

# Crystal electric field and the ground state properties of heavy fermion $\text{Ce}_3\text{Ru}_4\text{Sn}_{13}$

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We report on the electronic structure, electric transport and basic thermodynamic properties of the skutterudite-related  $\text{Ce}_3\text{Ru}_4\text{Sn}_{13}$  and  $\text{La}_3\text{Ru}_4\text{Sn}_{13}$ . X-ray photoelectron spectroscopy (XPS) core level spectra revealed a stable trivalent configuration of the Ce atoms in  $\text{Ce}_3\text{Ru}_4\text{Sn}_{13}$ , consistent with magnetic susceptibility data. Magnetic susceptibility and specific heat measurements reveal that the sixfold degenerated multiplet of  $\text{Ce}^{3+}$  ions splits into three doublets, due to the tetragonal Ce point local symmetry in the cubic  $\text{Ce}_3\text{Ru}_4\text{Sn}_{13}$  system.  $\text{Ce}_3\text{Ru}_4\text{Sn}_{13}$  exhibits a large increase in the specific heat,  $C/T$ , data due to Kondo effect and strong electron and short-range magnetic correlations, we also suggest significant contribution of the crystal field effect.  $\text{La}_3\text{Ru}_4\text{Sn}_{13}$  is typically obtained as BCS superconductor, however, specific heat and electrical resistivity data show that  $\text{La}_3\text{Ru}_4\text{Sn}_{13}$  also exhibits a second superconducting phase at higher temperatures, which is characteristic of inhomogeneous superconductors.