Crystal Field Softeing and Magnetic Phase Transition in HoB_4

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A tetragonal rare-earth system of RB_4 has attracted interest as a sytem where the quadrupolar and magnetic degrees of freedom are active on the so-called Shastry-Sutherland lattice. HoB_4 exhibits two phase transitions at $T_{N1} = 7.5$ K and at $T_{N2} = 5.9$ K. The details of the magnetic structures and the anomalous nature of the phase transitions have been reported in Ref. 1. Below T_{N1} an incommensurate magnetic order sets in with Q=$(\delta, \delta, \delta')$ ($\delta = 0.022$, $\delta' = 0.07$), followed by a first order transition into a commensurate order with Q=$(1, 0, 0)$ at T_{N2}. One of the anomalous results in the study was the very broad magnetic diffuse scattering around (0, 0, 0.5) and (1, 0, 0). In order to clarify the origin of this diffuse scattering and the anomalous phase transitions, we have carried out an inelastic neutron scattering experiment on a triple-axis spectrometer HER, using cold neutrons to achieve high energy resolution at low energies. Horizontal focusing analyzer, radial collimator, Be and PG filters were used at an final energy of 5.01 meV.

Fig. 1 shows the temperature dependences of the CEF excitation energy at Q=(1, 0, 1) and (2, 0, 0.43). The former and the latter corresponds to the commensurate and incommensurate magnetic structures, respectively. As shown by the plot, the CEF energies at these Q-vectors decrease with decreasing temperature down to T_{N1}. Simultaneously, in the paramagnetic phase above T_{N1}, quasi-elastic peaks gradually develop at these Q-vectors. The temperature dependences of the inverse intensity are plotted in the bottom figure. This clearly demonstrates that the commensurate and incommensurate correlations coexist in the paramagnetic phase, and well follow the Curie-Weiss behavior until they diverge at the respective transition temperatures. This can be understood within the mean-field approximation.

The softening of the CEF can also be understood within the mean-field approximation as reflecting $\chi(Q, \omega) = \chi_0(\omega)/(1 - J(Q)\chi_0(\omega))$. The CEF softening shows that the ground state of a Ho ion is a singlet with no magnetic moment and that the magnetic order of HoB_4 is caused by the mixing with higher CEF states. It was clarified that the diffuse scattering reported in Ref. 1 was these CEF excitations reflecting $J(Q)$.

Therefore, at zero magnetic field, there seems no indication of a magnetic frustration effect caused by the Shastry-Sutherland type lattice.

(1) D. Okuyama *et al.*, J. Phys. Soc. Jpn., **77**, 044709-1-14 (2008).

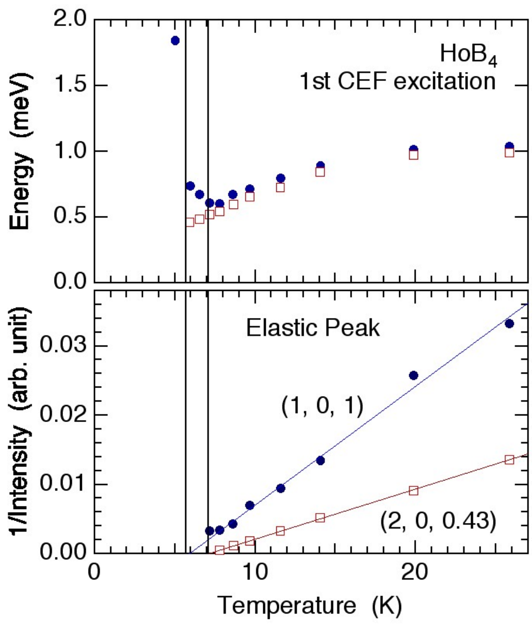

Fig. 1. (top) Temperature dependence of the 1st CEF excitation energy of HoB_4 at Q=(1, 0, 1) and (2, 0, 0.43). (Bottom) Temperature dependence of the inverse intensity of the elastic peak at Q=(1, 0, 1) and (2, 0, 0.43).