TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF HELIUM

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Experimental data for the thermal conductivity of helium are generalized. A computational equation is proposed.

New experimental data on the thermal conductivity of helium have appeared recently. Most of them are for elevated temperatures at P = 1 bar. This is explained by the fact that the experimental data of Blais and Mann [1] and of Timrot and Umanskii [2] presently in the literature differ by as much as 12%. New experimental data at P = 1 bar were obtained by Vargaftik and Vinogradov [3] using cyclic heating at T = 300-1200°K, by Marchenkov [4] using a hot wire with a tungsten measuring cell at T = 400-1400°K, by Springer and Faubert [5] using a modified hot-wire method at T = 800-2100°K, and by Jain and Saxena [6] using the same method at T = 400-2300°K. Figure 1 presents the results of the studies of λ at P = 1 bar. At temperatures of 20-1200°K, the main mass of the experimental data is within 2% of the averaged curve. At T > 1200°K, there is good agreement (within 1-2%) between the data of Springer [5] and Saxena [6]. The data of Timrot [2], which deviate from the averaged curve by as much as 3%, fall somewhat lower. The data of Blais and Mann [1] fall considerably higher, deviating from the averaged curve by as much as 10%.

It should be noted that an extremely interesting alternative hot-wire method, particularly at high temperatures, was proposed in 1960 by Blais and Mann. It was subsequently used by a number of investigators to study the thermal conductivity of gases at high temperatures; a number of important technical problems were solved in this way.

In the experimental arrangement of Blais and Mann, who first used this method to measure the thermal conductivity of helium, possible sources of systematic error may be the insufficient consideration of end effects, the determination of the intensity of thermal flux through

TABLE 1. Recommended Values of Thermal Conductivity for Gaseous Helium at P = 1 bar

T, °K	$\lambda \cdot 10^3$, W/(m·°K)	T, °K	$\lambda \cdot 10^3$, W/(m·°K)	T, °K	$\lambda \cdot 10^3$, W/(m·°K)	T, °K	$\lambda \cdot 10^3$, W/(m·°K)
2,0	3,87	45	43,4	250	134	700	273
2,5	4,90	50	46,6	260	138	750	287
3,0	6,00	60	52,7	270	141	800	301
3,5	7,20	70	58,6	280	145	850	315
4,0	8,25	80	64,4	290	148	900	328
4,5	9,10	90	68,7	300	152	950	342
5,0	9,90	100	73,3	310	155	1000	355
6,0	11,4	110	77,5	320	158	1100	380
7,0	13,0	120	82,2	330	161	1200	405
8,0	14,8	130	86,5	340	164	1300	429
9,0	15,9	140	90,8	350	167	1400	453
10	17,1	150	95,1	360	170	1500	475
12	19,3	160	99,3	370	173	1600	498
14	21,3	170	103	380	177	1700	519
16	22,9	180	107	390	180	1800	540
18	24,5	190	112	400	183	1900	561
20	26,0	200	116	450	199	2000	581
25	29,7	210	120	500	214	2100	601
30	33,1	220	124	550	229	2200	620
35	36,5	230	127	600	244	2300	638
40	39,9	240	131	650	259	—	—

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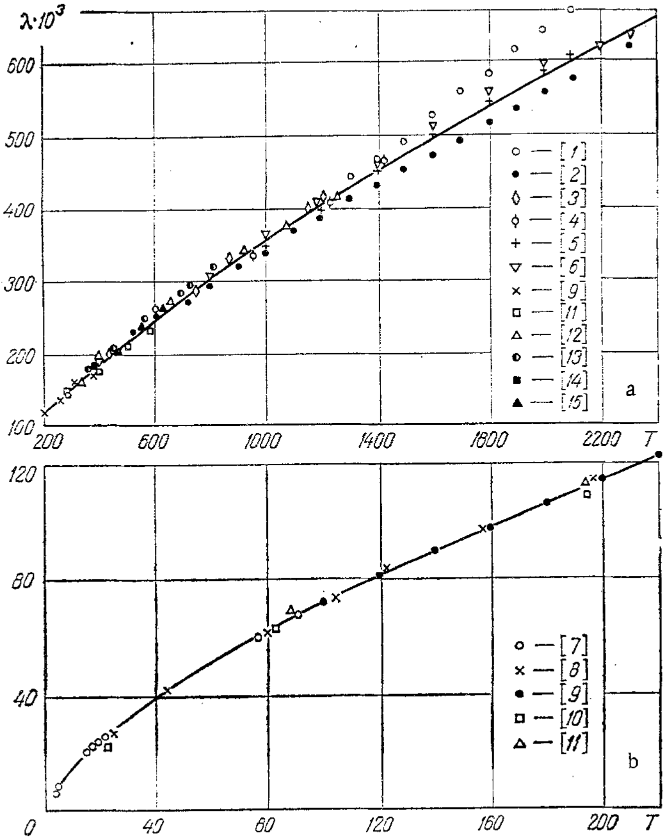

Fig. 1. Temperature dependence of the thermal conductivity of helium in the ranges 200-2300°K (a) and 2-200°K (b). λ, W/(m·°K); T, °K.

the gas, the variability of the temperatures in the wall of the measurement cell, and perhaps the presence of convection at the high temperature gradients which were present in the experiments. All these can lead to an overestimate of the results of the measurements. In averaging the experimental data, the results of [1] were taken with a statistical weight of 0.5.

Based on the experimental data shown in Fig. 1a, the equation

$$\lambda = 0{,}0476 + 0{,}362\cdot 10^{-3}T - 0{,}618\cdot 10^{-7}T^2 + 0{,}718\cdot 10^{-11}T^3,\ \mathrm{W/(m\cdot{}^\circ K)}.$$

was obtained by the method of least squares. It describes the experimental data in the temperature region from 200 to 2300°K. The data from [7-11, 16] were used for the range 2-200°K. These results are shown in Fig. 1b.

The experimental data of the various authors agree within 2% in the temperature range 80-200°K. There is no experimental data in the range 4-15°K, in which the thermal conductivity is strongly dependent on temperature (the value of λ varies by a factor of 3). There is little experimental data at 20-80°K. Therefore, it is desirable that measurements of thermal conductivity be made in that low-temperature region.

Table 1 gives values of the thermal conductivity for gaseous helium in the temperature range 2-2300°K. The error in the recommended values for the thermal conductivity is 2% in the temperature range 100-1200°K, 3% for 1200-2300°K, and 5% for temperatures less than 100°K.

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APPARATUS FOR COMPLEX THERMOPHYSICAL STUDIES OF LIQUIDS AT HIGH STATE PARAMETERS IN THE MONOTONIC HEATING REGIME

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Experimental apparatus used and results obtained in a complex of studies of thermophysical properties of n-undecane and n-tridecane are described.

The thermal conductivity λ and heat capacity c_p of liquids have been studied significantly less than other physical properties, and for the majority of materials the experimentally studied range of change of thermophysical properties with temperature is not large. Data on the effect of pressure on λ and c_p are very sparse. The difficulties in such studies are related mainly to realization of existing methods and experimental devices which will function in the range of high temperatures and pressures.

For studies of λ in liquids, in recent times nonstationary methods have become ever more popular, in particular, regular type I regime methods [1]. The theory of the regular type I regime was developed in the linear variant, so that these methods are convenient only at fixed temperatures. At high temperatures these methods require almost as much experimental time as stationary ones and, moreover, do not allow determination of the temperature dependence of λ from one experiment. Thus, monotonic heating methods deserve special attention, since they allow determination of the temperature dependences of thermophysical properties over a wide temperature range from one experiment which requires a relatively small amount of time.

The first attempt in this direction was that of Kraev [2], who proposed one of the simplest variants of the λ-calorimeter for measurement of λ in liquids close to room temperature. The method can be used successfully at moderate pressures and temperatures. Unfortunately, his calorimeter is not capable of high-accuracy measurements for operation at high pressures. In order to solve this problem, it is necessary to provide a more refined theoretical basis for the method and develop an improved calorimetric device. Somewhat later a similar closed-layer method was proposed by Platunov for studies of dispersed materials [3].

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