Hall Effect and Susceptibility of Gold

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IN AN EARLIER communication[1] we noted that the anomalous behavior of the resistivity of gold at low temperatures [the presence of a minimum on the $r(T)$ curve] disappeared when the variation of r as a function of T was measured in a constant magnetic field stronger than a certain critical value H_c.

We felt it would be of interest to investigate the effect of magnetic fields on other properties of gold.

In the present note we describe the preliminary results of an investigation of the Hall effect in and the magnetic susceptibility of gold. For measuring the Hall effect we took two gold samples of the same size (0.5 × 14 × 30 mm); sample Au-1 was prepared of the lot of gold for which the anomaly in the $r(T)$ curve was observed, while sample Au-4 was prepared from a lot of gold characterized by a normal $r(T)$ curve.

The design of the apparatus used for measuring the Hall effect at $T < 1°$ K has already been described.[1] (The temperature dependence of the resistivity of the samples Au-1 and Au-4 was also measured on the same apparatus.) The measurements were carried out by means of a potentiometer connected to a two-stage photoelectric amplifier with a sensitivity of 2×10^{-9} volts. Measurements of the temperature dependence of r for the Au-1 sample showed that $T_{\min} \approx 4°$ K and that the increase in r is proportional to log $(1/T)$; the value of $\Delta r/r_{\min}$ at $T = 0.07°$ K was found to be 15 percent. Measurements of the value of $\Delta r = r_{0.07} - r_{\min}$ as a function of the magnetic field led to a value of about 8500 oersted for H_c.

No anomaly was detected for the Au-4 sample.

Fig. 1 shows the dependence of the Hall field E_y on the magnetic field at $T = 1.45°$ K. Analogous dependences were obtained at 0.07°, 4.2°, 10°, 20.4°, 77° and 295° K.

The jump-like change in the Hall angle at $H \approx 8500$ oersted, which coincides with the field value at which Δr becomes zero, naturally led us to assume that the magnetic properties of this gold sample may also change in this field. To clarify this

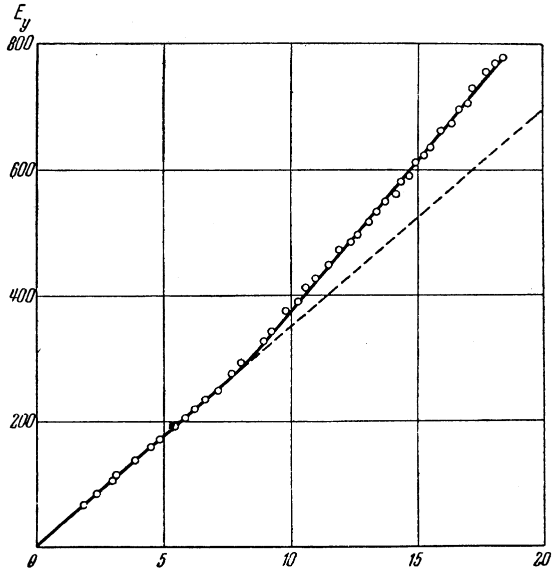

FIG. 1.

we undertook a series of preliminary measurements of the magnetic susceptibility of a sample of gold from the same lot as Au-1. The measurements were carried out by the Faraday method; the balance had a sensitivity of 0.01 mg. The specimen was prepared in the form of a cylinder of gold foil 0.05 mm thick. The cylinder diameter was 8 mm, the length 8 mm, and the weight 5.06 grams.

The measurements showed that the susceptibility χ remained diamagnetic in the temperature range from 295° to 1.45° K; at 1.45° K its value is 0.7 that at $T = 295°$ K.

The values of the force F acting on the specimen as a function of $H(dH/dx)$ are shown in Fig. 2. The

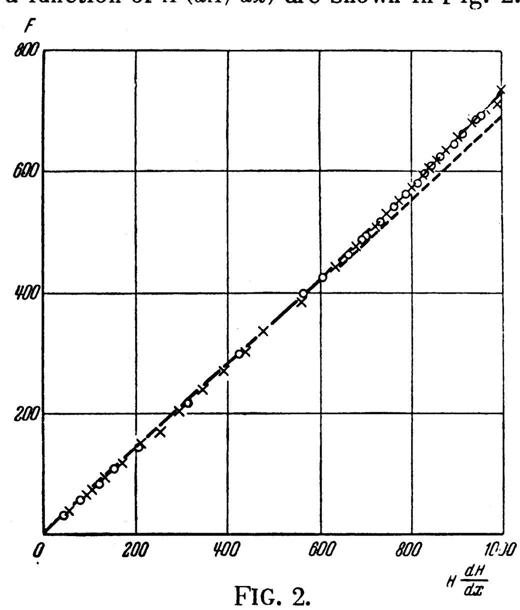

FIG. 2.

last quantity was determined by measuring at $T = 295°$ K the force acting on a gold specimen, the susceptibility of which was previously determined by the method of Huey. It will be seen that at a certain value of the magnetic field there is a break in the straight line, analogous to that in the curve for $E_y(H)$. It was found that the value of the magnetic field at which the change in the angle of the force occurs is ~ 8500 oersted.

The cited data show that some sort of phase transformation occurs at $H \approx 8500$ oersted. A detailed description of the results will be published in the near future.

[1]N. E. Alekseevskii and Iu. P. Gaidukov, J. Exptl. Theoret. Phys. (U.S.S.R.) 31, 947 (1956); Soviet Phys. JETP 4, 807 (1957).

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Ejection of Electrons from Metals by Fast Molecules

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IZMAILOV AND THE AUTHOR[1] have examined the question of ejection of electrons from metals by molecules of neutral gases. It was shown that the mechanism of "potential" ejection of electrons from metals by molecules of neutral gases takes place for those values of energy of gas molecules, at which they are sufficiently close to the metal at a distance x_0. The value of x_0 is related to the kinetic energy of the gas molecule by the expression

$$U(x_0) = mv_\infty^2/2, \tag{1}$$

where $U(x_0)$ is the potential energy of the repulsive force at the instant when the gas molecules stop near the metal surface, m is the mass of the molecule, and v_∞ is its velocity at a distance $x \gg x_0$. In Ref. 1 we expressed $U(x)$ as

$$U(x) = B/x^p. \tag{2}$$

From (1) and (2) we obtain

$$x_0 = (2B/mv_\infty^2)^{1/p}. \tag{3}$$

In the absence of reliable data on the values of the constant B and exponent p in expression (2) we are forced, as in Ref. 1, to restrict ourselves to an expression of the form $N = f(x_0)$ for the number of electrons N ejected from one cm^2 of metal surface by a stream of gas molecules. At the present time it seems possible to estimate the parameters in (2) and, consequently, to express N in terms of macroscopic parameters of the gas stream.

From Ref. 1 it is possible to obtain an expression for the charging of the gas stream

$$\frac{N}{n} = \frac{2\pi}{3}\left(\frac{\pi}{10p}\right)^{1/2}\frac{Q^2C}{B}\,mv_\infty^2\,x_0^{p-7}\,\lambda^{-1/2}e^{-\lambda}. \tag{4}$$

$$C = (e^2/4\pi^2\hbar^2)(w_i^{1/2}/w_a\varphi_0^{1/2}), \tag{4a}$$

$$\lambda = \left[\frac{2}{3}\left(2m_0\varphi_0^3\right)^{1/2}/\hbar e^2\alpha\right]x_0^5 = \beta x_0^5/2Q,\quad Q = e\alpha, \tag{4b}$$

where n is the concentration of gas molecules, e and m_0 the charge and mass of the electron, φ_0 the work function of the electrons in the metal, w_a the potential barrier on the metal surface, w_i the Fermi level, and α the polarizability of the gas molecules.

Substituting in (4) the value of x_0 from (3) and expressing it in terms of the velocity and of the parameter B, we obtain for $p = 7$

$$N/n = K_1(v_\infty/B)^{19/14}\exp(-K_2B^{5/7}/v_\infty^{10/7}), \tag{5}$$

$$K_1 = (4\pi/3)(\pi/70)^{1/2}Q^2C(2Q/\beta)^{1/2}(m/2)^{19/14}, \tag{5a}$$

$$K_2 = (\beta/2Q)(2/m)^{5/7}. \tag{5b}$$

The quantities entering in (5a) and (5b) can be determined for a given metal and gas from the tables of physical constants. The quantities appearing in (2) can be estimated. We do not know of any reliable data for the potential of the repulsive force between the solid and the gas. To determine the potential between the metal and the gas we proceed from the following premises: (1) The potential can be either a power or an exponential function. (2) If the parameters of the potential are known for each phase separately, the interphase potential is determined as an average[2] in the following form

$$B_{12} = (B_{11}B_{22})^{1/2},\quad p_{12} = 1/2\,(p_{11}+p_{22}),$$
$$(x_{12})_0 = 1/2\,[(x_{11})_0 + (x_{22})_0], \tag{6}$$

where the symbols correspond to those in (2) and (3). (3) The value of the energy of interaction between the gas molecules and the metal and their equilibrium internuclear distance x_0 serve as a start-