# Transport and Magnetic Properties of the New Cerium Ternary Ce-Pt-Ge Compounds

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**The new cerium ternary compounds $Ce_3Pt_4Ge_6$ and $Ce_2Pt_7Ge_4$ with novel crystal structure types have been prepared and characterized. We present transport and magnetic properties of these compounds in temperature range (2 - 300) K. Behavior of resistivity and magnetisation is similar, both compounds demonstrate Kondo-like features and possible magnetic transition near the helium temperature.**

## I. INTRODUCTION

The cerium intermetallic systems are the object of numerous experimental and theoretical studies in the past decade. These compounds represent a wide class of materials which demonstrate a different magnetic behavior that depends on the valence excitation energy of 4f states. The low temperature state of deep 4f level is determined by the direct exchange and crystal field effects and mostly involves magnetic order. Small valence excitation energy, on the other hand, leads to strong hybridization of 4f states with conduction electrons. The nonmagnetic intermediate-valent phase can occur in this case (see for example [1]).

The most interesting representatives of the cerium compounds belong to the narrow region in the valence excitation energies between the magnetic and intermediate-valent phase. This region is occupied by the so-called heavy-fermion systems [2], [3]. Heavy - fermion compounds demonstrate unusual low-temperature properties and are characterized by a large Sommerfield coefficient $\gamma$~$10^3$mJ/mol·$K^2$ that corresponds to the large quasiparticle mass $m^*$~$(10^2$-$10^3)m_0$. These features originate from the strong renormalization of the density of states due to sharp scatterring resonance near the Fermi level which is commonly connected with the Kondo effect in diluted alloys.

There are well-known and intensively studied ternary materials as $CeT_2X_2$ compounds, where T is a transition metal, and X represents Si or Ge. Members of this type of Ce based ternaries exhibit magnetic, heavy fermion and intermediate valent behavior for different compositions. However, some new cerium ternary systems have recently been discovered. At present, it appears still interesting to search for new types of cerium materials which might exhibit unusual behavior and complete the series of 4f systems.

In this paper, the synthesis and characterisation of two new cerium ternary intermetallics of the composition Ce-Pt-Ge are reported.

## II. EXPERIMENTAL

Polycrystalline samples of both $Ce_3Pt_4Ge_6$ and $Ce_2Pt_7Ge_4$ compounds were synthesized ([4], [5]) by melting the starting mixture in an arc furnace in an argon atmosphere followed by annealing at 870K for 600h. The purity of the starting metals was better than 99.9%. Single crystals suitable for X-ray analysis were taken from an ingot of 1g and were examined photographically (Mo K$\alpha$ and Cu K$\alpha$ radiation).

Electrical resistivity in the temperature range 2 - 300K was measured by the standard

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four-terminal DC method in helium cryostat. Thin copper wires were attached to the sample by electric spark method.

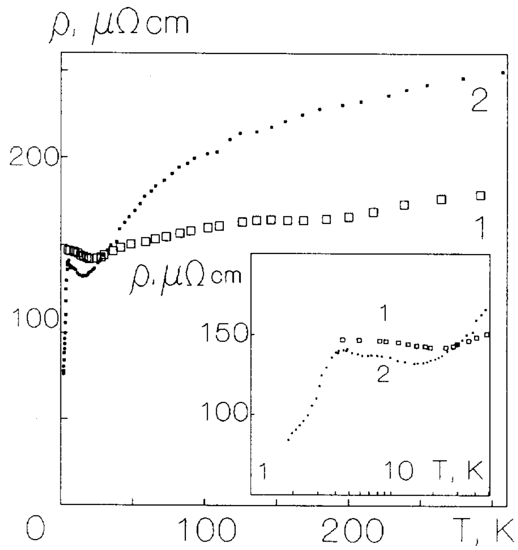


Fig.1 The temperature dependences of resistivity ρ(T) of $Ce_3Pt_4Ge_6$ (1) and $Ce_2Pt_7Ge_4$ (2). Inset shows the low temperature parts of the ρ(T) curves in semilogarythmic scale.

The magnetisation was measured by standard vibrating sample magnetometer PARC-155 in the fields up to 5kOe and in the temperature range 5 - 300K. The precise magnetic measurements were carried out by the SQUID magnetometer Quantum Design MPMS-5 at temperatures 2 - 300K and fields up to 5kOe.

## III. RESULTS AND DISCUSSION

The structure of $Ce_3Pt_4Ge_6$ was determined by direct methods to belong to space group Bmmb [4]. The results for $Ce_2Pt_7Ge_4$ sample show that this compound crystallizes in the structure of Pnma space group [5]. Both structures are novel types for ternary intermetallic compounds. The lattice parameters of both crystal structures are listed in table 1 below.

TABLE 1
THE UNIT CELL PARAMETERS OF THE Ce-Pt-Ge COMPOUNDS IN Å

| | a | b | c |
|---|---|---|---|
| $Ce_3Pt_4Ge_6$ | 4.419 | 4.422 | 26.222 |
| $Ce_2Pt_7Ge_4$ | 19.866 | 4.089 | 11.439 |

The temperature dependences of the resistivity ρ(T) of both samples are shown in fig.1. The ρ(T) curves demonstrate rather similar behavior characterized by the broad anomaly at $T^*$~100K, the minimum at $T_{min}$~20K and maximum $T_M$ around liquid helium temperature. The values of all these features are listed in table 2 for both samples. At temperatures between $T_{min}$ and $T_M$ the logarythmic increase of resistivity ρ~lnT were observed. However, the ρ(T) curve of $Ce_2Pt_7Ge_4$ has well defined features while that of $Ce_3Pt_4Ge_6$ is rather flat.

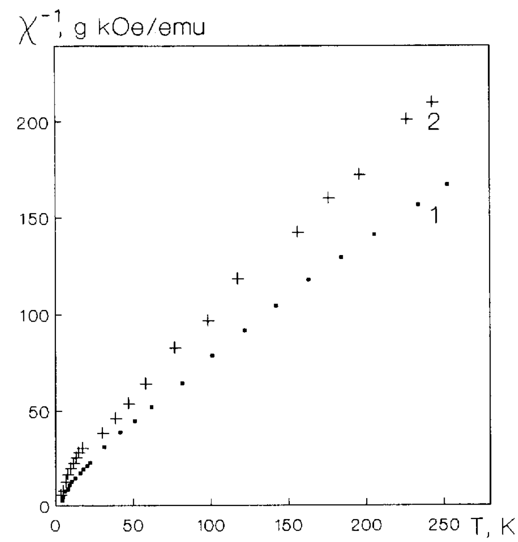


Fig.2 The temperature dependences of inverse magnetic susceptibility $\chi^{-1}$(T) of the $Ce_3Pt_4Ge_6$ (1) and $Ce_2Pt_7Ge_4$ (2) compounds.

Figure 2 shows the temperature dependences of the inverse magnetic susceptibility $\chi^{-1}$(T) of the Ce-Pt-Ge samples and figure 3 the field dependences of magnetisation M(H) of $Ce_2Pt_7Ge_4$. The χ(T) curves obey the Curie - Weiss law in the temperature range 50-250K, parameters of the fit, Curie constant $C_H$ and paramagnetic Curie temperature $T_P$ are presented in table 2. Corresponding effective magnetic moments $\mu_{eff}$ are of the order of that of free $Ce^{3+}$ ion. Below 20K the χ(T) data can be fitted by the same relation, but with $C_L$ about two times lower and $T_P$ about zero. Below the $T_M$ both χ(T) curves are situated over C/T relation. A difference between field cooling (FC) and zero field cooling (ZFC) measurements was observed below $T_M$ for the $Ce_2Pt_7Ge_4$ sample (see inset of fig.3). The shape of M(H) for both samples is similar to that of paramagnets (fig.3).

TABLE 2
PARAMETERS OF THE TRANSPORT AND MAGNETIC MEASUREMENTS OF THE Ce-Pt-Ge SAMPLES.

| | $Ce_3Pt_4Ge_6$ | $Ce_2Pt_7Ge_4$ |
|---|---|---|
| $T^*$ [K] | 140 | 80 |
| $T_{min}$ [K] | 30 | 20 |
| $T_M$ [K] | 4.2 | 3.5 |
| $C_H$ [emu/g·K] | $1.55 \cdot 10^{-3}$ | $1.26 \cdot 10^{-3}$ |
| $T_{PC}$ [K] | -20 | -20 |
| $C_L$ [emu/g·K] | $7.5 \cdot 10^{-4}$ | $6.8 \cdot 10^{-4}$ |

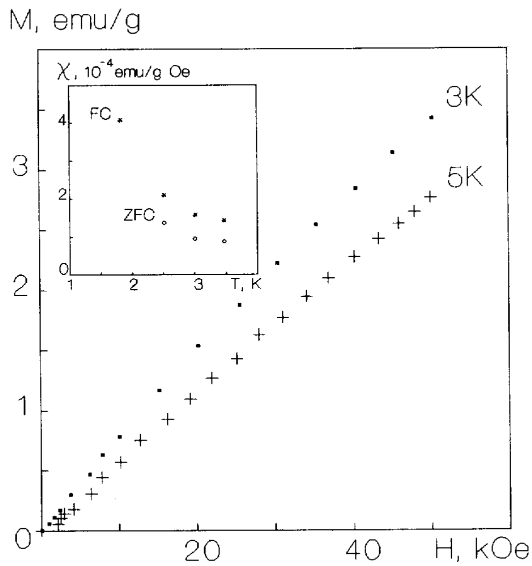


Fig.3 The field dependences of magnetisation M(H) of the $Ce_2Pt_7Ge_4$ compounds at temperatures 3 and 5K. Inset shows the difference between FC and ZFC measurements below 4K.

The maxima on the ρ(T) curves and logarythmic increase of the resistivity are characteristic features of Kondo lattices. The shape of the ρ(T) dependences could be explained by the combined influence of the Kondo effect that determines the low temperature behavior of the ρ(T) curves and the crystal electric field (CEF) splitting of the cerium f- level [3]. Such splitting in cerium Kondo systems is usually of the order of 100K and therefore may give an essential effect at higher temperatures. The Curie - Weiss dependence of χ(T) at high temperatures with the value of effective magnetic moment $\mu_H$ close to that of the free $Ce^{3+}$ ion is usual for Kondo systems too. The drop of the resistivity and upturn of the χ(T) together with the difference between FC and ZFC measurements below $T_M$ indicates that a magnetic transition might occur at this temperature.

In general, properties of cerium compounds depend on the Ce ion environment in crystal lattice. This determines the strength of f- and conduction electron hybridisation, CEF splitting of the f- levels and RKKY interaction, which is mostly responsible for magnetic ordering in cerium compounds. The similarity in the transport and magnetic properties of both $Ce_3Pt_4Ge_6$ and $Ce_2Pt_7Ge_4$ demonstrate that despite the different crystal structures there is rather small difference in cerium environment.

The results obtained here allow us to conclude that both cerium ternaries might be new memebers of the family of magnetic Kondo lattices. However, further study of transport, magnetic and thermodynamic properties is necessary.

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