Kinematic Viscosity of 1-Iodohexane, 1-Iodoheptane, and 1-Chlorononane at Temperatures from (293.15 to 423.15) K

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The kinematic viscosity, ν, values of 1-iodohexane, 1-iodoheptane, and 1-chlorononane have been measured at temperatures from (293.15 to 423.15) K. The uncertainty in the measured viscosity was ± 1 %. The experimental results were used to calculate absolute viscosity, η, at temperatures from (293.15 to 373.15) K. Experimental values of density necessary for estimating absolute viscosity have been taken from Bolotnikov and Neruchev (*J. Chem. Eng. Data* **2004**, *49*, 202−207).

Introduction

The transport properties of fluids are of fundamental importance for the development and optimization of industrial processes. Experimental liquid viscosities of pure hydrocarbons and their mixtures are needed for the design of chemical processes where heat and mass transfer and fluid mechanics are important. Therefore, experimental measurements are needed to understand the fundamental behavior of this property and then to develop new models.

New measurements have been made for the kinematic viscosity for 1-iodohexane, 1-iodoheptane, and 1-chlorononane at temperature from (293.15 to 423.15) K with an Ubbelohde viscometer. This work is part of a project of laboratory of molecular acoustic to provide thermophysical properties of monohaloalkanes and binary mixtures containing monohaloalkanes. In our earlier work,[1−6] we have determined the speed of sound, density, relative permittivity, and heat capacity of some monohaloalkanes and their binary mixtures with alkanes. To the best of our knowledge, the kinematic viscosity 1-iodohexane and 1-iodoheptane has not been reported in the literature. Viscosity of 1-chlorononane from (288.15 to 353.15) K have been investigated by Seng at al.[7]

Experimental Section

Materials. The material used in this study, 1-chlorohexane and 1-iodohexane (with a mole fraction purity > 0.99), 1-iodoheptane (with a mole fraction purity > 0.98) was supplied by Sigma-Aldrich Ltd. All chemicals were partially degassed. The purity of the products was checked by gas chromatography (GC). We obtained GC purity data of (99.3, 99.4, and 98.4) mol % give mole fractions for 1-chlorohexane, 1-iodohexane, and 1-iodoheptane, respectively.

Table 1. Kinematic Viscosityν in the Liquid Phase for 1-Iodohexane at Temperatures T

T/K	$\nu_{\mathrm{exptl}} \times 10^6/(\mathrm{m^2 \cdot s^{-1}})$	$\nu_{\mathrm{calc}} \times 10^6/(\mathrm{m^2 \cdot s^{-1}})$	$100(\nu_{\mathrm{calc}} - \nu_{\mathrm{exptl}})/\nu_{\mathrm{calc}}$
297.25	0.9099	0.9117	0.20
298.15	0.9026	0.9003	−0.25
298.25	0.8999	0.8991	−0.09
300.25	0.8743	0.8748	0.06
318.15	0.7007	0.6999	−0.11
319.15	0.6890	0.6920	0.43
323.15	0.6625	0.6618	−0.11
328.15	0.6261	0.6272	0.18
333.15	0.5971	0.5958	−0.23
338.15	0.5679	0.5671	−0.15
343.15	0.5394	0.5408	0.26
348.15	0.5179	0.5167	−0.25
358.15	0.4741	0.4739	−0.04
368.15	0.4366	0.4372	0.13
383.15	0.3913	0.3908	−0.13
393.15	0.3643	0.3644	0.03
413.15	0.3189	0.3197	0.26
423.15	0.3010	0.3004	−0.18

Table 2. Kinematic Viscosity ν in the Liquid Phase for 1-Iodoheptane at Temperatures T

T/K	$\nu_{\mathrm{exptl}} \times 10^6/(\mathrm{m^2 \cdot s^{-1}})$	$\nu_{\mathrm{calc}} \times 10^6/(\mathrm{m^2 \cdot s^{-1}})$	$100(\nu_{\mathrm{calc}} - \nu_{\mathrm{exptl}})/\nu_{\mathrm{calc}}$
296.35	1.1796	1.1804	0.07
297.20	1.1683	1.1647	−0.31
303.50	1.0560	1.0584	0.23
313.20	0.9239	0.9240	0.01
318.15	0.8666	0.8662	−0.05
323.15	0.8122	0.8140	0.23
328.15	0.7664	0.7672	0.10
333.15	0.7247	0.7249	0.02
338.15	0.6869	0.6866	−0.04
343.15	0.6533	0.6518	−0.23
348.15	0.6204	0.6201	−0.04
353.15	0.5905	0.5911	0.09
363.15	0.5411	0.5399	−0.24
368.15	0.5169	0.5171	0.04
373.15	0.4976	0.4961	−0.30
378.15	0.4759	0.4765	0.12
383.15	0.4578	0.4582	0.09
393.15	0.4238	0.4251	0.31
403.15	0.3955	0.3957	0.04
413.15	0.3695	0.3693	−0.05
423.15	0.3458	0.3455	−0.09

Measurements. The kinematic viscosity was measured at temperatures from (293.15 to 423.15) K at $p = 0.1$ MPa in a glass Ubbelohde suspended level viscometer of i.d. 0.53 mm. The range of flow time for the liquids investigated is varied from (40 to 160) s. The uncertainty of the flow time measurement was ± 0.01 s. Flow time used to estimate the kinematic viscosity of 10 measurements. The experimental reproducibility of the flow time at each temperature was ± 0.05 %. The mean values of the results are reported. The viscometer was always kept in a vertical position in a water thermostat (VIS-T, Termex Russia) controlled to temperature of ± 0.001 K. In all the determinations, the kinetic energy correction has been taken into account. The following equation was used to calculate the

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Table 3. Kinematic Viscosity ν in the Liquid Phase for 1-Chlorononane at Temperatures T

T/K	$\nu_{\mathrm{exptl}} \times 10^6/(\mathrm{m^2{\cdot}s^{-1}})$	$\nu_{\mathrm{calc}} \times 10^6/(\mathrm{m^2{\cdot}s^{-1}})$	$100(\nu_{\mathrm{calc}} - \nu_{\mathrm{exptl}})/\nu_{\mathrm{calc}}$
296.21	1.6827	1.6837	0.06
300.65	1.5672	1.5656	−0.11
313.15	1.2975	1.2975	0.00
318.15	1.2103	1.2112	0.07
323.15	1.1345	1.1344	−0.01
328.15	1.0661	1.0656	−0.05
333.15	1.0038	1.0038	0.01
338.15	0.9479	0.9481	0.01
343.15	0.8971	0.8976	0.06
348.15	0.8515	0.8517	0.02
353.15	0.8090	0.8098	0.09
358.15	0.7720	0.7714	−0.07
363.15	0.7371	0.7361	−0.13
368.15	0.7044	0.7036	−0.11
373.15	0.6730	0.6735	0.07
383.15	0.6194	0.6195	0.01
393.15	0.5719	0.5724	0.08
403.15	0.5305	0.5307	0.04
413.15	0.4937	0.4934	−0.06

Table 4. Values of the Parameters of Equation 2 for Kinematic Viscosity ν for 1-Iodohexane, 1-Iodoheptane, and 1-Chlorononane and Standard Deviation σ

liquid	A	B	C	D	σ
1-iodohexane	−14.539515	2441.075	0.02826976	-2.45406×10^{-5}	8.27×10^{-3}
1-iodoheptane	−17.924956	2966.236	0.03658903	-3.14448×10^{-5}	6.50×10^{-3}
1-chlorononane	−19.413573	3228.577	0.0409808	-3.53771×10^{-5}	2.77×10^{-3}

viscosities:

$$(\nu/\mathrm{m^2{\cdot}s^{-1}}) = A(t/\mathrm{s}) - \frac{B}{(t/\mathrm{s})} \qquad (1)$$

where t is the flow time, ν is the kinematic viscosity, $A = 0.01035\ \mathrm{m^2{\cdot}s^{-2}}$ and $B = 1.64865\ \mathrm{m^2}$ are the viscometer constants determined by the calibration fluids. The viscometer was calibrated by using high-purity hexane (99.85 mol %) and toluene (99.9 mol %) at the working temperatures. The viscosities of hexane and toluene were taken from the literature.[8−12] The estimated uncertainty of the viscosity measurements was ± 1 %.

Results and Discussion

The experimental values of kinematic viscosity for 1-iodohexane, 1-iodoheptane, and 1-chlorononane as a function of temperature are listed in Tables 1 to 3. These results were fit as a function of temperature by

$$\ln(\nu/\mathrm{m^2{\cdot}s^{-1}}) = A + B/(T/\mathrm{K}) + C(T/\mathrm{K}) + D(T/\mathrm{K})^2 \qquad (2)$$

where the coefficients A, B, C, and D were determined by regression to minimize the standard deviation $\sigma(\nu)$, defined by

$$\sigma(\nu) = [\sum_{i=1}^{n} (\nu_{\mathrm{obs}} - \nu_{\mathrm{cal}})^2/(n-p)]^{1/2} \qquad (3)$$

where ν_{obs} and ν_{cal} are the observed and calculated quantities, n is total number of experimental points, and p is the number of estimated parameters. The values of parameters A, B, C, and D of eq 2 and the standard deviation $\sigma(\nu)$ for all investigated liquids are given in Table 4. The results of calculated and relative deviations of experimental data from the correlation of eq 2 are shown in Tables 1 to 3.

We have compared our results for kinematic viscosity of the 1-chlorononane at temperature from (313.15 to 353.15) K with the data reported Seng et al.[7] As shown in Figure 1, their results deviated typically by ± 0.1 % from the values obtained from eq 2, with a maximum deviation of 0.27 % at $T = 313.15$ K.

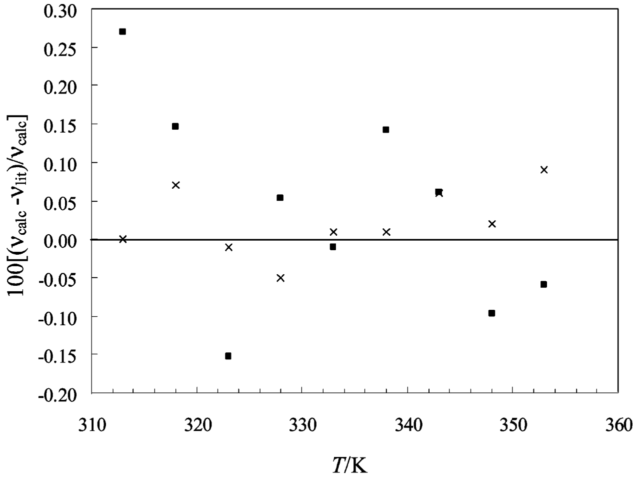

Figure 1. Relative deviations of literature kinematic viscosity ν of 1-chlorononane from eq 2 as a function of temperature. ■, ref 7; ×, this work.

Table 5. Absolute Viscosity η in the Liquid Phase for 1-Iodohexane, 1-Iodoheptane, and 1-Chlorononane at Temperature from (293.15 to 373.15) K

	η/mPa·s		
T/K	1-iodohexane	1-iodoheptane	1-chlorononane
293.15	1.3890	1.7124	1.5457
298.15	1.2879	1.5744	1.4141
303.15	1.1983	1.4532	1.2992
308.15	1.1184	1.3464	1.1985
313.15	1.0468	1.2518	1.1096
318.15	0.9825	1.1675	1.0309
323.15	0.9245	1.0922	0.9609
328.15	0.8720	1.0246	0.8983
333.15	0.8243	0.9637	0.8421
338.15	0.7808	0.9086	0.7914
343.15	0.7410	0.8585	0.7455
348.15	0.7050	0.8129	0.7038
353.15	0.6708	0.7711	0.6658
358.15	0.6397	0.7328	0.6310
363.15	0.6110	0.6976	0.5991
368.15	0.5843	0.6650	0.5696
373.15	0.5594	0.6347	0.5424

In our previous work,[4] we have reported the values of density for 1-iodohexane, 1-iodoheptane, and 1-chlorononane at temperatures from (293.15 to 373.15) K. These were used to determine absolute viscosity from results with

$$\eta = \nu\rho \qquad (4)$$

The values of absolute viscosity for 1-iodohexane, 1-iodoheptane, and 1-chlorononane at temperatures from (293.15 to 373.15) K are presented in Table 5.

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