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Non-Fermi-liquid signatures in stoichiometric Ce_7Ru_3 at ambient pressure

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Abstract

Magnetic ($\chi^{-1} \propto \sqrt{T}$) and thermal ($C_p/T \propto -\log T$) temperature dependencies of stoichiometric Ce_7Ru_3 are studied in order to establish whether its low temperature behavior corresponds to that of a non-Fermi-liquid system at normal pressure. Despite its reduced unit cell volume this compound shows a broadened antiferromagnetic transition, which involves only a small fraction of the expected entropy at $T = T_n = 0.8$ K. Scaling properties of $C_p/t = -A\log(t) + ET_o$ (with $t = T/T_o$) under magnetic field (B) are fulfilled with $A = 7.2$ J and $E = 0.07$ B. The thermal characteristics of the transition itself are compared with those of other Ce compounds that also exhibit a "Λ-shape" in the $C_p/T(T)$ dependence around T_n. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Cerium compound; Non-Fermi-liquid; Thermodynamic properties

Among the Ce_7T_3 compounds [1], antiferromagnetic (AF) Ce_7Ni_3 has received special attention because of the high density of states in its Ce_{II} sub-latttice [2] ($\gamma = 2.7$ J/Ce_{II}-atK^2), which coexists with the order ($T_n = 1.8$ K) of the Ce_I atoms. Measurements under pressure showed that in this compound $T_n \to 0$ at 0.38 GPa [3], where a non-Fermi-liquid (NFL) behavior sets in. There is another member of this family: Ce_7Ru_3, which appears to be closer to such a magnetic instability, showing the following characteristics: (i) the lowest $T_n = 0.8$ K among the Ce_7T_3 [1]; (ii) a volume 5% smaller than that of Ce_7Ni_3 despite that Ru atom is about 15% larger than Ni; similar contraction occurs with respect to other lanthanid homologues: Ln_7Ru_3; (iii) this is the only Ln_7Ru_3 keeping hexagonal Th_7Fe_3-type structure, and one of the few Ce compounds having different crystalline structure than that of the neighboring Ln isotypes. All these features can be understood as due to a significant charge transfer between the Ln and T sub-lattices, as suggested by the enhanced superconductor Th_7T_3 (T = Fe, Co, Ni), regardless of the large concentration of 3d atoms (notably Fe) [4]. Within the context of the NFL candidates, stoichiometry plays an important role because the different propositions concerning the microscopical origin of such a behavior involves disorder, frustration and zero temperature critical points [5]. A direct insight for an unusual behavior of Ce_7Ru_3 comes from the temperature dependence of its susceptibility, $\chi_{DC}(T)$, which between 2 and 300 K follows a continuously curved $\chi^{-1}(T)$ dependence (see Fig. 1), that cannot be accounted by crystal field (CF) effects only. Instead, a good description is obtained with a $\chi^{-1} \propto \sqrt{T}$ function (see also Fig. 1). Noteworthy, such a T dependence diverges at $T = 1.7$ K, despite its AF order with a maximum of $\chi_{AC}(T)$ at $T_n = 0.8$ K (see inset in Fig. 1).

The electronic specific heat $C_{el}(T)$ was obtained by subtracting the phonon contribution of superconducting La_7Ru_3 ($T_s = 1.9$ K), with $\gamma = 47$ mJ/mol K^2 and $\Theta_D = 160$ K [6]. At low temperature, $C_{el}(T)$ of Ce_7Ru_3 shows a

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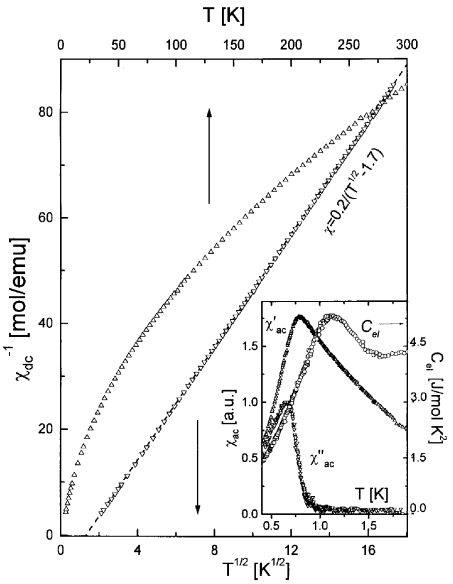

Fig. 1. Linear and root square temperature dependencies of the inverse DC-susceptibility. Inset: low-temperature AC-susceptibility and specific heat arround T_n (after Ref. [1]).

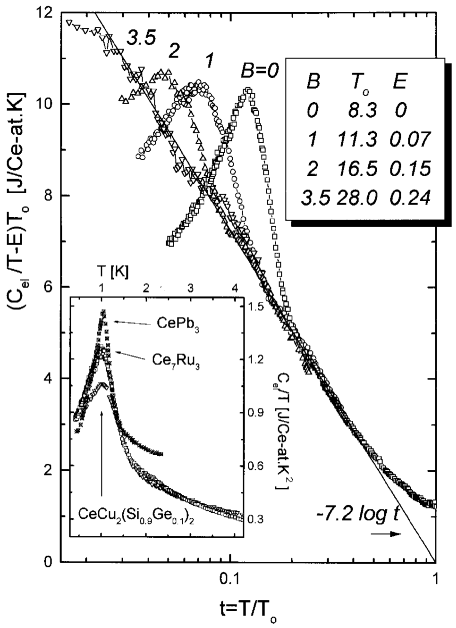

Fig. 2. Scaling of the specific heat results under applied field using the $C_{el}/t = -7.2\log(t) + ET_o$ equation. Units: B(Tesla), T_o(K) and E(J/Ce-at K^2). Inset: comparison of the Λ-shape transitions with identical T_n; the data of $CePb_3$ were re-scaled for clarity.

maximum at 1.15 K equal to $1.35T_n$ (see also inset of Fig. 1), like in randomly interacting systems. As shown in Fig. 2, the evolution of C_{el}/T is well described by the scaling function: $C_{el}/t = -7.2\log(t)$ [7], where $t = T/T_o$ and T_o is the only adjustable parameter. Such a function describes the magnetic field (B) effects by including an additive term $E = 0.07B$, which becomes the reference function that accounts for the entropy evolution when $T_n \to 0$ [7,8].

A $\chi^{-1} \propto \sqrt{T}$ dependence was already observed in the exemplary alloyed system $Ce(Cu_{5.9}Au_{0.1})$ [5] and in Ce_7Ni_3 above 0.38 GPa [3], though at much lower temperature. This suggests that the excitations related to the magnetic instability in Ce_7Ru_3 are distributed in a larger energy scale. This is in agreement with the greater hybridization strength denounced by the aforementioned significant volume effect and the absence of dominant CF effects on $\chi^{-1}(T)$. Other peculiar features of the magnetic transition of Ce_7Ru_3 are, the significant dissipation observed in $\chi''_{AC}(T)$ at T_n (see inset in Fig. 1) not present in mean field AF transitions, and the symmetrical "Λ-shape" of $C_{el}/T(T_n)$. Such a characteristic shape is also observed in $CePb_3$ [9] and $CeCu_2(Si_{0.9}Ge_{0.1})_2$ [10] at the same temperature (see inset in Fig. 2).

From the magnetic, thermal and structural properties of this stoichiometric compound at ambient pressure, we conclude that Ce_7Ru_3 lies even closer than Ce_7Ni_3 to a magnetic instability with the characteristics of a NFL system.

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