THERMAL CONDUCTIVITY OF Gd *AND* Tb *AT LOW TEMPERATURES*

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The temperature dependence of the thermal conductivity of samples of Gd and Tb has been measured between 2° and 100°K. A maximum in the thermal conductivity is observed in each case at a temperature of 16—20°K. The Lorentz number calculated for 4.2°K greatly exceeds the theoretical value. It is suggested that at these temperatures there exist, besides the heat transport by electrons, other transfer mechanisms which contribute to the thermal conductivity of these rare earth metals. Anomalies in the thermal and electric conductivities of Tb are observed at temperatures below 5°K.

THE low-temperature thermal conductivity of the rare-earth metals has not really been studies experimentally or theoretically. Indeed, in the literature known to us there are no theoretical papers on thermal conductivity which could be applied to the rare-earth metals, allowing for their particular electronic structure and magnetic properties. Therefore the experimental data are treated only qualitatively. The thermal conductivities of La and Ce[1], and those of Sc and Y[2] have been determined only in a small temperature range at low temperatures. The thermal conductivities of Dy[3] and Gd[4] have been determined at temperatures from 5 to 100°K.

We have carried out measurements of the thermal conductivity on one specimen of Gd and two specimens of Tb in the range of 2—100°K. The electric conductivity of these specimens was also measured at room temperature and 4.2°K. The specimens were 99.9% pure, and in the form of strips of 0.25 mm thickness. The specimens labelled Gd, Tb1, Tb2 were baked for $1\frac{1}{2}$ hours at 650°C in the atmosphere of the helium evaporating from the cryostat. The purity of the sample Tb2 turned out to be lower than that of Tb1. For the determination of the thermal conductivity we used an apparatus similar to the one described in the paper by Zavaritskiĭ and Zel'dovich[5].

Measurements of the electric resistivity of these samples showed at 4.2°K a residual resistivity of 3.00 microhm for Gd, 4.13 microhm for Tb1, and 7.90 microhm for Tb2. From our data the resistance ratio $\rho_{293°K}/\rho_{4.2°K}$ comes out to be 47.4 for Gd, and 30 and 15.6, respectively, for Tb1 and Tb2.

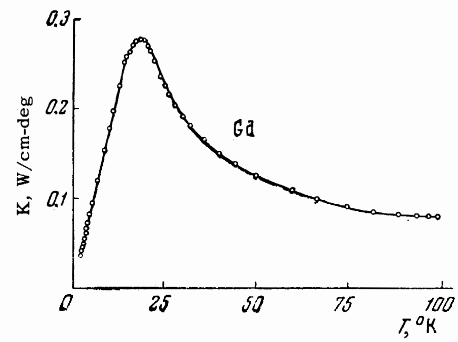

FIG. 1. Temperature dependence of the thermal conductivity of the Gd sample.

The temperature dependence of the thermal conductivity of Gd is shown in Fig. 1. The graph shows that the thermal conductivity of Gd rises linearly with temperature at low temperatures, reaches a maximum, and then decreases. This demonstrates that, at low temperatures, when $T \ll \Theta$, (Θ being the Debye temperature) the electronic conductivity dominates, which is then limited by the scattering of electrons on impurities. In that case the thermal conductivity is expected to be proportional to T.

At 18°K the thermal conductivity of Gd reaches its maximum of K = 0.279 W/cm-deg. Above this temperature the electron-phonon interactions begin to matter and lead to the temperature dependence $K \sim T^{-2}$.

Figure 2 shows the temperature dependence of the thermal conductivity for the two Tb specimens. The unusual feature of these curves is that between 2 and 5°K the thermal conductivity decreases with increasing temperature and reaches a minimum at 5°K. Since Tb1, and particularly

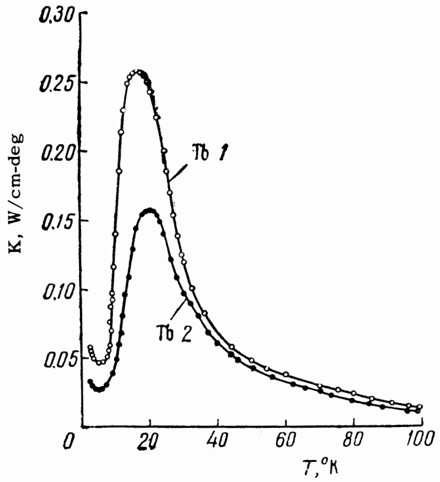

FIG. 2. Temperature dependence of the thermal conductivity of the two Tb samples.

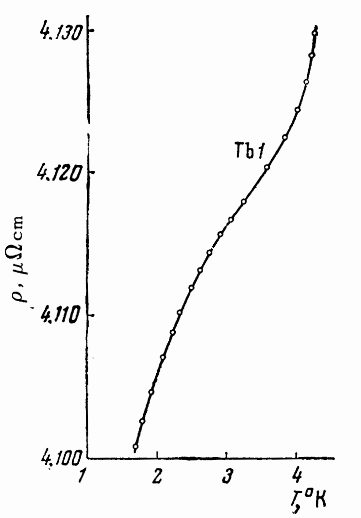

FIG. 3. Temperature dependence of the electric resistivity of Tb1.

Tb2, contains greater amounts of impurity than the Gd, it is possible that this phenomenon is associated with an anomaly in the electric resistivity in this temperature region.

Figure 3 shows the temperature dependence of the electric resistivity of Tb1. It is well known that in the case of pure metals the resistivity decreases at low temperatures monotonically with decreasing temperature, and approaches the residual resistivity. However, Fig. 3 shows that below 4°K the curve for the electric resistivity of Tb1 deviates from the typical form for pure metals and bends downwards Similar anomalies were found by Gerritsen et al.[6] in the low-temperature electric resistivity of dilute alloys. Such anomalies in the behavior of the electric resistivity are associated with the existence of localized states near the impurity centres with energies close to the Fermi energy of the solvent.

Above 5°K the thermal conductivity of both Tb samples, like that of Gd, starts rising proportionally to T. The thermal conductivity of Tb1 has a maximum of 0.257 W/cm-deg at 16°K, whereas for Tb2 the maximum is 0.158 W/cm-deg at 20°K. This means that for the purer sample of a given metal the maximum of the thermal conductivity is higher and shifted to lower temperatures.

From the electric and thermal conductivities at 4.2°K one deduces the Lorentz number $K/\sigma T$, where K and σ are the measured values of the thermal and electric conductivities at 4.2°K. It should be noted that the same terminals were used for the electric and thermal measurements. Any errors in the determination of the geometrical dimensions of the sample will therefore cancel in the ratio. The Lorentz numbers for Gd, Tb1, Tb2, are, respectively, 7.1, 5.16, and 5.53 in units of 10^{-8} W-Ω/deg^2.

For all the samples studied, the Lorentz number greatly exceeds the theoretical value of 2.45×10^{-8} W-Ω/deg^2. Evidently there are, in addition to the heat transport by electrons, other mechanisms of heat transfer, which give a contribution to the total thermal conductivity of these rare-earth metals.

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