^{11}B NMR study in the antiferromagnetic phase III of $Ce_{0.75}La_{0.25}B_6$

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Abstract

We have carried out the ^{11}B NMR experiments on single crystal of $Ce_{0.75}La_{0.25}B_6$ in order to investigate the magnetic structure of the antiferromagnetic (AFM) phase III. The NMR spectrum can be well fitted by the theoretical model, which reproduces the spectrum in phase III of CeB_6. It suggests that the magnetic structure in phase III of $Ce_{0.75}La_{0.25}B_6$ is similar to that of CeB_6. Also, from the analysis of the spectrum, the amplitude of the AFM moment is large enough even just below the phase IV-III transition point, which suggests that the AFM moment may grow up well in phase IV.

Key words: $Ce_{0.75}La_{0.25}B_6$; NMR; magnetic structure

1. Introduction

$Ce_xLa_{1-x}B_6$ is known to have an interesting phase diagram. Especially, the new phase called phase IV for $x \leq 0.8$ has attracted much attention, which shows mysterious low temperature properties. According to the phase diagram for $x = 0.75$, phase IV appears between the paramagnetic phase I and the antiferromagnetic (AFM) phase III, and remains only in a narrow region of the H-T plain. In $H = 0$, phase IV exists between 1.3 K and 1.7 K, and it exists up to 6 kOe[1]. The order parameter of phase IV is still controversial. An opinion is that phase IV is considered to be the incommensulate AFM state[2]. However, no magnetic superlattice peak has been discovered yet by the neutron scattering experiment[3]. Recently, a possibility of the AF octupolar ordering is discussed[4–6]. Further studies are necessary to get more information of phase IV. In order to clarify the order parameter in phase IV, it is very important to investigate the AFM phase III, neighboring phase IV. In case of CeB_6, it is indicated that the AF octupole moment plays an important role in phase III, as well as phase II[7]. The nuclear magnetic resonance (NMR) technique is one of the most suitable techniques to obtain the microscopic information of the magnetic state.

In this paper, we present the results of ^{11}B NMR experiments on single crystal of $Ce_{0.75}La_{0.25}B_6$ in order to elucidate the magnetic structure of phase III.

2. Results and Discussion

Figure 1 shows ^{11}B NMR spectrum in phase III of $Ce_{0.75}La_{0.25}B_6$ for $H \parallel [001]$ at 6.5 MHz and 0.1 K. Inset shows the spectrum in the AFM phase III of CeB_6 for $H \parallel [001]$ at 10.7 MHz and 1.4 K. In CeB_6, the spectrum is composed by sharp peaks. On the other hand, in $Ce_{0.75}La_{0.25}B_6$, the spectrum is considerably broadened by the La doping. According to the theoretical model[7], there are 9 non-equivalent B sites with satellite lines (that is, 27 peaks) for $H \parallel [001]$. This model can reproduce the spectrum in phase III of CeB_6[7]. In case of $Ce_{0.75}La_{0.25}B_6$, each resonance line obtained is

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Fig. 1. ^{11}B NMR spectrum in the AFM phase III of $Ce_{0.75}La_{0.25}B_6$ for $H \parallel [001]$ at 6.5 MHz and 0.1 K. Inset shows the spectrum in phase III of CeB_6 for $H \parallel [001]$ at 10.7 MHz and 1.4 K.

Fig. 2. Temperature dependences of the parameters, $4Tc_{10}$ and $4Ac_3$, in the AFM phase III of $Ce_{0.75}La_{0.25}B_6$. Inset shows the temperature dependences of the same parameters in phase III of CeB_6.

shown by vertical bar at the bottom in Fig. 1. The lines that are situated closely compose a broad peak. Solid line in the figure shows a fit to the experiment. The assumed parameters, defined in Ref. [7], are $4M(c_9 - c_1)$ = 196 Oe, $4Ac_3$ = 164 Oe, and $D = 4Tc_{10}$ = 63 Oe, with the Lorentzian width 230 Oe. Here, A is the amplitude of the AFM moment, T is the amplitude of the octupolar moment T_{xyz}, M is the uniform magnetization along [001]-axis, and c_i's are the coupling constants. As seen in the figure, the spectrum is well reproduced by this model. It suggests that the magnetic structure in phase III of $Ce_{0.75}La_{0.25}B_6$ is similar to that of CeB_6. Also, the nuclear quadrupole frequency is estimated to be 0.53 MHz, which is the same value as that in the paramagnetic phase I. Also, it is known that the amplitude of the octupolar moment decreases by La-doping, in comparison with the case of CeB_6. As for the magnetic structure in phase III of CeB_6, a complicated double k-k' structure (k = [1/4 1/4 0] and k' = [1/4 1/4 1/2]) was proposed by the neutron scattering experiment[8]. Quite recently, it is indicated that the magnetic structure of $Ce_{0.75}La_{0.25}B_6$ is characterized by the same two ordering vectors as those of CeB_6. But, the possibility that the magnetic structure may be different from that of CeB_6 is also suggested[3].

Figure 2 shows the temperature dependences of the parameters, $4Tc_{10}$ and $4Ac_3$, related to the amplitude of the octupolar and the AFM moments, in phase III of $Ce_{0.75}La_{0.25}B_6$. Inset shows the the temperature dependences of the same parameters in phase III of CeB_6. In case of CeB_6, $4Tc_{10}$ has only weak T dependence, which characterizes in the field-induced AF octupolar ordering phase II and grows up sufficiently in phase II. Also, $4Ac_3$ grows up suddenly below the phase II-III boundary, because of the order parameter in the AFM phase III. On the other hand, in case of $Ce_{0.75}La_{0.25}B_6$, $4Tc_{10}$ is almost T independent. Also, $4Ac_3$ has a weak T dependence and is large enough just below the phase IV-III boundary, in contrast to the phase II-III boundary of CeB_6. This result indicates that the AFM moment may grow up well in phase IV, suggesting that phase IV is a kind of AFM phase.

3. Summary

The ^{11}B NMR experiments has been carried out on single crystal of $Ce_{0.75}La_{0.25}B_6$ in order to clarify the magnetic structure of phase III. The NMR spectrum is broadened as compared with that of CeB_6, but can be reproduced by the theoretical model, the same as the case of CeB_6. It suggests that the magnetic structure in phase III of $Ce_{0.75}La_{0.25}B_6$ is similar to that of CeB_6. Also, from the analysis of the spectrum, the amplitude of the AFM moment is large enough even just below the phase IV-III transition point, which suggests that the AFM moment grows up well in phase IV. These results obtained support the view that phase IV is considered to be an AFM ordered phase.

Acknowledgements

The experiments at low-T were performed by using the equipment of Kitaoka Lab. of Osaka Univ. One of the authors (K.M.) would like to express thanks to Prof. Y. Kitaoka, Dr. G.-q. Zheng, Dr. K. Ishida, and Dr. Y. Kawasaki for their practical advice and help.

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