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^{31}P NMR study of quadrupolar ordering and the field-induced heavy fermion state in $PrFe_4P_{12}$

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We have measured ^{31}P NMR in $PrFe_4P_{12}$ to investigate the quadrupolar-ordered and field-induced heavy-fermion states. Below the transition temperature T_A (= 6.5 K at zero field), field-induced splitting of the ^{31}P NMR lines was observed for the magnetic-field (H) directions lying in the $(1\bar{1}0)$ and (001) planes. The splitting comes mainly from alternation of the hyperfine coupling between P and Pr atoms, which evidences antiferro-quadrupolar ordering with a propagation vector $\mathbf{Q} = (1, 0, 0)$. The ^{31}P nuclear spin-lattice relaxation rate $1/T_1$ decreases rapidly below T_A at low fields, indicating a nonmagnetic crystal-electric-field ground state. At high fields where the quadrupolar ordering is suppressed, marked anisotropy of $1/T_1$ was observed. $1/T_1$ with $\mathbf{H}\|[100]$ decreases as T^p at low temperatures (the power p depends on the field strength) and is systematically reduced at higher fields. On the other hand, $1/T_1$ is almost field-independent and remains large for $\mathbf{H}\|[111]$, showing T-independent behavior down to 1.5 K. The enhancement of $1/T_1$ for $\mathbf{H}\|[111]$ may be related to the enhanced magnetoresistence with this field configuration [1].

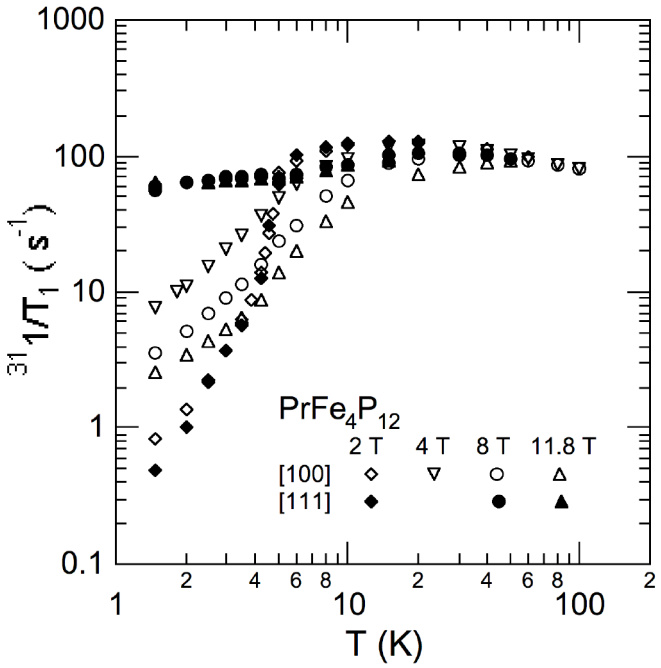

Figure 1: Temperature dependence of the ^{31}P nuclear spin-lattice relaxation rate in $PrFe_4P_{12}$.

[1] H. Sugawara, E. Kuramochi, T. D. Matsuda, T. Namiki, Y. Aoki and H. Sato, Meeting Abstracts of the Physical Society of Japan **58**-1-3 (2003) 576.