

Broken time-reversal symmetry in superconducting $\text{Pr}_{1-x}\text{La}_x\text{Pt}_4\text{Ge}_{12}$

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Filled skutterudite $\text{PrPt}_4\text{Ge}_{12}$ has been proposed to be the candidate to host gapless Majorana fermions. We argue that unconventional superconductivity with a complex order parameter in $\text{PrPt}_4\text{Ge}_{12}$ by our doping studies of $\text{Pr}_{1-x}\text{La}_x\text{Pt}_4\text{Ge}_{12}$ using specific heat, magnetization measurements, and zero-field muon spin relaxation. An additional inhomogeneous local magnetic field, indicative of broken time-reversal symmetry (TRS), is observed in the superconducting states of the alloys. For $x \leq 0.5$ the broken-TRS phase sets in below a temperature T_m distinctly lower than the superconducting transition temperature T_c . For $x > 0.5$, $T_m \approx T_c$. The local field strength decreases as $x \rightarrow 1$, where $\text{LaPt}_4\text{Ge}_{12}$ is characterized by conventional pairing. The lower critical field $H_{c1}(T)$ of $\text{PrPt}_4\text{Ge}_{12}$ shows the onset of a second quadratic temperature region below $T_q \sim T_m$. Upper critical field $H_{c2}(T)$ measurements suggest multi-band superconductivity, and point gap nodes are consistent with the specific heat data. In $\text{Pr}_{1-x}\text{La}_x\text{Pt}_4\text{Ge}_{12}$ only a single specific heat discontinuity is observed at T_c , in contrast to the second jump seen in $\text{PrOs}_4\text{Sb}_{12}$ below T_c . These results suggest that superconductivity in $\text{PrPt}_4\text{Ge}_{12}$ is characterized by a complex order parameter.