THE MAGNETIC PROPERTIES OF SCANDIUM

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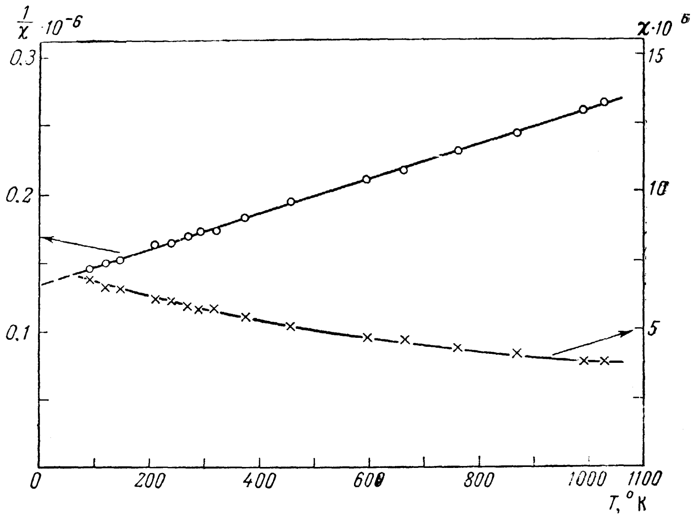
SCANDIUM belongs to the weakly-magnetic transition metals, the atoms of which, as is well known, have unfilled electronic d-shells. The magnetic properties of the majority of the transition metals are being studied quite thoroughly at the present time over a wide range of temperatures.

As far as metallic scandium is concerned, its magnetic properties are completely unknown. This is because it is so difficult to obtain pure scandium. The limited data in the literature on the magnetic properties of scandium were obtained on insufficiently pure metal. [1,2] Moreover, the temperature dependence of the magnetic susceptibility is not yet established.

Recently, metallic scandium has been prepared with a high degree of purity. This scandium was obtained from spectrally-pure scandium oxide by the metallo-thermal reduction of scandium fluoride with distilled calcium. The reduction process was carried out in a molybdenum crucible in an atmosphere of spectroscopically pure helium. After reduction the metal was melted in an arc furnace on a water-cooled copper hearth. Chemical analysis showed the following impurities: oxygen ≤ 0.116, hydrogen ≤ 0.0074, nitrogen ≤ 0.04, copper ≤ 0.07, molybdenum ≤ 0.002, calcium $\leq 0.05\%$.

Before the measurements the metallic scandium was annealed at 1000° for one hour. The magnetic properties were studied over the wide temperature interval of 77 to 1100°K. The magnetic susceptibility was measured in vacuum by the Faraday method. The samples had masses of 10—20 mg and were investigated in a magnetic field of $\sim$ 12,000 Oe.

The figure shows our data for the specific susceptibility (χ) and its reciprocal ($1/\chi$) as a function of temperature. It can be seen from the figure that $1/\chi$ changes linearly with temperature over the entire range investigated, and $d\chi/dT < 0$. Applying the Curie-Weiss law in the form $\chi = C/(T - \Theta_p)$, we find for the constants C, Θ_p and the effective atomic magnetic moment P_p the following values: $C = 0.35$, $\Theta_p = -1050$°K, and $P_p = 1.67\ \mu_B$.



Temperature dependence of χ and $1/\chi$ for pure scandium.

It should be observed, however, that the Curie-Weiss law should be applied with caution in this case, and that the constants entering into it probably have here somewhat different physical meanings from the usual ones. We know that scandium is the first transition metal in the iron group and that it has a single unpaired electron in the 3d shell. Hence, we should expect that spatial localization of the d-electron will not have a significant effect. It is more probable that the s- and d-electrons here form a single association with a complicated electron-density distribution.

Our results confirm this point of view. The experiment showed that the susceptibility of scandium depends weakly on temperature and is close to that of an electron gas in order of magnitude. Evidently, in metallic scandium a weak Curie-Weiss type of paramagnetism is superimposed on the Pauli paramagnetism. Also, we cannot overlook the possibility that an antiferromagnetic exchange interaction exists in scandium, which is suggested by the sign of Θ_p.

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[1] H. Bommer, Z. Elektrochem. **45**, 357 (1939).

[2] V. K. Iya, J. des recherches de C.N.R.S. No. 35, 91 (1956).

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