# Investigation of the magnetic state of the rare-earth sublattice in the compound $TbCo_5$

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A neutron-diffraction investigation of $TbCo_5$ has established a correspondence between the change of the diffuse background and the change of the terbium-sublattice magnetization. It is concluded that the absolute value of the magnetic moment of the rare-earth ion is conserved in the region where the orientation of the easy-magnetization axis changes.

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The anomalous decrease of the magnetization of the rare-earth (R) sublattice in $TbCo_5$, which sets in at 390—420 K in the "easy plane—easy axis" transition, is attributed in[1] to the influence of the crystallographic anisotropy, which reaches large values (on the order of $10^8$ erg/cm$^2$ in compounds of the $RCo_5$ type. It is assumed in this explanation that the anomalous magnetization $\Delta m \approx 0.8\mu_B$ of the R-sublattice is due only to the change in the disorienting influence of the thermal motion. The absolute value of the magnetic moment of the terbium ion is assumed constant.

The assumption that the moment of the terbium in $TbCo_5$ is conserved when the temperature changes can be confirmed or refuted by measurement of the of the magnetic diffuse scattering of thermal neutrons. This conclusion is deduced from the following considerations.

One can expect the temperature-induced magnetic disordering of the R- and Co-sublattices to lead to magnetic diffuse scattering of neutrons. Since the exchange parameters in $TbCo_5$ are related as $I_{Tb\text{-}Tb} \ll I_{Tb\text{-}Co} < I_{Co\text{-}Co}$, it follows that the magnetic disordering of the rare-earth sublattice manifests

  

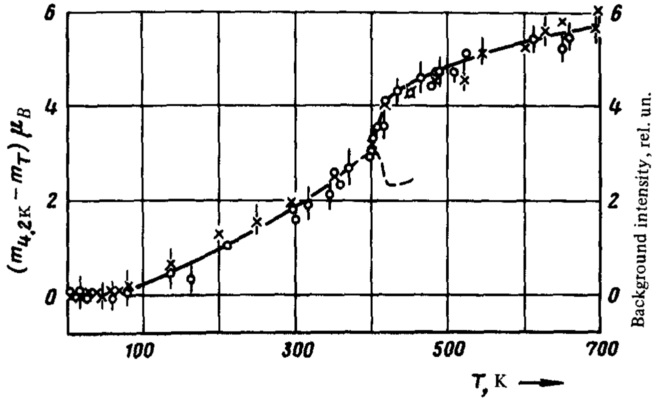


FIG. 1. Temperature dependence of the changes of the terbium sublattice magnetization and of the background in the compound $TbCo_5$; crosses—change of Tb-sublattice magnetization ($\mu_B$/atom), circles—change of background (relative units).

itself to a larger degree with increasing temperature than the disordering of the cobalt sublattice. If we recognize in addition that the magnetic moment of the R-ion is of much larger absolute magnitude than the Co magnetic moment, and the cross section for diffuse magnetic scattering of the neutrons depends almost quadratically on the magnetic moment of the scatterer, then it should be assumed that in the region 4.2—700 K, which encompasses the "easy plane—easy axis" transition, the contribution of the R-sublattice to the diffuse background will predominate. The character of the change of the magnetic diffuse background with increasing temperature should, naturally, be determined by the manner in which the easy axis is rotated, and whether the magnetic moment of the R-ion is preserved in this case or decreases.

## EXPERIMENTAL PROCEDURE

The measurements were made with a neutron-diffraction camera mounted on one of the horizontal channels of the IVV-2 reactor. We used a beam of neutrons of wavelength $\lambda = 1.075$ Å. The measurements of the temperature dependence were made in the interval 4.2—700 K. To study the temperature dependence of the background intensity $I_b(T)$ the counter was mounted at an angle $2\theta = 6°$. In this position, the form factor is still large, and the influence of the primary beam is already practically nil. The nearest reflection (001) is located in the region of 12°. The scattering due to the thermal vibrations of the lattice can likewise be neglected here.

To determine the temperature dependence of the magnetization of the terbium sublattice for the purpose of comparing it with the temperature dependence of the background, neutron diffraction patterns from powdered samples were obtained at certain temperatures within the interval indicated above; the sample preparation procedure is described in[1].

## MEASUREMENT RESULTS AND DISCUSSION

The R-sublattice magnetization depends strongly on temperature starting approximately with 60 K. At 700 K it is already one-fourth the initial value (at 4.2 K). In accord with the assumption made in[1] and the calculations of[2], the character of the change of the magnetization is different before and after the "easy plane—easy axis" transition. Its rate of change is larger in the interval 60—390 K than in section 420—700 K. As already noted,[1] in the narrow region 390—420 K corresponding to the rotation of the easy-magnetization axis, an anomaly is observed in the change of the magnetization ($\Delta m \approx -0.8\mu_B$).

As expected, when the temperature is raised, an appreciable diffuse scattering appears and its temperature dependence readily reveals a connection with the state of the R-sublattice.

Indeed, in the interval 4.2—60 K the background level remains practically unchanged. In the section 100—390 K it increases at an approximately constant rate. In the region of the "easy plane—easy axis" transition 390—420 K the growth rate of the background is approximately triple that in the preceding interval. With further rise in temperature, the background continues to increase, but more slowly than in the second section, and a tendency of the growth to slow down gradually can be observed as 700 K is approached. Figure 1 shows the experimental temperature dependences of the change $\Delta m_R = m_{4.2\,K} - m_T$ in the magnetization of the R-sublattice and the change $\Delta J_b$ of the background. The scale of $\Delta J_b$ was chosen such that the points corresponding to the change of both the magnetization and the background were as close as possible on Fig. 1 at 420 K.

It is seen that in this case both dependences are satisfactorily described by a single curve, i.e., the background intensity increases with temperature in proportion to the change of the R-sublattice magnetization. This connection shows that the increase of the background is due mainly to magnetic (incoherent neutron scattering by the R-ions. It is natural to assume that in the intervals 4.2—390 K and 420—700 K the magnetic moment of the R-ion is conserved. It can then be reliably concluded from the proportionality of $\Delta J_b$ and $\Delta m_{Tb}$ in the entire interval that the absolute value of the magnetic moment of the terbium ion is conserved also in the intermediate region (390—420 K).

The change of the R-sublattice magnetization due the decrease of the magnetic moment of the Tb ion should have inevitably led to a corresponding decrease of the background level, i.e., just the opposite of the observed behavior of the background. The dashed curve in Fig. 1 is the plot of $J_b(T)$ calculated under the assumption that a change of $0.8\mu_B$ takes place in the magnetic moment of the terbium ion ($\mu_{Tb}$ changes from 8.35 to $7.55\mu_B$).

It can thus be assumed that the rotation of the easy-magnetization axis in $TbCo_5$, which takes place in the interval 390—420 K, leads only to an increase in the sensitivity of the terbium sublattice to the action of the thermal motion of the atoms.

[1]A. S. Ermolenko, E. V. Rozenfel'd, Yu. P. Irkhin, V. V. Kelarev, A. F. Rozhda, S. K. Sidorov, A. N. Pirogov, and A. P. Vokhmyanin, Zh. Eksp. Teor. Fiz. 69, 1743 (1975) [Sov. Phys. JETP 42, 885 (1975)].

[2]V. V. Druzhinin, S. P. Zapasskiĭ, and V. M. Povyshev, Fiz. Tverd. Tela **19**, 159 (1977) [Sov. Phys. Solid State **19**, 90 (1977)].