Low-temperature NMR studies of SrB$_6$

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Abstract

We report the results of a $^{11}$B nuclear magnetic resonance (NMR) study of SrB$_6$ at temperatures between 0.1 and 30 K and in a magnetic field of 4.74 T. Below 30 K the NMR spectrum is temperature independent but the spin–lattice relaxation rate $T_1^{-1}$ exhibits different features in two different temperature regimes. At high temperatures, between 30 K and a field-dependent crossover temperature $T_B$ between 0.5 and 2 K, $T_1^{-1}$ is almost temperature independent. We point out that for $T$ in the crossover temperature range the magnitude of $T_1^{-1}$ of SrB$_6$ is distinctly larger than for LaB$_6$, a metal with a charge carrier concentration at least two orders of magnitude higher than that of SrB$_6$. A possible cause for this behavior maybe the very weak itinerant ferromagnetism that has subsequently been established to occur in nominally pure SrB$_6$. At low temperatures, below $T_B$, $T_1^{-1}$ decreases substantially with decreasing temperature confirming a cross-over or phase transition phenomenon as observed by measurements of thermal and transport properties. © 2000 Elsevier Science B.V. All rights reserved.

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SrB$_6$ is a semimetal with a very small itinerant charge carrier density, of at least two orders of magnitude smaller than that of LaB$_6$ [1]. Its low-temperature properties seem to depend critically on details of the electronic structure [2]. From the results of magnetization measurements, it has recently been inferred that SrB$_6$ orders ferromagnetically with an onset temperature $T_C$ of the order of 900 K and involving very small magnetic moments (unpublished results).

Our NMR studies were performed at the B sites which form a network of octahedra joined by covalent bonds. The symmetry of the B sites is 4 mm, which allows for a nonzero field gradient, with axial symmetry. In Fig. 1 we display an example of the $^{11}$B-NMR spectrum for SrB$_6$ measured at a frequency of 64.81 MHz and at a temperature of 1.31 K. The shape of the spectrum is that of a characteristic powder pattern for spin $\frac{3}{2}$ nuclei, where a small quadrupolar perturbation splits the Zee-
Fig. 1. $^{11}$B-NMR spectrum of SrB$_6$ measured at 64.81 MHz and 1.13 K.

Fig. 2. $T_1^{-1}(T)$ for SrB$_6$ measured in an applied magnetic field of 4.74 T.

The temperature dependence of $T_1^{-1}$ for SrB$_6$ is not compatible at all with that expected for a paramagnetic metal or a semiconductor. Furthermore the magnitude of $T_1$ at $T \approx T_B$ is surprisingly large, even larger than that for LaB$_6$. This is not expected because LaB$_6$ has a much larger charge carrier concentration. We rule out magnetic impurities as a possible source for the anomalous relaxation because these result in a characteristic temperature and field dependencies for $T_1$ [4], not observed in our experiments. In addition, in the absence of spin diffusion, which seems to be the case here, the relaxation of paramagnetic impurities also implies a distribution of $T_1$s [4], again not observed here.

In view of the above one is tempted to associate the relaxation with excitations related to the ‘small-moment ordering’. However, in the temperature range of our experiments ($T < T_C$) this yields a $T_1^{-1} \propto T$ [5], instead of the observed $T$-independent relaxation. The crossover phenomenon at $T_B$ only adds another puzzle to the unexpected features of this seemingly simple compound.

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