# Phase transitions in magnetically ordered state seen by neutron diffraction method

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Below the appropriate characteristic temperatures (the Curie temperature ($T_C$) for ferromagnets and the Néel temperature ($T_N$) for antiferromagnets) the magnetic moments of atoms become ordered. For a large number of compounds below these temperatures additional magnetic phase transitions are observed.

Neutron scattering widely used powerful microscopic tool the condensed matter research. Apart from nuclear scattering, neutrons interact with magnetic moments of unpaired electrons in a sample. That makes neutrons an ideal probe for investigations of magnetic ordering.

In this work some results concerning the change of the magnetic structure as a function of temperature from an incommensurate collinear at low temperatures to an incommensurate modulated near the Néel temperature are discussed. The results of neutron diffraction experiments are compared with the data from macroscopic methods and the correlations between them were studied. Some examples are briefly presented below:

- $Tb_2Ni_3Si_5$ crystallizes in an orthorhombic crystal structure. The magnetic data indicate two distinct magnetic transitions at $T_N$=19.5 K and $T_t$=12 K. Below $T_t$ neutron diffraction measurements give a collinear magnetic structure with the magnetic unit cell identical to the crystallographic one. In the temperature region between $T_t$ and $T_N$ the magnetic structure becomes sine-modulated with the propagation vector **k**=(0, 1.0, 0.206). Specific heat measurements give also two phase transitions. The value of entropy $\Delta S$=1.13 R at $T_N$ is much larger than that expected for a doublet ground state (Rln2=0.69 R). Therefore the ground states of the Tb ion is not a doublet but is likely to be a quartet as the value is only slightly less than Rln4=1.39,
- $Tb_2Rh_3Si_5$ crystallizes in a monoclinic crystal structure. Specific heat measurements give two phase transitions at 8 and 8.5 K. Neutron diffraction data indicate that below $T_t$=7 K a collinear magnetic ordering with the propagation vector **k**=(½, ½, ½) developes while at 7.5 K the sine modulated one is observed,
- $TbCo_2Si_2$ and $DyCo_2Si_2$ crystallize in the tetragonal body-centered $ThCr_2Si_2$-type crystal structure. Both compounds are antiferromagnets with the Néel temperature equal 46 K for $TbCo_2Si_2$ and 21.4 K for $DyCo_2Si_2$.The collinear antiferromagnetic ordering of the AF1-type with the **k**-vector [001] observed at low temperature changes into an incommensurate sine-modulated one described by the propagation vector **k**=(0, 0, 1-$k_z$). The value of the $k_z$ components equal 0.045 for $TbCo_2Si_2$ and 0.049 for $DyCo_2Si_2$, indicates the modulated structure with the long period of about 20 c.

The magnetic transitions between commensurate and incommensurate phases observed in these compounds have been discussed in connection with wave–dependent molecular field coefficients.

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