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Experiments on new correlated electron systems [1]

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Multinary d- and f-electron compounds have proven to be a rich reservoir of strongly correlated electron ground states and phenomena: e.g., valence fluctuations, heavy fermion behavior, non-Fermi liquid behavior, quantum criticality, unconventional superconductivity, high temperature superconductivity, exotic forms of magnetic order, quadrupolar order, etc. These ground states and phenomena arise from a delicate interplay between competing interactions that can be tuned by variation of chemical composition (x), pressure (P) and magnetic field (H), resulting in complex electronic $T(x, P, H)$ phase diagrams. In this talk, we describe recent research performed in our laboratory on correlated electron phenomena in two classes of materials: (1) the noncentrosymmetric compounds with the formula $M_2T_{12}Pn_7$, where M = a rare earth or an actinide element, T = Mn, Fe, Co, Ni, and Pn = P, As, and (2) the filled skutterudite compounds $M\mathrm{Pt_4Ge_{12}}$, where M = an alkaline earth, a rare earth, or an actinide element [1, 2]. An extensive investigation of single crystals of $M_2\mathrm{Fe_{12}P_7}$, where M = Sm, Yb, Th, and U, grown in a Sn flux, was carried out by means of electrical resistivity, specific heat, and magnetization measurements as a function of temperature (T) and magnetic field (H). The $T - H$ phase diagram for single crystals of $\mathrm{Yb_2Fe_{12}P_7}$ reveals a crossover from a magnetically ordered non-Fermi-liquid (NFL) phase at low H to another NFL phase at higher H [3].

The crossover occurs near the value of H where the magnetic ordering temperature (T_M) is no longer observable, but not where T_M extrapolates smoothly to $T = 0$ K at a possible quantum critical point (QCP), indicating the occurrence of a quantum phase transition between the two NFL phases. The lack of a clear relationship between the extrapolated QCP and NFL behavior suggests an unconventional route to the NFL ground states.

We have also explored the behavior of other members of this "2-12-7" family of compounds including $\mathrm{U_2Fe_{12}P_7}$, which displays antiferromagnetic behavior below 14 K and possible metamagnetism [4], and $\mathrm{Sm_2Fe_{12}P_7}$, which appears to be a new heavy fermion, itinerant ferromagnet with a Curie temperature of ∼6 K [5]. Superconductivity and correlated electron behavior in the pseudoternary Pr-based filled skutterudite system $\mathrm{Pr_{1-x}Ce_xPt_4Ge_{12}}$ were studied by means of electrical resistivity, specific heat, and magnetization measurement down to 2 K. The compound $\mathrm{PrPt_4Ge_{12}}$ exhibits unconventional superconductivity below $T_c = 7.9$ K [2] with evidence for point-like nodes in the gap function [6] and time reversal symmetry breaking [7], while $\mathrm{CePt_4Ge_{12}}$ is a nonmagnetic Fermi liquid in which Ce has an intermediate valence [8]. The experiments show that T_c is suppressed linearly with increasing Ce concentration up to $x = 0.4$ and Fermi liquid behavior persists throughout the entire series ($0 \leq x \leq 1$).

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