High-temperature Hall effect in rare earth metals

M. Vedernikov, V. Dvunitkin, N. Moreva

To cite this version:

M. Vedernikov, V. Dvunitkin, N. Moreva. High-temperature Hall effect in rare earth metals. Journal de Physique Colloques, 1979, 40 (C5), pp.C5-46-C5-47. <10.1051/jphyscol:1979518>. <jpa-00218935>

HAL Id: jpa-00218935
https://hal.archives-ouvertes.fr/jpa-00218935
Submitted on 1 Jan 1979

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
High-temperature Hall effect in rare earth metals

M. V. Vedernikov, V. G. Dvunitkin and N. I. Moreva
A. F. Ioffe Physical-Technical Institute, Leningrad, 194021, USSR

Résumé. — Jusqu'à présent l'effet Hall a été bien étudié dans les métaux de terres rares (REM) au-dessous de la température ambiante. A température élevée seules existaient des données expérimentales pour 4 terres rares légères. L'article contient les données pour les autres terres rares, à l'exception de Eu, dans l'intervalle de températures 80-1 000 K.

Abstract. — Up to date the Hall effect in rare earth metals (REM) was studied rather extensively below the room temperature. At high temperatures there are experimental data for 4 light REM only. For the first time the paper contains the data for the rest of REM at 80-1 000 K, excluding Eu.

During last some years thermopower and resistivity \( \rho \) of all REM at high temperatures (80-1 000 K) were studied in detail by our group [1]. The third important transport coefficient of REM, the Hall constant \( R \), was studied rather well below the room temperature. However, the region of higher temperatures remained almost unstudied (see book [2]). Apparently except the measurements on light REM La, Ce, Pr, Nd [3], nothing was made. At present time the measurements at 80-1 000 K have been carried out by us for all heavy REM beginning from Sm, except only Eu. The sharp change of dependence \( R(T) \), which is typical for magnetic substances at the critical point, was experimentally discovered in Sm at \( T_c = 106 \) K (figure 1). Near 730 K there exist a small jump of \( R \) corresponding to the recently revealed phase transition of Sm. Data for Gd, Tb, Dy, Ho, Er, Tm and Lu are shown in figures 2-5. The \( R(T) \)-curve for Yb clearly shows the presence of phase transitions (figure 1). While heating the first transition takes place at 360 K, the second one at 590 K. While cooling in both cases a strong hysteresis is observed. The nature of these transitions was discussed in [1]. Considering the Hall constants of the studied part of REM family it is easy to see the usual situation : the properties of all heavy REM, except anomalous ones, are rather similar. Sm and Yb are anomalous metals. A peculiarity of the curve \( R(T) \) having a form of a little stretched jump was noticed for Gd, Tb, Dy, Ho, Er at temperatures 400-750 K. For all metals excluding Gd it was observed at the first heating run. A hysteresis of the jump is noticed in cooling run only for Gd and Ho. Such a jump permits to suggest the existence of some phase transition. In the case the corresponding peculiarities of other properties must be observed at the

![Fig. 1. — Hall constant vs. temperature. The left scale, Sm. \( T_c \) is the magnetic critical point of Sm. The right scale, Yb. The arrows indicate a direction of temperature change.](image1)

![Fig. 2. — Hall constant of Gd vs. temperature. The left scale, curve 1 : the first heating run. The right scale, curve 2 : the first heating run; curve 3 : the second cycle of heating and cooling.](image2)

![Fig. 3. — Hall constant vs. temperature. 1) Tb. 2) Dy.](image3)
not unlikely that near 500 K in both cases there is a slight bend of $\rho(T)$-curve. The more detailed study of all REM in temperature range 400-750 K may be of significant interest. As for physical interpretation we tried only to make some useful estimations by means of simplest analysis. REM at high temperatures are paramagnets and thus for measured Hall constant may be written [2]:

$$R = R_0 + R_* \frac{4 \pi \chi}{1 + 4 \pi \chi} = R_0 + R_* Z.$$

Knowing the temperature dependences of $R$ and $\chi$ it is possible to construct the dependence $R(Z)$. For linear parts of these dependences the constants $R_0$ and $R_*$ were determined. The results are presented in the table. The calculated curves $R(T)$ in figures 4 and 5 are constructed in the whole temperature range using invariable values of $R_0$ and $R_*$ from the table. If one compares the values $R_0$ and $(R_*, Z)$ received in our analysis it may be seen that only for Gd the term $(R_*, Z) \gg R_0$. For other metals included in the table $R_0 > (R_*, Z)$, and the difference increases while heating. For Ho, for example, at room temperature $(R_*, Z)$ makes up less than 5% of $R_0$. Therefore, $R(T)$-dependence of Gd only is determined by temperature dependence of magnetic susceptibility $\chi$. The considerable temperature dependence of $R$ of other metals represents temperature variation of the normal Hall constant $R_0$. It is confirmed by the similarity of the high-temperature parts of these curves with the curves for Lu and Sm for which $R = R_0$ because of the very small values of $\chi$.

Table I.

<table>
<thead>
<tr>
<th>Metal</th>
<th>$T_c$ (K)</th>
<th>Region of linearity of $R(Z)$</th>
<th>$R_0 10^{10}$ (m$^3$ A$^{-1}$ s$^{-1}$)</th>
<th>$R_*$ 10$^{10}$ (m$^3$ A$^{-1}$ s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gd</td>
<td>293</td>
<td>410-800 K</td>
<td>- 1.2</td>
<td>- 448.0</td>
</tr>
<tr>
<td>Tb</td>
<td>230</td>
<td>330-450 K</td>
<td>- 3.7</td>
<td>- 55.5</td>
</tr>
<tr>
<td>Dy</td>
<td>179</td>
<td>190-290 K</td>
<td>- 2.5</td>
<td>- 8.9</td>
</tr>
<tr>
<td>Ho</td>
<td>133</td>
<td>165-220 K</td>
<td>- 3.2</td>
<td>- 5.1</td>
</tr>
<tr>
<td>Er</td>
<td>85</td>
<td>120-200 K</td>
<td>- 2.9</td>
<td>- 8.2</td>
</tr>
<tr>
<td>Tm</td>
<td>56</td>
<td>120-200 K</td>
<td>- 2.4</td>
<td>- 28.2</td>
</tr>
<tr>
<td>Lu</td>
<td></td>
<td></td>
<td>- 2.2</td>
<td></td>
</tr>
</tbody>
</table>

References