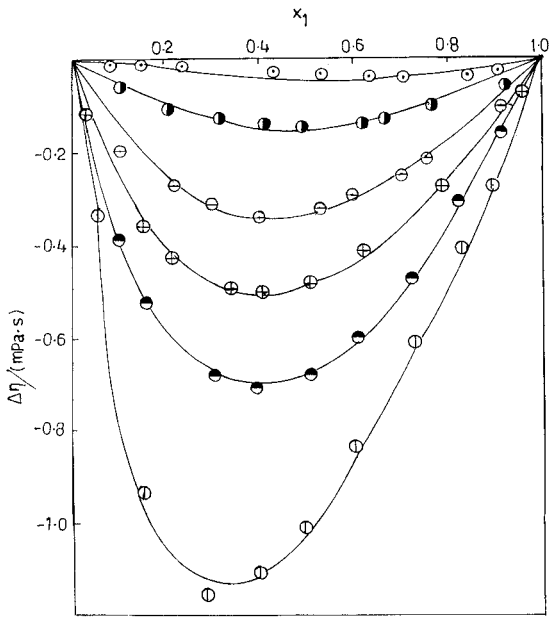

Figure 2. $\Delta\eta$ values at 303.15 K for (x_1)benzonitrile + (1 − x_1)-alkanols: (⊙) methanol; (◑) ethanol; (⊖) propan-1-ol; (⊕) butan-1-ol; (◓) pentan-1-ol; (⊕) 2-methylpropan-2-ol.

$$V^E = (x_1M_1 + x_2M_2)/\rho_{12} - (x_1M_1/\rho_1) - (x_2M_2/\rho_2) \quad (2)$$

where ρ_{12} is the density of the mixture and x_1, M_1, ρ_1 and x_2, M_2, ρ_2 are the mole fraction, molecular weight, and density of pure components 1 and 2, respectively. The viscosity deviations $\Delta\eta$ are obtained by

$$\Delta\eta = \eta_{mix} - x_1\eta_1 - x_2\eta_2 \quad (3)$$

where η_{mix} is the viscosity of the mixture and x_1, x_2 and η_1, η_2 are the mole fraction and viscosity of pure components 1 and 2, respectively. The estimated uncertainties are ±0.002 cm^3·mol^{-1} for V^E and ±0.0005 mPa·s for $\Delta\eta$.

The mixing functions V^E and $\Delta\eta$ are fitted to the Redlich−Kister equation (Redlich and Kister, 1948):

$$Y = x_1x_2\sum a_i(x_1 - x_2)^i \quad (4)$$

where Y refers to V^E/cm^3·mol^{-1} or $\Delta\eta$/mPa·s and x_1 and x_2 are the mole fractions of benzonitrile and alkanol, respectively. The variables a_i are the coefficients which were obtained by fitting the equation to the experimental results with a computerized least-squares regression method. The calculated results are given in Table 3, in which the tabulated standard deviation σ was defined as

$$\sigma = [\sum(Y_{exp} - Y_{cal})^2/(n - m)]^{1/2} \quad (5)$$

where n is the number of data points and m is the number of coefficients.

The variations of V^E and $\Delta\eta$ with the mole fraction of benzonitrile (x_1) for the six systems at 303.15 K are presented in Figures 1 and 2, respectively.

The values of V^E are negative for mixtures of benzonitrile with all the alkanols, except for 2-methylpropan-2-ol. Treszczanowicz et al. (1981) suggested that V^E is resultant of several opposing effects. In the present binary systems of benzonitrile with *n*-alkanols, the negative V^E can be attributed to interactions between unlike molecules through H-bonding. The increase in V^E with increasing chain length of alkanols implies that dipole−dipole interactions are weak in higher alkanols owing to their decrease in polarizability with increasing chain length (Mecke, 1950). Higher V^E values for the benzonitrile + 2-methylpropan-2-ol system may be attributed to steric hindrance due to branching of the alkyl group.

At equimolar concentrations, V^E values at 308.15 K for benzonitrile + propan-1-ol, + butan-1-ol, and + pentan-1-ol (−0.279, −0.141, and −0.150 cm^3·mol^{-1}) agree well with those (−0.232, −0.169, and −0.137 cm^3·mol^{-1}) reported by Karunakar et al. (1982).

The effect of temperature on V^E is not the same in all the cases; that is, with benzonitrile + methanol and +

Table 2. Densities ρ, Viscosities η, and Excess Molar Volumes V^E for Benzonitrile (1) + Alkanols (2) at T = (303.15, 308.15, and 313.15) K

x_1	$10^{-3}\rho$/ (kg·m^{-3})	V^E/ (cm^3·mol^{-1})	η/ (mPa·s)	x_1	$10^{-3}\rho$/ (kg·m^{-3})	V^E/ (cm^3·mol^{-1})	η/ (mPa·s)	x_1	$10^{-3}\rho$/ (kg·m^{-3})	V^E/ (cm^3·mol^{-1})	η/ (mPa·s)
Benzonitrile (1) + Methanol (2)											
303.15 K											
0.0000	0.781 62		0.514	0.4349	0.928 19	−0.394	0.763	0.8439	0.981 89	−0.099	1.011
0.0854	0.825 30	−0.160	0.562	0.5335	0.945 05	−0.360	0.820	0.9059	0.987 43	−0.043	1.061
0.1569	0.854 92	−0.292	0.603	0.6304	0.958 46	−0.276	0.875	1.0000	0.995 44		1.148
0.2408	0.882 70	−0.378	0.652	0.7155	0.968 75	−0.211	0.926				
308.15 K											
0.0000	0.776 89		0.480	0.4349	0.923 57	−0.401	0.709	0.8439	0.977 43	−0.109	0.938
0.0854	0.820 69	−0.170	0.525	0.5335	0.940 49	−0.370	0.761	0.9059	0.983 01	−0.055	0.985
0.1569	0.850 27	−0.300	0.562	0.6304	0.953 92	−0.284	0.811	1.0000	0.990 92		1.063
0.2408	0.877 99	−0.382	0.608	0.7155	0.964 34	−0.228	0.859				
Benzonitrile (1) + Ethanol (2)											
303.15 K											
0.0000	0.780 58		0.965	0.4131	0.903 49	−0.357	0.901	0.7690	0.965 93	−0.182	1.006
0.1051	0.820 17	−0.223	0.923	0.4921	0.919 85	−0.349	0.912	0.9218	0.986 04	−0.051	1.075
0.2045	0.850 85	−0.278	0.891	0.6214	0.943 34	−0.300	0.938	1.0000	0.995 44		1.148
0.3213	0.882 31	−0.351	0.897	0.6673	0.950 82	−0.272	0.963				
308.15 K											
0.0000	0.776 15		0.881	0.4131	0.898 78	−0.346	0.834	0.7690	0.961 29	−0.174	0.935
0.1051	0.815 58	−0.217	0.846	0.4921	0.915 12	−0.336	0.849	0.9218	0.981 45	−0.045	1.005
0.2045	0.846 20	−0.269	0.817	0.6214	0.938 65	−0.289	0.873	1.0000	0.990 92		1.063
0.3213	0.877 55	−0.335	0.826	0.6673	0.946 12	−0.260	0.893				
313.15 K											
0.0000	0.771 71		0.805	0.4131	0.894 06	−0.335	0.772	0.7690	0.956 61	−0.163	0.870
0.1051	0.811 00	−0.211	0.775	0.4921	0.910 45	−0.330	0.785	0.9218	0.976 86	−0.041	0.939
0.2045	0.841 56	−0.262	0.750	0.6214	0.933 95	−0.279	0.813	1.0000	0.986 38		0.993
0.3213	0.872 92	−0.331	0.762	0.6673	0.941 42	−0.249	0.828				
Benzonitrile (1) + Propan-1-ol (2)											
303.15 K											
0.0000	0.795 40		1.705	0.4082	0.896 02	−0.329	1.138	0.7547	0.958 47	−0.138	1.071
0.1072	0.825 50	−0.174	1.447	0.5248	0.918 86	−0.293	1.096	0.9108	0.982 50	−0.041	1.094
0.2174	0.853 61	−0.290	1.310	0.5951	0.931 58	−0.246	1.079	1.0000	0.995 44		1.148
0.2995	0.872 55	−0.310	1.222	0.6992	0.949 53	−0.187	1.066				
308.15 K											
0.0000	0.791 30		1.526	0.4082	0.891 42	−0.307	1.037	0.7547	0.953 91	−0.129	0.991
0.1072	0.821 20	−0.163	1.308	0.5248	0.914 23	−0.272	1.006	0.9108	0.977 92	−0.033	1.018
0.2174	0.849 16	−0.273	1.190	0.5951	0.927 04	−0.236	0.994	1.0000	0.990 92		1.063
0.2995	0.868 01	−0.289	1.113	0.6992	0.944 90	−0.170	0.986				
313.15 K											
0.0000	0.787 10		1.372	0.4082	0.886 85	−0.293	0.955	0.7547	0.949 23	−0.111	0.919
0.1072	0.816 66	−0.138	1.187	0.5248	0.909 65	−0.260	0.930	0.9108	0.973 28	−0.021	0.951
0.2174	0.844 50	−0.243	1.082	0.5951	0.922 41	−0.221	0.918	1.0000	0.986 38		0.993
0.2995	0.863 41	−0.268	1.017	0.6992	0.940 28	−0.158	0.913				
Benzonitrile (1) + Butan-1-ol (2)											
303.15 K											
0.0000	0.802 40		2.246	0.3392	0.874 67	−0.192	1.382	0.7894	0.959 01	−0.070	1.108
0.0330	0.810 08	−0.065	2.094	0.4092	0.888 51	−0.187	1.300	0.9629	0.989 15	−0.013	1.119
0.1519	0.835 81	−0.126	1.716	0.5040	0.906 75	−0.166	1.213	1.0000	0.995 44		1.148
0.2155	0.849 43	−0.175	1.583	0.6218	0.928 69	−0.121	1.149				
308.15 K											
0.0000	0.798 50		1.982	0.3392	0.870 38	−0.177	1.245	0.7894	0.954 51	−0.060	1.021
0.0330	0.806 08	−0.057	1.844	0.4092	0.884 15	−0.170	1.186	0.9629	0.984 60	−0.008	1.040
0.1519	0.831 72	−0.119	1.534	0.5040	0.902 36	−0.152	1.108	1.0000	0.990 92		1.063
0.2155	0.845 22	−0.159	1.414	0.6218	0.924 26	−0.110	1.053				
313.15 K											
0.0000	0.794 47		1.764	0.3392	0.866 04	−0.167	1.140	0.7894	0.949 99	−0.055	0.945
0.0330	0.801 99	−0.053	1.660	0.4092	0.879 76	−0.159	1.080	0.9629	0.980 06	−0.006	0.978
0.1519	0.827 55	−0.115	1.378	0.5040	0.897 93	−0.142	1.020	1.0000	0.986 38		0.993
0.2155	0.840 93	−0.147	1.281	0.6218	0.919 80	−0.102	0.976				
Benzonitrile (1) + Pentan-1-ol (2)											
303.15 K											
0.0000	0.806 79		2.973	0.3870	0.878 85	−0.173	1.558	0.8200	0.960 43	−0.050	1.153
0.1034	0.825 88	−0.065	2.395	0.5033	0.900 65	−0.168	1.374	0.9162	0.978 92	−0.008	1.140
0.1623	0.836 82	−0.098	2.152	0.6086	0.920 32	−0.129	1.262	1.0000	0.995 44		1.148
0.3038	0.863 31	−0.163	1.737	0.7205	0.941 46	−0.089	1.182				

Table 2 (Continued)

x_1	$10^{-3}\rho$/(kg·m^{-3})	V^E/(cm^3·mol^{-1})	η/(mPa·s)	x_1	$10^{-3}\rho$/(kg·m^{-3})	V^E/(cm^3·mol^{-1})	η/(mPa·s)	x_1	$10^{-3}\rho$/(kg·m^{-3})	V^E/(cm^3·mol^{-1})	η/(mPa·s)
Benzonitrile (1) + Pentan-1-ol (2)											
308.15 K											
0.0000	0.803 02		2.592	0.3870	0.874 61	−0.152	1.406	0.8200	0.955 95	−0.039	1.079
0.1034	0.821 95	−0.055	2.116	0.5033	0.896 34	−0.150	1.244	0.9162	0.974 38	0.001	1.064
0.1623	0.832 81	−0.083	1.925	0.6086	0.915 98	−0.117	1.162	1.0000	0.990 92		1.063
0.3038	0.859 11	−0.139	1.565	0.7205	0.937 02	−0.075	1.097				
313.15											
0.0000	0.799 25		2.262	0.3870	0.870 37	−0.132	1.283	0.8200	0.951 46	−0.030	1.010
0.1034	0.818 03	−0.046	1.895	0.5033	0.892 04	−0.134	1.140	0.9162	0.969 88	0.003	0.993
0.1623	0.828 82	−0.071	1.723	0.6086	0.911 65	−0.107	1.070	1.0000	0.986 38		0.993
0.3038	0.854 92	−0.116	1.412	0.7205	0.932 66	−0.071	1.017				
Benzonitrile (1) + 2-Methylpropan-2-ol (2)											
303.15 K											
0.0000	0.775 02		3.359	0.3997	0.867 85	−0.054	1.365	0.8283	0.959 11	0.098	1.121
0.0567	0.788 93	−0.027	2.895	0.4923	0.888 27	−0.037	1.262	0.8923	0.972 48	0.091	1.114
0.1542	0.811 80	−0.051	2.017	0.5993	0.911 34	−0.003	1.203	1.0000	0.995 44		1.148
0.2837	0.841 72	−0.061	1.578	0.7289	0.938 40	0.076	1.142				
308.15 K											
0.0000	0.769 75		2.623	0.3997	0.862 95	−0.075	1.223	0.8283	0.954 51	0.088	1.034
0.0567	0.783 77	−0.039	2.311	0.4923	0.883 42	−0.056	1.137	0.8923	0.967 93	0.082	1.028
0.1542	0.806 71	−0.067	1.696	0.5993	0.906 56	−0.019	1.094	1.0000	0.990 92		1.063
0.2837	0.836 71	−0.078	1.368	0.7289	0.933 69	0.066	1.043				
313.15 K											
0.0000	0.764 48		2.014	0.3997	0.858 06	−0.099	1.072	0.8283	0.949 91	0.075	0.962
0.0567	0.778 60	−0.050	1.811	0.4923	0.878 54	−0.073	1.021	0.8923	0.963 37	0.072	0.951
0.1542	0.801 63	−0.085	1.429	0.5993	0.901 81	−0.041	1.001	1.0000	0.986 38		0.993
0.2837	0.831 76	−0.104	1.187	0.7289	0.929 03	0.049	0.980				

Table 3. Parameters and Standard Deviations σ of Eqs 3 and 4 for Benzonitrile + Alkanols

system		temp/K	a_0	a_1	a_2	a_3	σ
benzonitrile + methanol	V^E/(cm^3·mol^{-1})	303.15	−1.5342	1.2136	0.2872	−0.3812	0.0133
		308.15	−1.5563	1.1394	0.1462	−0.2787	0.0120
	$\Delta\eta$/(mPa·s)	303.15	−0.1236	−0.1403	−0.1155	−0.0162	0.008
		308.15	−0.1154	−0.1476	−0.0897	0.0219	0.0017
benzonitrile + ethanol	V^E/(cm^3·mol^{-1})	303.15	−1.3548	0.3682	−0.2881	0.9509	0.0151
		308.15	−1.3046	0.3447	−0.2603	1.0071	0.0145
		313.15	−1.2706	0.3828	−0.2160	0.9349	0.0147
	$\Delta\eta$/(mPa·s)	303.15	−0.5607	0.1164	−0.2329	−0.2939	0.0079
		308.15	−0.4956	0.1022	−0.1467	−0.1545	0.0061
		313.15	−0.4556	0.0784	−0.1286	−0.0974	0.0051
benzonitrile + propan-1-ol	V^E/(cm^3·mol^{-1})	303.15	−1.1985	0.8454	0.0320	−0.0326	0.0076
		308.15	−1.1261	0.7741	0.0751	0.0605	0.0064
		313.15	−1.0765	0.7412	0.3247	−0.0152	0.0058
	$\Delta\eta$/(mPa·s)	303.15	−1.2612	0.3604	−0.6093	0.2149	0.0109
		308.15	−1.1074	0.3138	−0.4398	0.1887	0.0097
		313.15	−0.9828	0.2596	−0.3570	0.1529	0.0062
benzonitrile + butan-1-ol	V^E/(cm^3·mol^{-1})	303.15	−0.6026	0.2223	−0.5672	0.7196	0.0261
		308.15	−0.5614	0.2455	−0.4173	0.6381	0.0202
		313.15	−0.5279	0.2439	−0.3644	0.6037	0.0176
	$\Delta\eta$/(mPa·s)	303.15	−1.8469	0.6678	−1.0253	0.2485	0.0163
		308.15	−1.5760	0.4338	−0.9662	0.5752	0.0171
		313.15	−1.4127	0.4828	−0.5075	0.2132	0.0027
benzonitrile + pentan-1-ol	V^E/(cm^3·mol^{-1})	303.15	−0.6708	0.3529	0.3797	−0.0209	0.0052
		308.15	−0.5980	0.2714	0.4350	0.1085	0.0045
		313.15	−0.5247	0.2187	0.3813	0.0735	0.0019
	$\Delta\eta$/(mPa·s)	303.15	−2.7104	1.0211	−0.7017	0.4583	0.0035
		308.15	−2.2117	0.8272	−0.4018	0.4074	0.0079
		313.15	−1.9125	0.7024	−0.0837	0.0489	0.0057
benzonitrile + 2-methylpropan-2-ol	V^E/(cm^3·mol^{-1})	303.15	−0.1247	0.6277	0.6301	0.4339	0.0065
		308.15	−0.1874	0.6424	0.5263	0.5046	0.0090
		313.15	−0.2718	0.6704	0.4403	0.5332	0.0095
	$\Delta\eta$/(mPa·s)	303.15	−4.1246	4.2276	−1.2966	−3.1342	0.0853
		308.15	−2.9416	2.9089	−0.7534	−2.3686	0.0623
		313.15	−1.9708	1.8971	−0.4993	−1.7556	0.0284

2-methylpropan-2-ol mixtures, the negative values of V^E increase with increasing temperature, whereas with benzonitrile + propan-1-ol, + butan-1-ol, and + pentan-1-ol mixtures, the negative values of V^E decrease with increasing temperature.

Figure 2 shows that the values of $\Delta\eta$ are negative in all systems and become more negative with an increase in chain length and branching of alkanols, suggesting a decrease in heteroassociation of molecules with an increase in molar mass of alkanols. The temperature dependence

Table 4. Excess Molar Volumes V^E and Deviations in Viscosity $\Delta\eta$ at Equimolar Concentrations at T = (303.15, 308.15, and 313.15) K

system	temp/K	V^E/(cm^3·mol^{-1})	$\Delta\eta$/(mPa·s)
benzonitrile + methanol	303.15	−0.384	−0.031
	308.15	−0.389	−0.029
benzonitrile + ethanol	303.15	−0.339	−0.140
	308.15	−0.326	−0.124
	313.15	−0.317	−0.114
benzonitrile + propan-1-ol	303.15	−0.299	−0.315
	308.15	−0.279	−0.277
	313.15	−0.269	−0.246
benzonitrile + butan-1-ol	303.15	−0.151	−0.462
	308.15	−0.141	−0.394
	313.15	−0.132	−0.353
benzonitrile + propan-1-ol	303.15	−0.168	−0.677
	308.15	−0.150	−0.553
	313.15	−0.131	−0.478
benzonitrile +	303.15	−0.031	−1.031
2-methylpropan-2-ol	308.15	−0.047	−0.735
	313.15	−0.068	−0.493

of V^E and $\Delta\eta$ at equimolar concentration of all the systems studied is included in Table 4.

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