# THERMAL CONDUCTIVITY OF HELIUM AT TEMPERATURES FROM 300 TO 6000°K

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Experimental data on the thermal conductivity of helium at atmospheric pressure and temperatures from 300 to 6000°K are correlated.

The experimental data on the thermal conductivity of krypton and xenon up to 5000°K at atmospheric pressure were correlated in [1]. It was shown that above a certain temperature the thermal conductivity of these gases can be represented by a power law with a fixed value of the exponent. We perform a similar investigation below for helium.

During the last few years a relatively detailed study has been made of the thermal conductivity of helium at high temperatures. Table 1 lists the available papers on the measurement of the thermal conductivity of helium at high temperatures and atmospheric pressure. Figure 1 is a log—log plot of the results of all the research papers listed in Table 1. It is clear from the figure that the experimental values of the thermal conductivity of helium in the temperature range 300-6000°K lie approximately on a straight line. This shows that for the conditions indicated the temperature dependence of the thermal conductivity of helium can be represented by a power law.

The data in [2], obtained by the conductivity column method first proposed by the authors, deviate appreciably from the straight line of Fig. 1. At 2000°K these data lie 9-12% above the later more precise measurements [3-6] made by the same method. The results of Saxena et al. [5, 6] and Springer et al. [4] at high temperatures are in good agreement with data obtained by the hot-wire method [7-9]. The experimental results obtained by the method of periodic heating [10, 11] lie close to the straight line. The experimental value of Timrot and Umanskii [3] for $T > 800$°K lie up to 5% below the main mass of data obtained by steady-state methods, but even in this case the deviation is within the limits of error of [3].

The data of both shock tube experiments [12, 13] lie systematically below the straight line by about 5%. The fact that this displacement of the shock-tube data relative to the results in [5, 6] obtained by the more accurate conductivity column method is practically constant over a rather broad range (1000-2500°K) of overlap of temperature ranges investigated is a basis for assuming that the shock tube values are somewhat too low even a higher temperatures.

Analysis of the available experimental research on the thermal conductivity of helium at high temperatures and at pressures near atmospheric showed that from 300 to 6000°K the thermal conductivity of helium is described by the power law

TABLE 1. Papers on the Thermal Conductivity of Helium at High Temperatures (in chronological order)

| Ref. | Method of investigation | Temp. range, °K | Error in % estimated by author |
|---|---|---|---|
| [7] | Hot wire | 347—804 | — |
| [2] | Conductivity column | 1200—2100 | — |
| [8] | Hot wire | 273—1273 | 2 |
| [10] | Periodic heating | 306—1268 | 1,25 |
| [12] | Shock tube | 1600—6700 | 10 |
| [3] | Conductivity column | 400—2400 | 5,5 |
| [13] | Shock tube | 1000—4000 | 20 |
| [4] | Conductivity column | 800—2100 | 4 |
| [11] | Periodic heating | 308—1208 | 3—4 |
| [9] | Hot wire | 407—1413 | 4 |
| [5] | Conductivity column | 400—2300 | 3,7—2 |
| [6] | Conductivity column | 400—2500 | 3—4 |

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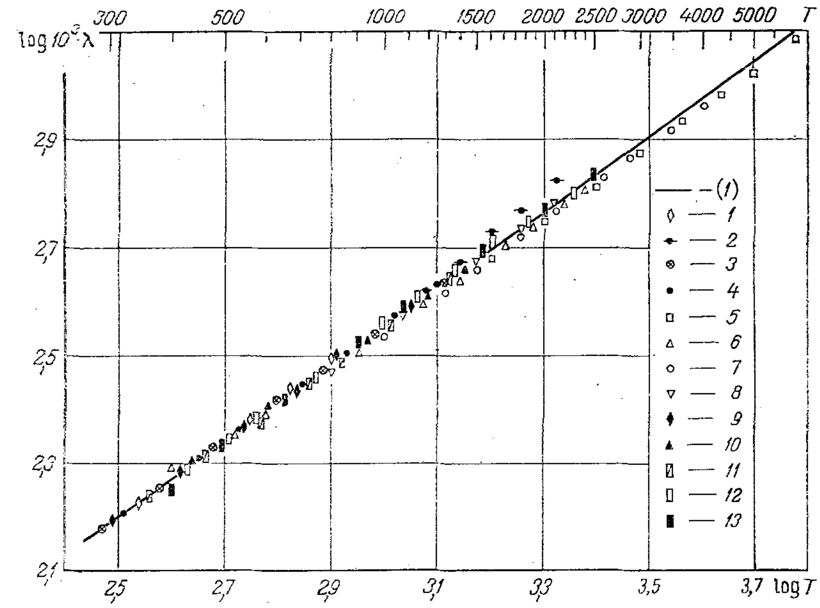


Fig. 1. Thermal conductivity of helium from the following data: 1) [7]; 2) [2]; 3) [8]; 4) [10]; 5) [12]; 6) [3]; 7) [13]; 8) [4]; 9) [11]; 10) [9]; 11) [25]; 12) [5]; 13) [6]; λ is in W/m·°K and T is in °K.

TABLE 2. Thermal Conductivity of Helium λ, $10^{-3}$ W/m·°K

| T, °K | λ | T, °K | λ | T, °K | λ |
|---|---|---|---|---|---|
| 300 | 152 | 1800 | 542 | 3600 | 887 |
| 400 | 186 | 1900 | 564 | 3800 | 922 |
| 500 | 218 | 2000 | 585 | 4000 | 956 |
| 600 | 249 | 2100 | 605 | 4200 | 990 |
| 700 | 277 | 2200 | 625 | 4400 | 1023 |
| 800 | 305 | 2300 | 645 | 4600 | 1056 |
| 900 | 331 | 2400 | 665 | 4800 | 1088 |
| 1000 | 357 | 2500 | 685 | 5000 | 1120 |
| 1100 | 382 | 2600 | 704 | 5200 | 1152 |
| 1200 | 407 | 2700 | 723 | 5400 | 1183 |
| 1300 | 431 | 2800 | 742 | 5600 | 1214 |
| 1400 | 454 | 2900 | 761 | 5800 | 1245 |
| 1500 | 476 | 3000 | 780 | 6000 | 1275 |
| 1600 | 499 | 3200 | 816 | | |
| 1700 | 521 | 3400 | 852 | | |

$$\lambda = 0.152 \left(\frac{T}{300}\right)^{0.71}, \quad (1)$$

where λ is the thermal conductivity in W/m·°K, and T is the temperature in °K.

The values of the thermal conductivity calculated by Eq. (1) may be in error by 3% for T = 300-2500°K, and by 5% for $T > 2500$°K.

The values of the thermal conductivity of helium calculated by Eq. (1) are listed in Table 2.

Figure 2 shows the deviation of the experimental data available in the literature (Table 1) from Eq. (1). For comparison the figure also shows the results of known correlations [14-18] and kinetic theory calculations [23] using various interaction potentials [19-22].

The correlated data of Liley [14] and Touloukian et al. [15] above 1500°K are too high. This results from the fact that at the time these handbooks [14-15] were being prepared the only experimental data available to the authors were those of Blais and Mann [2], which, as noted above, are substantial overestimates.

The results of correlation [16] for $T > 1500$°K are 3-4% lower than Eq. (1). The handbook data [17, 18] for $T > 1000$°K deviate from Eq. (1) by less than 1%. The values calculated

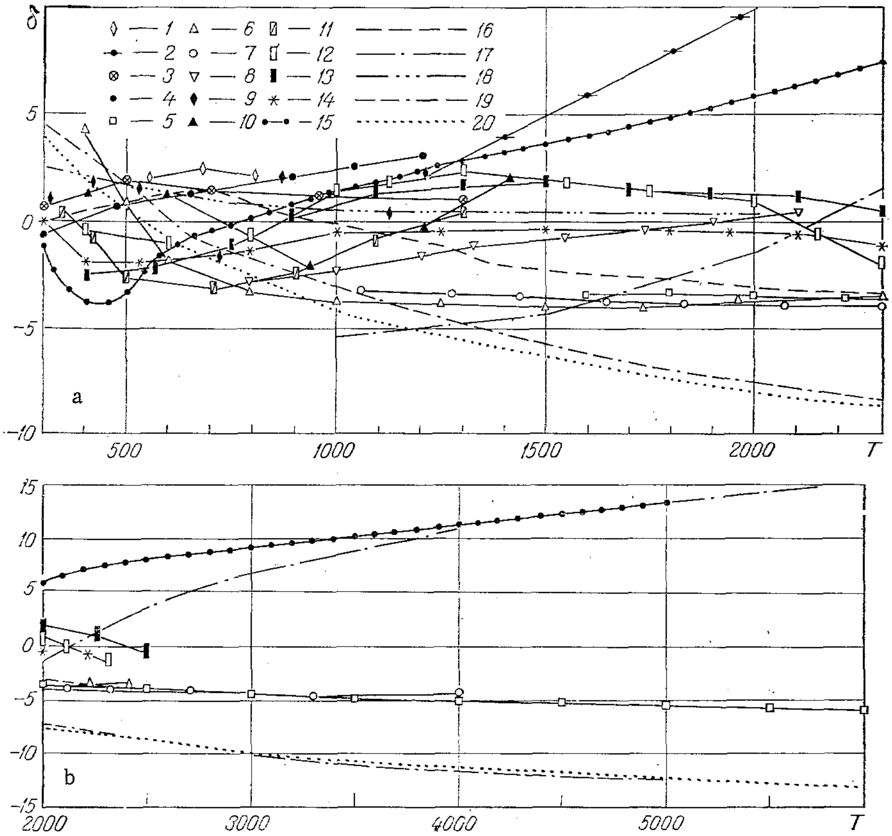


Fig. 2. Deviation $\delta = (\lambda - \lambda_{pow})/\lambda_{pow}$ (%) from the power law (1) for helium according to the following data: 1-13) notation the same as in Fig. 1; 14) [17-18]; 15) [15]; 16) [16]; 17) [19]; 18) [20]; 19) [21]; 20) [22].

by Amdur and Mason [19] by using a potential found from scattering experiments deviate from Eq. (1) by less than the error (10%) of the calculations up to 3000°K. With increasing temperature the divergence increases to 16% at 6000°K.

The values calculated by Watson [20] are in good agreement with our correlation. These calculations were performed by using a (12-6) Lennard-Jones potential with parameters at various temperatures determined from recent reliable experimental data on the viscosity of helium at high temperatures.

Earlier calculations by Swehla [21] were performed on the same basis as in [20], but with parameters of the (12-6) potential determined from experimental data of Trautz on the viscosity below 1000°K and extended to temperatures as high as 5000°K. Above 1200°K the results of these calculations are substantial underestimates. The values in this paper obtained by using parameters for the same potential found from low-temperature experimental data on the thermal conductivity of helium lie still lower, and are not shown on our figure.

In the paper by Sevast'yanov and Zykov [22] transport coefficients of monatomic gases were calculated by using a (12-7) interatomic potential. The parameters of the potential were determined from experimental data on the second virial coefficient, the compressibility, and the viscosity.

Kolenchits [24] investigated the thermal accommodation and temperature jump at a gas–solid boundary as applied to various methods of measuring the thermal conductivity of gases. In particular, he examined in detail the effect of the temperature jump on the results of investigations of the thermal conductivity in shock tubes, and estimated this effect on the data of [12, 13] for helium. He concluded that this effect should be much more pronounced for helium than for heavier gases.

Figure 1 shows that the differences between the experimental data for helium at high temperatures obtained by steady-state methods [5, 6] and in shock tube measurements [12, 13] lie within the limits of error. But the data in [12, 13] are systematically lower, possibly as a result of neglecting the temperature jump at the end of the shock tube.

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