Order parameter of magnetic ion doped CexLa1-xB6

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Interactions between multipole degrees freedom give rise to rich variety of ordered phases in f-electron systems. $Ce_xLa_{1-x}B_6$ with the Γ_8-quartet ground state is a typical system. For $x > 0.75$, the ground state is an antiferro-quadrupole and antiferromagnetic ordered phases. An exotic phase of antiferro-octupole (AFO) order appears for $x < 0.75$. However, there remains a problem whether the AFO phase is purely of octupole or is mixed with other multipole degrees of freedom. The present theoretical model does not include the quadrupolar interaction [1].

Recently, Kondo and Sera discovered that the transition temperature of the AFO phase increases when Pr or Nd ion is doped [2]. The increase is larger for Pr, without the octupolar degree of freedom. At $x = 0.5$, it increases from 0.8 K to 1.8 K when 10 % of Pr is substituted with La, i.e., $Ce_{0.5}La_{0.4}Pr_{0.1}B_6$. This means that the AFO phase can mix with magnetic degree of freedom, which is contradictory to the proposed theoretical model.

We have performed neutron diffraction experiment on $Ce_{0.5}La_{0.4}Pr_{0.1}B_6$ to investigate whether the ordered state is an octupole phase. We used the triple-axis spectrometer TOPAN installed at the 6G port of JRR-3. The incident energy of 60 meV was selected and the collimation was Blank-60′-60′-Blank. A Joule-Thomson type ^{3}He gas cryostat was used. No magnetic field was applied. Figure shows the magnetic Bragg peak that develops below 1.8 K at q=(1/4, 1/4, 1/2), which is a propagation vector of the antiferromagnetic phase in CeB_6. The Q-dependence of the intensity for 17 equivalent spots well follows the magnetic form factor of Ce^{3+}, and this peak can definitely be ascribed to magnetic dipole order.

This result poses a new question whether the ordered phase of pure $Ce_{0.5}La_{0.5}B_6$ without doping is really an antiferro-octupole order as is so far believed. Studies of basic physical properties suggest that the relationship between the transition temperature and the concentration x seems to change at around $x = 0.6$. These result may suggest the ground state might be of magnetic dipole for $x < 0.6$. This is quite an important issue because the ground state must have intimate relation with the Kondo singlet in the dilute limit. Further experiment to clarify the real order paprameter for $x = 0.5$ is required.

[1] K. Kubo and Y. Kuramoto, J. Phys. Soc. Jpn. **72**, 1859 (2003).

[2] A. Kondo, T. Taniguchi, H. Tanida, T. Matsumura, M. Sera, F. Iga, H. Tou, T. Sakakibara, and S. Kunii, J. Phys. Soc. Jpn. **78**, 093708 (2009).

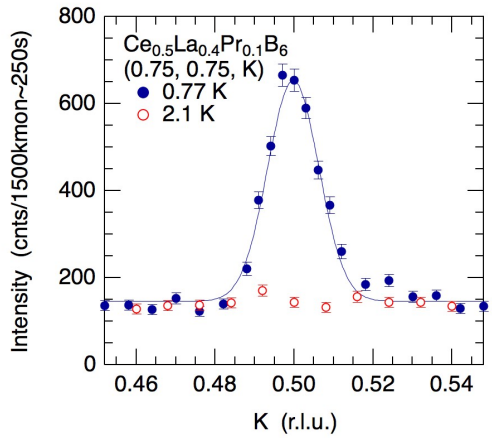

Fig. 1. Magnetic peak observed below 1.8 K.