Temperature Dependence of the Speed of Sound of Nonane + 1-Chlorononane in the Range of (293.15 to 423.15) K

Mikhail F. Bolotnikov* and Yurij A. Neruchev

Department of General Physics, Laboratory of Molecular Acoustics, Kursk State University, Kursk, Radishcheva 33, Russia

The speed of sound of binary mixtures of nonane with 1-chlorononane has been measured as a function of composition at temperatures between (293.15 and 423.15) K. The speed of sound was measured by a pulse-phase echo ultrasonic device at a frequency of 1 MHz with an uncertainty of ± 0.1 %.

Introduction

The thermophysical properties of binary mixtures containing alkanes with 1-chloroalkanes have been extensively studied with the aim of better understanding intermolecular interactions. A detailed understanding of the effect of the presence of the chlorine (−Cl) group in a mixture on the excess thermodynamic properties and the behavior of haloalkanes in mixtures with alkanes is important from both practical and fundamental viewpoints. On the other hand, a knowledge of the thermophysical properties of nonelectrolyte solutions such as speed of sound will be helpful for the chemical industry for the design of processes of mass transfer, heat transfer, and fluid flow.

In this work, the speed of sound of the binary mixtures nonane + 1-chlorononane was measured in the temperature range of (293.15 to 423.15) K. Our literature survey indicated there is no experimental data on the thermophysical properties of the above mixture.

Experimental Section

Nonane and 1-chlorononane (mole fraction > 0.98) were supplied by Sigma-Aldrich Ltd. and were used without further purification. The mixtures were prepared by mass, with a precision of $\pm 5 \cdot 10^{-5}$ g. The uncertainty in the mole fraction is less than $5 \cdot 10^{-4}$. The ultrasonic speed was measured along the saturation line by a pulse-phase echo ultrasonic device constructed by the authors[1] at a frequency of 1 MHz, to a precision of ± 0.1 %. The acoustic cell consisted of two transducer piezoceramics of 20 mm in diameter located on the fixed distance of 21.234 ± 0.001 mm. The temperature change of the acoustic path was taken into account. Experimental values of sound speed for nonane at different temperatures were compared with Boelhouer's data and were in good agreement, as shown in Table 1. The data on speed of sound for 1-chlorononane in the literature are absent.

Table 1. Comparison of Speed of Sound *u* for Nonane with Literature Data at Different Temperatures

	$u/(\mathrm{m \cdot s^{-1}})$			$u/(\mathrm{m \cdot s^{-1}})$	
T/K	ref 2	this work	T/K	ref 2	this work
293.15	1227.0	1227.3	353.15	992.1	992.8
303.15	1186.6	1187.2	373.15	916.7	917.9
313.15	1146.9	1147.5	393.15	844.1	844.7
333.15	1068.7	1069.3	413.15	771.7	773.2

Table 2. Speed of Sound *u* of Nonane (1) + 1-Chlorononane (2) from (293.15 to 423.15) K

	$u/(\mathrm{m \cdot s^{-1}})$ for x_1 =								
T/K	0	0.100	0.300	0.500	0.700	0.800	0.850	0.900	1
293.15	1297.2	1283.1	1268.5	1254.2	1243.5	1232.8	1231.8	1222.6	1227.3
298.15	1278.2	1264.2	1249.0	1235.0	1223.5	1212.9	1211.9	1203.3	1207.2
303.15	1259.5	1245.4	1229.8	1215.9	1203.6	1193.0	1192.1	1184.1	1187.2
308.15	1240.9	1226.7	1210.6	1197.0	1183.9	1173.3	1172.4	1165.0	1167.3
313.15	1222.5	1208.1	1191.7	1178.1	1164.3	1153.7	1152.8	1145.9	1147.5
318.15	1204.3	1189.7	1172.8	1159.3	1144.9	1134.2	1133.4	1126.9	1127.8
323.15	1186.3	1171.4	1154.1	1140.6	1125.6	1114.9	1114.0	1107.9	1108.2
328.15	1168.4	1153.2	1135.6	1122.0	1106.5	1095.6	1094.7	1088.9	1088.7
333.15	1150.7	1135.2	1117.1	1103.6	1087.5	1076.5	1075.5	1070.0	1069.3
338.15	1133.2	1117.2	1098.9	1085.2	1068.7	1057.5	1056.4	1051.2	1050.0
343.15	1115.9	1099.4	1080.7	1066.9	1050.0	1038.6	1037.4	1032.4	1030.8
348.15	1098.8	1081.8	1062.7	1048.7	1031.5	1019.8	1018.5	1013.7	1011.8
353.15	1081.9	1064.2	1044.9	1030.6	1013.1	1001.1	999.7	995.0	992.8
358.15	1065.1	1046.8	1027.2	1012.6	994.9	982.6	981.0	976.3	973.9
363.15	1048.5	1029.5	1009.6	994.7	976.8	964.2	962.4	957.8	955.2
368.15	1032.2	1012.3	992.2	976.9	958.9	945.8	943.9	939.2	936.5
373.15	1015.9	995.2	974.9	959.2	941.1	927.7	925.5	920.7	917.9
378.15	999.1	978.3	957.8	941.6	923.5	909.6	907.2	902.3	899.5
383.15	982.7	961.5	940.8	924.1	906.0	891.6	889.0	883.9	881.1
388.15	966.4	944.8	924.0	906.7	888.7	873.8	870.9	865.6	862.9
393.15	950.3	928.3	907.3	889.4	871.5	856.1	852.9	847.3	844.7
398.15	934.3	911.8	890.7	872.1	854.5	838.5	835.0	829.1	826.7
403.15	918.4	895.5	874.3	855.0	837.6	821.0	817.2	810.9	808.8
408.15	902.6	879.3	858.0	838.0	820.9	803.6	799.5	792.7	790.9
413.15	887.0	863.3	841.9	821.1	804.3	786.3	781.9	774.6	773.2
418.15	871.4	847.4	825.9	804.3	787.8	769.2	764.4	756.6	755.6
423.15	856.0	831.5	810.0	787.5	771.6	752.2	747.0	738.6	738.0

Table 3. Values of Parameters of Equation 1 and Standard Deviation for Nonane (1) + 1-Chlorononane (2) from (293.15 to 423.15) K

x_1	A_1	A_2	A_3	$\sigma/(\mathrm{m \cdot s^{-1}})$
0.000	2621.6	−5.309	$2.69 \cdot 10^{-3}$	2.0
0.100	2611.1	−5.262	$2.50 \cdot 10^{-3}$	1.9
0.300	2656.6	−5.573	$2.86 \cdot 10^{-3}$	1.6
0.500	2548.6	−4.988	$1.95 \cdot 10^{-3}$	1.6
0.700	2679.2	−5.776	$2.99 \cdot 10^{-3}$	2.7
0.800	2607.2	−5.375	$2.34 \cdot 10^{-3}$	1.2
0.850	2571.2	−5.151	$1.98 \cdot 10^{-3}$	2.2
0.900	2438.4	−4.442	$1.00 \cdot 10^{-3}$	1.1
1.000	2587.7	−5.248	$2.07 \cdot 10^{-3}$	1.1

* Author to whom correspondence should be addressed. E-mail: bolotnikov@mail.ru.

10.1021/je700021f CCC: $37.00
Published on Web 05/03/2007

The speed of sound of nonane (1) + 1-chlorononane (2) is given in Table 2 from (293.15 to 373.15) K. The speed of sound (u) values are fitted by the method of least-squares using the polynomial

$$u/(\mathrm{m \cdot s^{-1}}) = A_0 + A_1(T/\mathrm{K}) + A_2(T/\mathrm{K})^2 \qquad (1)$$

Here T is absolute temperature and A_0, A_1, and A_2 are the adjustable parameters. The parameters are presented in Table 3 along with the standard deviation σ, defined by

$$\sigma = \left[\sum_{i=1}^{n} (u_{\mathrm{obsd}} - u_{\mathrm{calcd}})^2/(n - p)\right]^{1/2} \qquad (2)$$

where u_{obsd} and u_{calcd} are the observed and calculated quantities as defined earlier; n is the total number of experimental points; and p is the number of parameters.

Literature Cited

(1) Bolotnikov, M. F.; Neruchev, Yu. A. Speed of Sound of Hexane + 1-Chlorohexane, Hexane + 1-Iodohexane and 1-Chlorohexane + 1-Iodohexane at Saturation Condition. *J. Chem. Eng. Data* **2003**, *48*, 411−415.

(2) Boelhouwer, J. W. M. Sound Velocities In and Adiabatic Compressibilities of Liquid Alkanes at Various Temperatures and Pressures. *Physica (Amsterdam)* **1967**, *34*, 484−490.

Received for review January 13, 2007. Accepted April 2, 2007. This study was supported by the Russian Foundation for Basic Research under Grant No. 06-08-00875.

JE700021F