THE MAGNETISM OF YFe_6Al_6

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The RFe_6Al_6 (R = rare earth) spinels crystallize in the $ThMn_{12}$ structure where four lattice sites can be distinguished. Site $2a$ contains all R ions, site $8i$ only Al, site $8f$ only Fe while site $8j$ is randomly occupied by Fe and Al in equal proportion. We had previously studied the R=Tb, Ho, Er compounds which are known ferrimagnets ($T_N \approx 340$ K) and found evidence for frustration due competing exchange interactions [1]. Unpublished neutron diffraction results on YFe_6Al_6 gave no indication for the presence of long-range order. In addition, line shape analysis provided even no conclusive evidence for any short-range order. If correct, these results mean that the absence of a magnetic $2a$ sublattice prevents magnetic order altogether, although the Fe containing $8f$ sublattice is considered the driving force for magnetism in all RFe_6Al_6 materials. To gain more insight into the situation from a local point of view, we employed μSR and Mössbauer spectroscopies. The μSR data were taken at the GPS (He-flow cryostat down to 1.8 K) and GPD (N_2-flow cryo-oven up to 400 K) facilities.

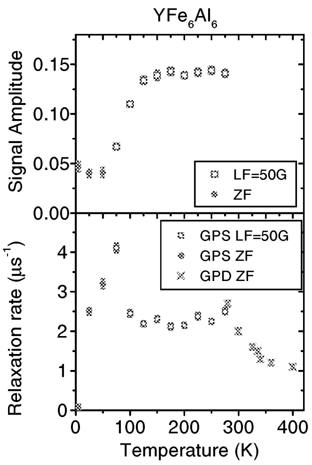

Figure 1: Temperature dependences of the μSR signal amplitude (top) and relaxation rate (bottom) in YFe_6Al_6.

A large loss of μSR signal amplitude occurs around 60 K (see Fig. 1 - top). This points strongly towards an onset of long-range ordered magnetism. The signal at 50 K and below can be understood as the 1/3 longitudinal part of the typical μSR spectrum of an ordered magnet. The oscillatory transverse part is damped too rapidly by excessive field distributions. The variation of muon spin relaxation rate with temperature is shown in Fig. 1 - bottom. It shows critical behavior on approach to 60 K and thus confirms the conclusion of presence of a magnetic transition. The behavior of relaxation rate at lower temperatures reveals the typical approach to the quasistatic limit of ordered magnetism. Between 60 K$\leq T \leq$320 K one observes a relaxation rate much too large for a free paramagnet. At least strong spin correlations must be present. The rate drops in the vicinity of 320 K. Whether this is due to another phase transition or whether muon diffusion sets in, cannot be decided on μSR data alone. Mössbauer spectroscopy comes to aid. Typical spectra are shown in Fig. 2. We shall not discuss the (still preliminary) fits to the spectra at this stage. At low temperature all iron atoms exhibit magnetic hyperfine splittings in accordance with long-range ordered magnetism. A considerable field distribution is visible here as well. The Zeeman splitting of the majority of Fe atoms collapses towards 60 K, but a small portion remains unaffected. Up to 320 K a coexistence of magnetically ordered and very short range-ordered, or otherwise highly correlated paramagnetic states exists. Beyond 320 K the Mössbauer spectra show no longer magnetic splittings, the pure paramagnetic state has been reached. The residual quadrupole doublet exhibits a distinct asymmetry which most probably arises from slow paramagnetic spin fluctuations (paramagnetic relaxation spectrum). Slow spin fluctuations tie in with the still large muon spin relaxation rate seen above the final magnetic transition of 320 K. In summary the local magnetic data clearly show the existence of different kinds of magnetic order in YFe_6Al_6. The discrepancy to the neutron data remains a mystery.

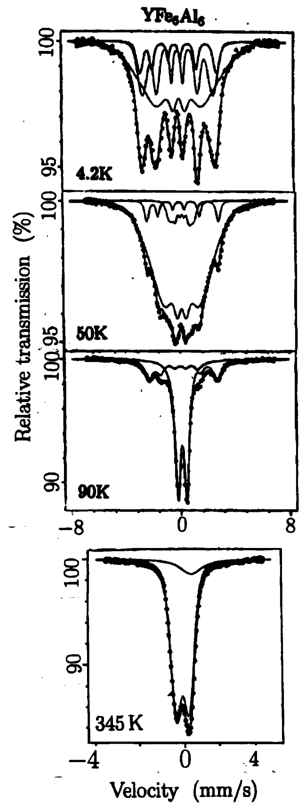

Figure 2: ^{57}Fe Mössbauer spectra of YFe_6Al_6 at various temperatures.

REFERENCES

[1] G. M. Kalvius et al. Physica **B 289-290**, 225 (2000).