International Journal of Thermophysics, Vol. 12, No. 5, 1991

Note

The Thermal Conductivity of Some Alkyl Ethers and Alkanones

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Received February 25, 1991

New absolute measurements, by the transient hot-wire technique, of the thermal conductivity of some alkyl ethers and alkanones are presented. The alkyl ethers studied are tert-butyl methyl ether, di-iso-propyl ether and di-butyl ether, while the alkanones studied are 2-butanone, 4-methyl pentan-2-one, and 2-octanone. The temperature range examined was 295–350 K, and the pressure atmospheric. The overall uncertainty in the reported thermal conductivity data is estimated to be better than ±1%, an estimate confirmed by the measurement of the thermal conductivity of water.

KEY WORDS: alkanones; alkyl ethers; thermal conductivity; transient hot wire.

1. INTRODUCTION

Recently a new semiempirical scheme for the prediction of the thermal conductivity of liquids, based on an extension of concepts derived from the rigid-sphere model of dense-fluid properties, has been presented [1]. This scheme made use of the idea of group contributions to the molecular volume and was developed with the aid of accurate thermal conductivity data for the alkanes, the aromatic hydrocarbons, the alcohols, and the diols, along the saturation line and at elevated pressures. The procedure was tested against other thermal conductivity data, not included in its formulation, and has been found to predict values within ±4% of the experimental data in the temperature range 110–370 K for pressures up to 600 MPa.

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0195-928X/91/0900-0937$06.50/0

In an attempt to extend the aforementioned scheme to a larger group of liquids, the present measurements were performed. The alkyl ethers studied are tert-butyl methyl ether, di-iso-propyl ether, and di-butyl ether, while the alkanones studied are 2-butanone (ethyl methyl ketone), 4-methyl pentan-2-one (iso-butyl methyl ketone), and 2-octanone (hexyl methyl ketone). The temperature range examined was 295–350 K, and the pressure atmospheric.

2. EXPERIMENTAL

The thermal conductivity measurements have been performed in a transient hot-wire instrument described in detail elsewhere [2, 3]. Two 25-μm diameter anodized Tantalum wires were used as the heat source. The thermal conductivity of water (HiPerSolv grade, supplied by BDH Ltd.) was measured before and after each liquid to ensure the continuing good operation of the instrument. The measurements of the thermal conductivity of water were found to agreee with our previously reported measurements [2] within $\pm 0.1\%$.

The samples of tert-butyl methyl and di-iso-propyl ethers were supplied by BDH Ltd. at nominal purities of 99.5 and 98.0%, respectively, while the sample of di-butyl ether was supplied by Fluka at 99.0% nominal purity. The samples of 2-butanone and 4-methyl pentan-2-one alkanones were supplied by BDH Ltd. at nominal purities of 99.5 and 99.0%, respectively, and the sample of 2-octanone was supplied by Fluka at 98.0% nominal purity. Although the accuracy of the instrument is better than $\pm 0.5\%$, as it was not possible to purify these liquids further, an accuracy of $\pm 1\%$ is considered a better estimate.

To account for the wire-properties correction of the measurements [4], the density of the liquids is required. Density values were obtained from the following sources. In the case of tert-butyl methyl ether, di-iso-propyl ether, and di-butyl ether, the density measurements of Obama et al. [5], performed with a Lipkin–Davison-type pycnometer over the temperature range 288–308 K with a quoted uncertainty of $\pm 0.3\%$, were used. In the case of 4-methyl pentan-2-one, the density measurements of Riggio et al. [6], performed with an Anton Paar DMA 46 densimeter over the temperature range 298–308 K with a quoted uncertainty of $\pm 0.5\%$, were used. For 2-butanone and 2-octanone, calculated values at 298 K were used [7]. For our measurements above these temperatures, extrapolation of the values was required. Since this correction is very small, however, less than $\pm 0.1\%$, the uncertainty introduced is negligible.

Table I. The Thermal Conductivity of Alkyl Ethers as a Function of Temperature at Atmospheric Pressure

Tert-butyl methyl ether		Di-iso-propyl ether		Di-butyl ether	
T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)	T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)	T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
297.83	105.5	301.06	104.5	298.92	126.5
299.86	105.0	304.72	103.6	300.33	126.1
303.06	104.5	310.28	102.4	306.20	125.2
305.56	103.8	312.68	101.8	311.50	124.4
309.73	103.1	317.74	100.9	316.56	123.4
311.79	102.6	321.45	99.9	322.06	122.5
316.47	101.9	327.77	98.7	327.09	121.4
		333.37	97.5	335.81	120.2
				340.99	119.3
				347.28	118.2

3. RESULTS

Tables I and II present the experimental thermal conductivity values for these liquids at atmospheric pressure as a function of temperature. The thermal conductivity values for each liquid have been correlated, for the purpose of interpolation only, by a linear function of the absolute temperature T, as

$$\lambda = \lambda_0[1 + \alpha(T - 298.15)] \tag{1}$$

Table II. The Thermal Conductivity of Alkanones as a Function of Temperature at Atmospheric Pressure

2-Butanone		4-Methyl pentan-2-one		2-Octanone	
T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)	T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)	T (K)	λ ($mW \cdot m^{-1} \cdot K^{-1}$)
302.04	143.6	300.33	121.8	304.71	131.6
305.15	142.5	306.94	120.8	309.11	131.1
307.37	142.0	311.11	120.3	313.47	130.7
309.90	141.3	313.97	119.6	317.23	130.4
317.00	138.9	319.04	119.1	322.58	130.1
		324.47	118.2	328.10	129.5
		331.14	117.3	339.33	128.8
		340.19	116.5	347.04	128.0
		344.53	115.6		

Table III. Coefficients of the Least-Squares Straight-Line Fit of the Thermal Conductivity of Alkyl Ethers and Alkanones as a Function of Temperature, Eq. (1)

	λ_0 $(mW \cdot m^{-1} \cdot K^{-1})$	α $(10^{-3} K^{-1})$	σ (%)
Alkyl ethers			
tert-butyl methyl ether	105.37	-1.855 ± 0.054	± 0.09
Di-iso-propyl ether	105.03	-2.048 ± 0.026	± 0.08
Di-butyl ether	126.56	-1.347 ± 0.015	± 0.09
Alkanones			
2-Butanone	144.80	-2.138 ± 0.066	± 0.09
4-Methyl pentan-2-one	121.97	-1.122 ± 0.031	± 0.15
2-Octanone	132.02	-0.616 ± 0.017	± 0.08

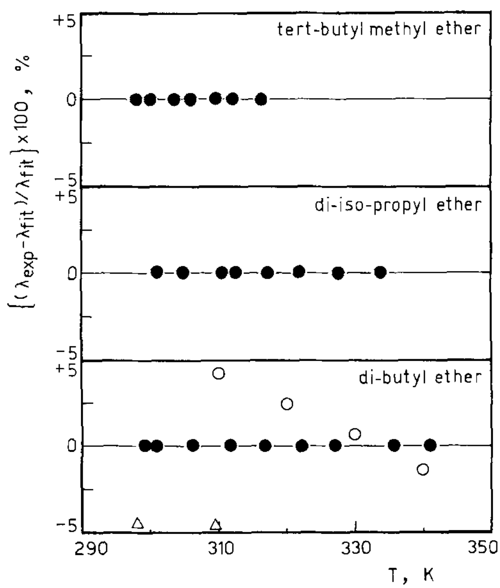

Fig. 1. Deviations of the thermal conductivity data of alkyl ethers from their representation as a function of temperature according to Eq. (1). (●) Present Work; (○) Ref. 8; (△) Ref. 9.

where λ_0 is the thermal conductivity at 298.15 K and α the linear thermal conductivity gradient for the temperature region studied. The values of λ_0 and α for each liquid are shown in Table III. In the same table the absolute standard deviation of the fits are also displayed. It can be seen that the maximum standard deviation of the present measurements, from Eq. (1), is $\pm 0.15\%$.

Figure 1 shows the deviations of the present measurements of the thermal conductivity of the three alkyl ethers, from Eq. (1). The maximum deviation is less than $\pm 0.2\%$. In the case of di-butyl ether the measurements of other investigators are also included. The measurements of Sakiadis and Coates [8] were performed in a steady-state parallel-plate type of instrument with a quoted uncertainty of $\pm 1\%$, while the measurements of Jobst [9] were performed in an early version of a transient hot-wire instrument with a quoted uncertainty of $\pm 0.5\%$. Both sets of measurements show a maximum deviation of $\pm 4.5\%$, which probably can be attributed to an incomplete theory of the instruments.

In Fig. 2 the deviations of the present measurements of the thermal conductivity of the alkanones, from Eq. (1), are presented. The maximum

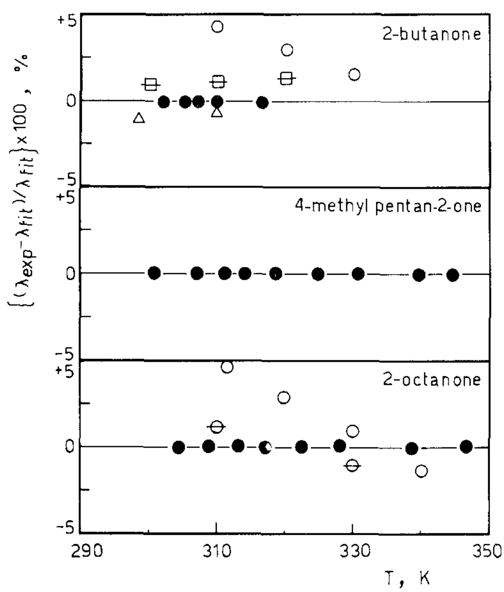

Fig. 2. Deviations of the thermal conductivity data of alkanones from their representation as a function of temperature according to Eq. (1). (●) Present Work; (○) Ref. 8; (△) Ref. 9; (⊟) Ref. 10; (⊖) Ref. 11.

deviation is less than $\pm 0.2\%$. In the same figure the measurements of other investigators are also included. The measurements of Sakiadis and Coates [8] and those of Jobst [9], already discussed in relation to Fig. 1, show maximum deviations of ± 5 and $\pm 1\%$, respectively. The measurements of Mukhamedzyanov and Usmanov [10, 11], performed in a steady-state hot-filament type of instrument with a quoted accuracy of $\pm 1\%$, show a maximum deviation of $\pm 1\%$.

The purpose of these measurements was the extension of the recently developed predictive scheme for the thermal conductivity of liquids [1] to more liquid groups. This scheme, however, is strongly density dependent so that prediction of the thermal conductivity can be accomplished up to 600 MPa. It is unfortunate that we were unable to find any density values above 308 K for these liquids, as already discussed. Thus the application of such schemes, or their extension to more liquid groups, will have to be postponed until proper density values are measured.

4. CONCLUSIONS

New absolute values of the thermal conductivity of three alkyl ethers and three alkanones are presented. The measurements were performed in a transient hot-wire instrument with an estimated accuracy of $\pm 1\%$, over the temperature range 295–350 K at atmospheric pressure.

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