Speed of Sound and Ratio of Heat Capacity in 1-Nonanol, 1-Undecanol, and 1-Dodecanol

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The speed of sound has been measured in 1-nonanol, 1-undecanol, and 1-dodecanol in the temperature range 303.15–333.15 K. It was observed that the speed of sound in all the primary alcohols increases smoothly with the number of carbon atoms. The ratio of heat capacities C_p/C_v calculated for these alcohols decreases with an increase in the carbon number.

Introduction

Sound speed is one of those physical properties that are helpful in understanding the nature of the liquid state. The speed of sound is closely related to adiabatic compressibility, and through its determination, it is possible to evaluate the ratio of the heat capacities C_p/C_v. The speed of sound has been reported (*1, 2*) for various primary alcohols at one temperature and the temperature variation of sound speed has been studied in detail by Marks (*3*) in different alcohols. Due to the scanty data available for higher primary alcohols, this paper reports the speed of sound with temperature in 1-nonanol, 1-undecanol, and 1-dodecanol.

Experimental Section

The speed of sound was measured in the temperature range 303.15–333.15 K using a single-crystal variable-path interferometer operating at 1-MHz frequency to an accuracy of ±0.1% as established in our earlier paper (*4*).

Densities were determined with a 25 cm^3 specific gravity bottle that was calibrated with redistilled water at all temperatures, maintaining the temperature within ±0.1 K by using a MLW ultrathermostat U10, at 0.1 MPa, to an accuracy of ±0.05% as reported earlier (*2*). The measured densities and those reported in the literature are compared in Table I. All the chemicals used in these experiments were supplied by Aldrich with stated minimum purities of 99% in the case of 1-nonanol and 1-undeconol, and 98% purity for 1-dodeconol.

Results and Discussion

The Speed of sound (c) and densities (ρ) have been measured in three primary alcohols at different temperatures, and the results are presented in Table II. The speeds of sound obtained in the present investigation for the alcohols 1-nonanol and 1-dodecanol are 1385 and 1410 m/s, respectively, at 293.15 K. These values compare favorably with the literature (*2*) values 1391 and 1432 m/s, respectively, for the same alcohols at that specified temperature. Also in the case of 1-dodecanol the speed of sound at 303.15 K obtained as 1376 m/s is comparable with 1388 m/s as reported by Weissler (*1*). Using the relation for adiabatic compressibility $\beta_s = 1/\rho c^2$, the values were computed and presented in Table II. The isothermal compressibilities (β_t) at various temperatures have been interpolated from the available literature data (*5*) for computing the ratio of heat capacities $\gamma = \beta_t/\beta_s$. The γ values so determined have been presented in the last column of Table II.

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Table I. Densities of Pure Compounds at 333.15 K

	$\rho/(\text{g·cm}^{-3})$		
		literature	
component	present study	ref 5	ref 6
1-nonanol	0.8000	0.799 91	0.8010
1-undecanol	0.8051	0.804 95	0.8050
1-dodecanol	0.8061	0.806 06	0.8067

Table II. Speed of Sound and Ratio of Specific Heats in Three Primary Alcohols at Different Temperatures

T/K	$c/(\text{m·s}^{-1})$	$\rho/(\text{g·cm}^{-3})$	$\beta_{ad}/(\text{TPa}^{-1})$	C_p/C_v
		1-Nonanol		
303.15	1350	0.8208	668.4	1.14_9
313.15	1315	0.8140	710.4	1.15_1
323.15	1283	0.8069	752.8	1.15_7
333.15	1248	0.8000	802.5	1.15_0
		1-Undecanol		
303.15	1371	0.8258	644.2	1.15_3
313.15	1337	0.8188	683.2	1.14_7
323.15	1304	0.8120	724.2	1.14_6
333.15	1271	0.8051	768.8	1.14_4
		1-Dodecanol		
303.15	1376	0.8268	638.7	1.13_8
313.15	1342	0.8200	677.1	1.13_8
323.15	1309	0.8130	717.8	1.13_8
333.15	1275	0.8061	763.1	1.13_2

Table III. Comparison of the Speed of Sound in Primary Alcohols between Calculated and Experimental Values at 303.15 K

	$c/(\text{m·s}^{-1})$		
	exptl	calcd (eq 1)	$100(c_{exptl} - c_{calcd})/c_{exptl}$
methanol	1100.8[a]	1086.7	1.28
ethanol	1146.7[a]	1144.3	0.21
1-propanol	1189.5[a]	1191.9	−0.20
1-butanol	1225.8[a]	1231.3	−0.45
1-pentanol	1260.6[a]	1263.9	−0.26
1-hexanol	1286.5[a]	1290.9	−0.34
1-heptanol	1311.0[a]	1313.2	−0.17
1-octanol	1332.1[a]	1331.7	0.03
1-nonanol	1350.0[b]	1346.9	0.23
1-decanol	1363.3[a]	1359.5	0.28
1-undecanol	1371.0[b]	1370.0	0.07
1-dodecanol	1376.0[b]	1378.6	−0.19

[a] Reference 3. [b] Present study.

The speed of sound decreases linearly with an increase in temperature in all the alcohols studied. When the speeds of sound in the primary alcohols at 303.15 K were plotted against the carbon number, N, as shown in Figure 1, they were found to be a smooth function of the carbon number of the alcohols.

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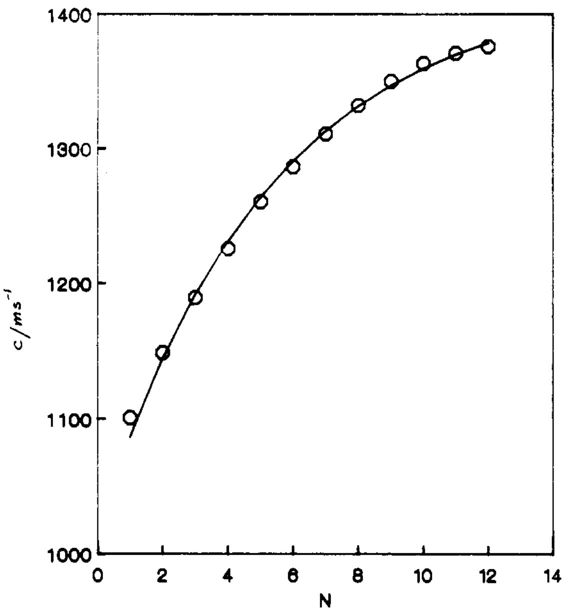

Figure 1. Variation of the speed of sound in primary alcohols at 303.15 K with carbon number N: (O) experimental, (—) calculated using eq 1.

This confirms that the speed of sound results obtained in the present study are consistent with those reported for other alcohols. The speed of sound at 303.15 K in all the primary alcohols can be fitted into the empirical equation by correlating N and by taking the logarthimic values of experimental c with a constant incorporated so as to minimize the absolute overall percent error and maximize the R^2 value for the regression carried out between the two. The value of R^2 is 0.9965, and the absolute overall percent error is 0.3. The empirical equation thus obtained can be written as

$$c/(\mathrm{m \cdot s^{-1}}) = 1420 - e^{5.99-0.189N} \qquad (1)$$

In Figure 1 the speed of sound values are compared with those calculated with eq 1. The calculated values are in good agreement with the experimental values, the average percent error being 0.3 for the 12 alcohols.

The γ values for the alcohols (Table II) are not sensitive to temperature. The variation of γ values with the carbon number is presented in Figure 2. In general the γ values decrease with an increase of the number of carbon atoms N.

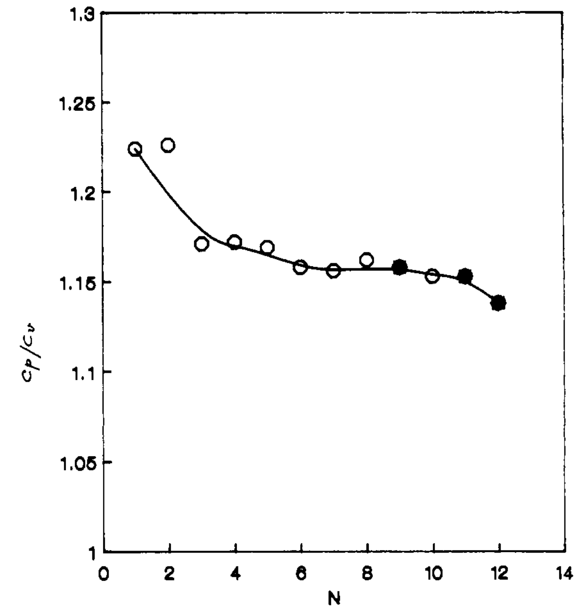

Figure 2. Variation of C_p/C_v in primary alcohols at 303.15 K with carbon number N: (O) literature, (●) present study.

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