MAGNETIC PROPERTIES OF $DyAu_2$ AND $DyAg_2$

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Résumé. — L'aimantation des alliages $DyAg_2$ et $DyAu_2$ est mesurée à des températures de 4,2° à 300 °K et dans un champ magnétique jusqu'à 100 kOe. On trouve que $DyAu_2$ et $DyAg_2$ sont antiferromagnétiques. Dans le cas de $DyAu_2$ il y a une discontinuité dans la courbe susceptibilité-température. A 4,2 °K, l'aimantation croît en deux sauts avec le champ magnétique. Cette variation en deux sauts disparaît graduellement avec l'élévation de la température. Ce résultat peut s'expliquer en considérant un changement de la structure des spins.

Abstract. — The magnetization of compounds $DyAu_2$ and $DyAg_2$ was measured at temperatures between 4.2° to 300 °K and under the magnetic field up to 100 kOe. Both compounds were found to be antiferromagnetic. In $DyAg_2$, spin flopping occurred at low temperature. In $DyAu_2$, a jump at 25 °K in the susceptibility-temperature curve was observed. At 4.2 °K, the magnetization increased in two steps with magnetic field. Such stepped transformation gradually blurred with rise of temperature till it vanished above 25 °K. These facts may be interpreted as an antiferromagnetic structure change.

I. **Introduction.** — Several rare earth metals (R) and noble metals (M) form intermetallic compounds with a $MoSi_2$-type structure [1, 2]. The neutron diffraction study showed that a compound of the formulae $TbCu_2$ has a double-layered antiferromagnetic spin structure [3]. However, magnetic properties of other compounds of this type have not yet been investigated. In this paper, results of measurements are reported on the temperature dependence of the susceptibilities of the compounds $DyAu_2$ and $DyAg_2$ and also on their magnetizations under the magnetic field up to 100 kOe.

II. **Experimental Procedure.** — The specimens were prepared by arc-melting the mixture of dysprosium (99.9 % purity) and gold (99.99 %) or silver (99.9 %) with desired compositions in the atmosphere of argon, and by subsequent annealing in vacuum at 500 °C for 500 hours. The X-ray analysis showed that both of prepared specimens had the structure of $MoSi_2$-type with lattice parameters as shown in Table I. These values are in good agreement with the result by Dwight [1].

TABLE I

	$DyAu_2$	$DyAg_2$
a (A)	3.694	3.696
c (A)	8.96	9.29
T_N (°K)	31	9
θ_p (°K)	− 13	− 25
$\mu_{eff}(\mu_B)$	10.6	10.5

III. **Experimental Results and Discussion.** — Susceptibility χ vs temperature T curves for $DyAu_2$ and $DyAg_2$ are shown in figure 1. Each compound has a maximum in the susceptibility-temperature curve, at 31 °K for $DyAu_2$ and 9 °K for $DyAg_2$, respectively. Above the temperature of the maximum susceptibility, reciprocal susceptibility of $DyAg_2$ follows the Curie-Weiss law in a wide range of temperature higher than the temperature of maximum susceptibility and the asymptotic Curie point is 25 °K. The reciprocal susceptibility vs temperature curve of $DyAu_2$ also follows the Curie-Weiss law above 180 °K with negative asymptotic Curie point, − 13 °K. However, below 180 °K the value of the reciprocal susceptibility deviates downward from the extension of the linear portion of the curve. This deviation from the Curie-Weiss law is regarded to be due to the effect of the crystalline field on the term splitting of the magnetic ions.

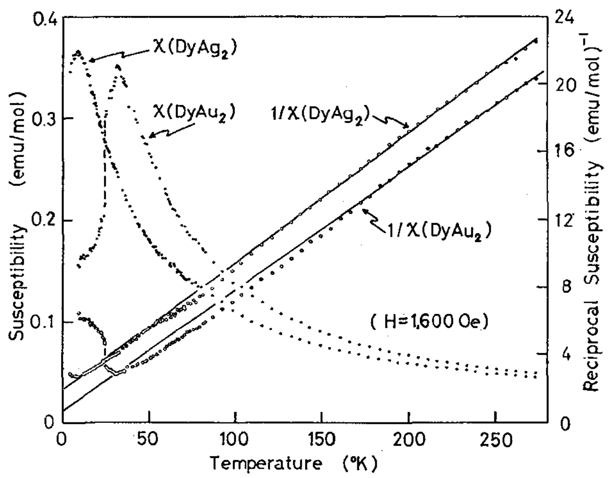

FIG. 1. — Susceptibility versus temperature curves.

On the basis of the facts mentioned above, it may be concluded that the spin arrangements in these compounds are antiferromagnetic below the temperature of the maximum susceptibility, which are defined as the Néel points. The Néel point T_N, asymptotic Curie points θ_p and χ_{max} are shown in Table I.

The effective magnetic moments per dysprosium atom estimated from the Curie constants are 10.6 μ_B for $DyAu_2$ and 10.5 μ_B for $DyAg_2$, which are in good agreement with 10.6 μ_B of a free trivalent ion of dysprosium.

As seen from figure 1, the susceptibility vs temperature curve of $DyAu_2$ has a discontinuous increase of

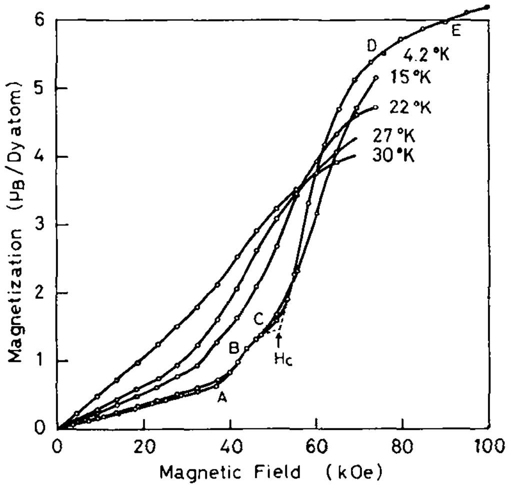

FIG. 2. — Magnetization curves of $DyAu_2$.

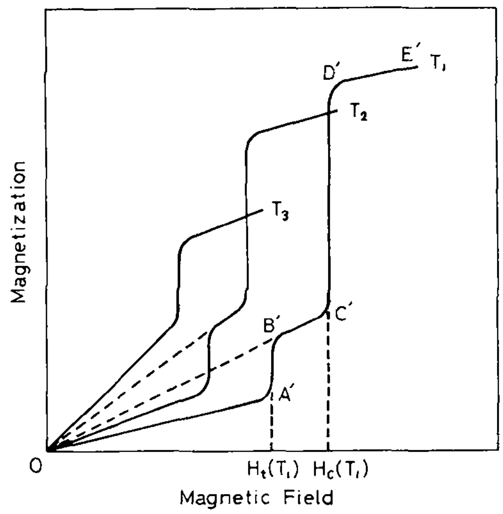

FIG. 3. — Schematic magnetization curves for $DyAu_2$.

susceptibility at about 25 °K, which may be considered to be due to a change of the magnetic spin structure. In order to make clear this magnetic transition, the magnetization process was studied under the magnetic field up to 100 kOe. The results of measurement are shown in figure 2, which suggests the existence of fairly complex transitions in the magnetic structure.

Peculiar behavior of these magnetization curves may be understood by introducing the following mechanism.

(1) $DyAu_2$ has an antiferromagnetic structure (AF-I state) at low temperature ; Under the application of the magnetic field H, AF-I state transforms into another antiferromagnetic structure (AF-II state) at a transition temperature $T_t(H)$.

(2) Susceptibility of AF-II state, χ_{II} is larger than that of AF-I state, χ_I.

(3) AF-II state has a metamagnetic transition at a certain critical field $H_c(T)$.

(4) The transition temperature $T_t(H)$ decreases with increase of the magnetic field. Magnetization processes derived from the mechanism assumed above are schematically shown in figure 3, in which temperatures T_1, T_2 and T_3 are in order of

$$T_1 < T_2 < T(0) < T_3 .$$

Based on the schematic curves of the magnetization shown in figure 3, we can interpret the present experimental results as follows. It is considered that in the case of magnetization curve at 4.2 °K, the part OA corresponds to the initial susceptibility of the AF-I state. The magnetic field at a point A corresponds to a critical field $H_t(T)$, which cause the transition from the AF-I state of the AF-II state. In the field higher than H_t, the magnetization σ, should increase following the relation $\sigma = \chi_{II} H$, as shown schematically by the part B′ C′ in figure 3, but the observed magnetization curve shows a non-linear increase ABC, which can be regarded as due to the polycrystalline specimen. defined in figure 2 at a point C is taken as a critical

The magnetization increases rapidly between C and D, then after reaching a point D, it increases gradually and seems to saturate along the line DE. It is to be noticed here that the extrapolation of the part DE to $H = 0$ does not pass the origin O. Therefore, the part BC can be thought to correspond to the region of the metamagnetic transition as shown by B′ C′ in figure 3. The critical field $H_t(T)$ represented by point A decreases with increase of temperature. Temperature dependence of the critical field H_t is plotted in figure 4. If the field

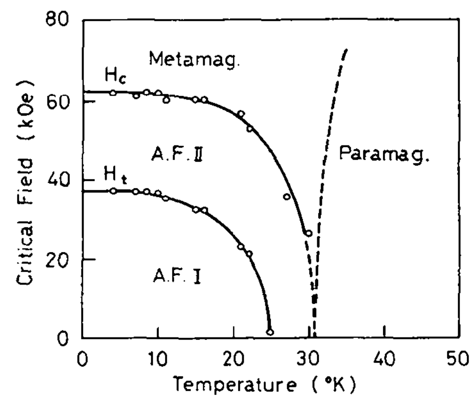

FIG. 4. — Critical fields, H_t and H_c, versus temperature curves.

field $H_c(T)$, $H_c(T)$ then changes as shown in figure 4. In figure 4 of the diagram of $DyAu_2$, the H-T plane is devided into four regions by the curves H_t and H_c, e. g. AF-I, AF-I and the metamagnetic state in the figure a boundary of the paramagnetic state is also illustrated.

It is also to be noticed that $DyAg_2$ was found to show a different magnetic behavior as compared with $DyAu_2$. In the magnetization curve of $DyAg_2$ only a spin flopping was seen near 35 kOe and a field proportional magnetization at a field higher than 50 kOe was found.

References

[1] DWIGHT (A.) et al., *Acta. Cryst.*, 1967, **22**, 745.
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[3] AOJI (M.), *Phys. Letters*, 1967, **25A**, 528.