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 typical 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.