Viscosity of a Series of 1,2-Alkanediols

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This paper presents the viscosity data for the series of 1,2-alkanediols, $H(CH_2)_{n-2}CH(OH)CH_2(OH)$, for $n = 3$ to 6, 8, 10, and 12. The results are compared with those obtained for 1,*n*-alkanediols.

Introduction

In a recent paper[1] we presented the results of the viscosity measurements performed for the series of 1,*n*-alkanediols, $HO(CH_2)_nOH$. With increasing length of the $(CH_2)_n$ chain, which separates the two OH groups in 1,*n*-alkanediols, one observes an increase of the viscosity of the compounds with some tendency of saturation for increasing number of *n*. It seems to be worthy of notice that an extrapolation of the experimental dependence $\eta(n)$ to $n =$ 1 points out a very low viscosity of methanediol, $HOCH_2$-OH, the compound known to be highly unstable in a pure state. Despite the fact that our data do not allow a reasonable estimation of methanediol viscosity, mainly because of the natural limit of possible changes of n ($\pm$1), it is quite possible that the above observation can be useful in understanding the methanediol instability.

This paper presents the viscosity data for 1,2-alkanediols, $H(CH_2)_{n-2}CH(OH)CH_2(OH)$. It will be interesting to compare the viscosity of this series of diols to the viscosity of 1,*n*-alkanediols.[1] An essential structural difference between 1,2- and 1,*n*-alkanediol molecules consists of a different distribution of the two OH groups with respect to the hydrocarbon chain. In a series of 1,2-alkanediols, two parts of the molecule, hydrophilic and hydrophobic, can be distinguished, and with an increase of the number of CH_2 groups, the two parts are more and more differentiated.

Experimental Section

The source and purity of studied compounds are given in Table 1.

The viscosity was measured with a Haake viscometer RV20 with the measuring system CV100. The system consists of a rotating vessel filled with the liquid under study and a cylindrical sensor of Mooney-Ewart type (M15), placed in the center of the vessel. The liquid gap was 0.5 mm. The liquids showed Newtonian behavior at the shear rates used (30 s^{-1} to 300 s^{-1}). The uncertainty of the viscosity determination was 1%. The temperature of the sample was controlled to within $\pm$0.1 °C.

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Table 1. Purities (in vol %) of 1,2-Alkanediols, $H(CH_2)_{n-2}CH(OH)CH_2(OH)$

n	name	formula	source	purity
3	1,2-propanediol	$H(CH_2)CH(OH)CH_2(OH)$	Fluka	≥99.5
4	1,2-butanediol	$H(CH_2)_2CH(OH)CH_2(OH)$	Fluka	>98
5	1,2-pentanediol	$H(CH_2)_3CH(OH)CH_2(OH)$	Fluka	>95
6	1,2-hexanediol	$H(CH_2)_4CH(OH)CH_2(OH)$	Merck	>98
8	1,2-octanediol	$H(CH_2)_6CH(OH)CH_2(OH)$	Aldrich	98
10	1,2-decanediol	$H(CH_2)_8CH(OH)CH_2(OH)$	Aldrich	98
12	1,2-dodecanediol	$H(CH_2)_{10}CH(OH)CH_2(OH)$	Merck	for synthesis

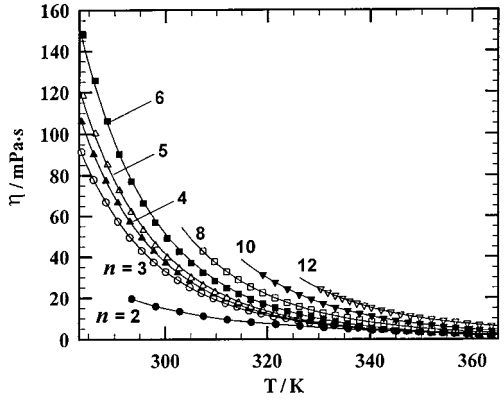

Figure 1. Temperature dependences of the viscosity of 1,2-alkanediols, $H(CH_2)_{n-2}CH(OH)CH_2(OH)$. The solid lines represent the best fit of eq 1 to the experimental values of the viscosity. The data for 1,2-ethanediol ($n = 2$) were taken from ref 1.

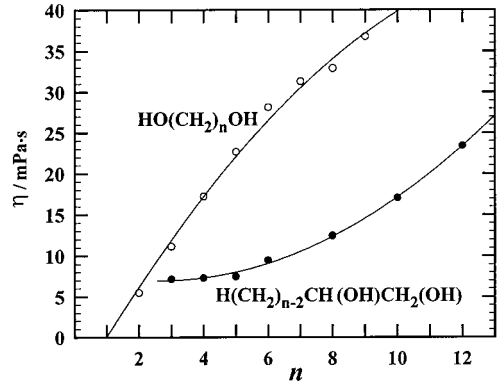

Figure 2. Comparison of the *n* dependence of the viscosity of 1,*n*-alkanediols and 1,2-alkanediols at $T = 331$ K.

Results and Discussion

The results of the viscosity measurements for 1,2-alkanediols are presented in Figure 1 and Table 2. The

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Table 2. Experimental Values of the Viscosity η of the Series 1,2-Alkanediols

T/K	η/mPa·s	T/K	η/mPa·s	T/K	η/mPa·s	T/K	η/mPa·s
			1,2-Propanediol				
283.6	91.41	304.8	25.17	325.9	8.92	347.1	3.73
286.0	77.91	307.1	22.22	328.3	8.05	349.4	3.39
288.3	66.89	309.5	19.71	330.6	7.29	351.8	3.13
290.7	57.39	311.8	17.45	333.0	6.60	354.2	2.85
293.0	49.52	314.2	15.54	335.3	6.01	356.5	2.60
295.4	42.94	316.5	13.86	337.7	5.45	358.9	2.38
297.7	37.33	318.9	12.39	340.0	4.95	361.2	2.16
300.1	32.60	321.2	11.09	342.4	4.51	363.6	1.98
302.4	28.60	323.6	9.95	344.7	4.10		
			1,2-Butanediol				
283.6	106.00	304.8	28.31	325.9	9.32	347.1	3.59
286.0	90.30	307.1	24.75	328.3	8.36	349.5	3.23
288.3	77.25	309.5	21.75	330.6	7.48	351.8	2.90
290.7	66.64	311.8	19.17	333.0	6.72	354.2	2.62
293.0	57.27	314.2	16.87	335.3	6.02	356.5	2.37
295.4	49.43	316.5	14.91	337.7	5.39	358.9	2.15
297.7	42.84	318.9	13.25	340.0	4.89	361.2	1.96
300.1	37.12	321.2	11.75	342.4	4.42	363.6	1.77
302.4	32.40	323.6	10.48	344.8	3.99		
			1,2-Pentanediol				
283.9	118.40	305.1	29.85	326.2	9.57	347.4	3.49
286.3	100.20	307.4	26.04	328.6	8.54	349.8	3.10
288.6	85.16	309.8	22.80	330.9	7.64	352.1	2.75
291.0	72.66	312.1	20.03	333.3	6.81	354.5	2.49
293.3	62.05	314.5	17.62	335.6	6.05	356.8	2.20
295.7	53.25	316.8	15.52	338.0	5.46	359.2	1.90
298.0	45.85	319.2	13.70	340.3	4.89	361.5	1.64
300.4	39.64	321.5	12.15	342.7	4.40	363.9	1.40
302.7	34.28	323.9	10.77	345.0	3.93		
			1,2-Hexanediol				
283.9	148.00	305.0	37.05	326.2	12.00	347.4	4.61
286.2	125.70	307.4	32.27	328.6	10.69	349.7	4.16
288.6	106.20	309.7	28.28	330.9	9.60	352.1	3.74
290.9	90.23	312.1	24.71	333.3	8.59	354.4	3.37
293.3	77.12	314.5	21.85	335.6	7.74	356.8	3.06
295.6	66.38	316.8	19.28	338.0	6.97	359.1	2.75
298.0	56.93	319.2	17.04	340.3	6.28	361.5	2.49
300.3	49.15	321.5	15.10	342.7	5.65	363.8	2.20
302.7	42.57	323.9	13.46	345.0	5.09		
			1,2-Octanediol				
307.4	42.97	321.5	19.90	335.6	10.20	349.7	5.45
309.7	37.61	323.8	17.68	337.9	9.15	352.0	4.92
312.1	32.69	326.2	15.73	340.3	8.25	354.4	4.44
314.4	28.78	328.5	14.06	342.6	7.46	356.8	3.99
316.8	25.35	330.9	12.64	345.0	6.72	359.1	3.60
319.1	22.44	333.2	11.33	347.3	6.06	361.5	3.25
			1,2-Decanediol				
319.1	31.20	330.9	17.08	342.6	10.02	354.4	6.07
321.5	27.53	333.2	15.33	345.0	9.05	356.8	5.49
323.8	24.20	335.6	13.73	347.4	8.15	359.1	4.98
326.2	21.48	337.9	12.35	349.7	7.36	361.5	4.52
328.5	19.29	340.3	11.07	352.1	6.71	363.8	4.10
			1,2-Dodecanediol				
330.3	24.23	337.4	17.21	345.9	11.90	356.7	8.32
331.8	22.50	338.8	16.23	347.8	11.15	359.0	7.60
333.2	21.00	340.2	15.19	349.6	10.35	361.4	6.94
334.6	19.59	342.1	13.95	352.0	9.60	363.7	6.40
336.0	18.34	344.0	12.91	354.3	8.90		

solid lines in the figure correspond to the best fitting of the Vogel−Tamman−Fulcher (VTF) equation[2,3]

$$\eta(T) = \eta_\infty \exp\left(\frac{DT_0}{T - T_0}\right) \tag{1}$$

to the experimental data. The values of the fit parameters η_∞, D, and T_0 are given in Table 3. The table also contains the standard deviation calculated from the equation

$$\sigma = \left(\frac{\sum_i (\eta_{\text{exp}} - \eta_{\text{calc}})^2}{n_\text{d} - n_\text{p}}\right)^{1/2} \tag{2}$$

where n_d and n_p denote the number of experimental points and the number of parameters, respectively.

Table 3. Values of the Parameters η_∞, D, and T_0 Corresponding to the Best Fitting of Eq 1 to the Viscosity Experimental Data for 1,2-Alkanediols, and the Standard Deviation σ (Eq 2)

n	η_∞/μPa·s	D	T_0/K	σ/mPa·s
3	0.584843	19.2944	108.517	0.087
4	0.018236	64.8356	54.931	0.066
5	0.024328	48.6399	68.262	0.155
6	0.126828	29.2874	91.686	0.138
8	0.078455	38.7073	78.212	0.108
10	0.083676	39.6957	77.934	0.070
12	0.197134	39.5665	75.326	0.078

Figure 2 shows the dependence of the viscosity (at 331 K) of 1,2-alkanediols and previously studied 1,*n*-alkanediols[1] on the length of hydrocarbon chain of the molecules. The two series of diols show quite different viscosity dependences on n. An especially interesting dependence is observed in the case of 1,*n*-alkanediols, where an extrapolation of $\eta(n)$ to $n = 1$ suggests a very small viscosity of methanediol. The results presented in Figures 1 and 2 suggest that 1,2-ethanediols, $HO(CH_2)_2OH$, which formally can be considered as a first member of the 1,2-alkanediol or 1,*n*-alkanediol series, from the viscosity point of view belong to the 1,*n*-alkanediol family.

Literature Cited

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