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Magnetic Properties of Rare Earth—Lead Intermetallics*

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Magnetic susceptibilities of the series of intermetallics represented by the formula $R\mathrm{Pb}_3$ (R = Ce, Pr, Nd, Sm, Eu and Gd) are reported for temperatures ranging from 2.8 to 300°K. Curie–Weiss behavior is noted for all compounds except SmPb_3 with slopes in good agreement with that expected for assemblages of free tripositive ions (dipositive for EuPb_3). The behavior of SmPb_3 is in accordance with the behavior usually observed for Sm compounds and is due to the narrowness of the multiplet spacing in the tripositive samarium ion. PrPb_3 exhibits Van Vleck paramagnetism below 15°K; its susceptibility-temperature behavior is analyzed in terms of an overall crystal field splitting of 80°K. Results indicate the possible onset of antiferromagnetism at 17 and 22°K for GdPb_3 and EuPb_3, respectively. The other compounds give no indication of forming a cooperative magnetic phase at temperatures down to 2.8°K.

Introduction

Magnetic characteristics of intermetallic compounds containing the rare earths have been the subject of numerous studies carried out in this laboratory in recent years (*1*). The present work dealing with the rare earth-lead compounds represents a continuation of these studies. Phase diagram determinations and crystallographic work carried out by Gschneidner and his associates (*2, 3*) have revealed a series of intermetallics of composition $R\mathrm{Pb}_3$ (R = a rare earth) occurring in the $\mathrm{Cu}_3\mathrm{Au}$ structure. Magnetic susceptibilities of six $R\mathrm{Pb}_3$ compounds (with R = Ce, Pr, Nd, Sm, Eu and Gd) have been determined over the temperature range extending from 2.8 to 300°K and are reported in this communication.

Experimental Details and Results

The compounds were made by fusing together stoichiometric proportions of the components. The compounds were then annealed at 800°C for 1–2 weeks. Magnetic measurements were made by the Faraday method using technique and equipment which is standard in this laboratory (*4*).

Results are summarized in Table I and Figs. 1–3. Curie–Weiss behavior is noted at higher temperatures for all compounds except SmPb_3 with effective moments in reasonable agreement with those expected for free tripositive ions (the dipositive ion in case of EuPb_3). Predominance of antiferromagnetic exchange is indicated by the negative values of θ. Results obtained for CePb_3 are in good agreement with those reported in an earlier study from this laboratory (*5*). Only the Eu and Gd compounds give evidence of magnetic ordering; they seem to order antiferromagnetically near 20°K. The others give no evidence of the formation of a cooperative magnetic phase down to 2.8°K, despite their large negative Weiss Constants.

TABLE I

MAGNETIC CHARACTERISTICS OF RPb_3 COMPOUNDS

	μ_{eff} Meas	μ_{eff} Calcd*	θ(°K)	T_N
CePb_3	2.3	2.56	−20	—
PrPb_3	3.7	3.62	−10	—
NdPb_3	3.5	3.68	−25	—
SmPb_3	—	—	—	—
EuPb_3	7.5	7.94	−47	22°
GdPb_3	7.6	7.94	−60	17°

* $g\sqrt{J(J+1)}$.

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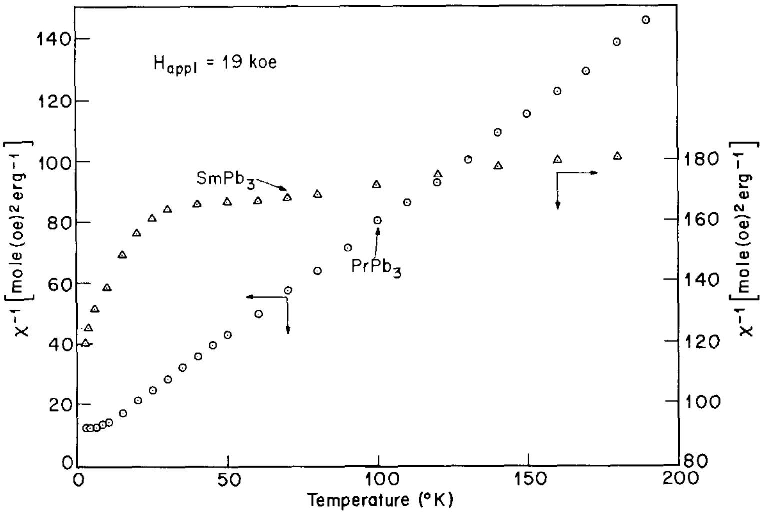

FIG. 1. Temperature dependence of inverse susceptibility of $SmPb_3$ and $PrPb_3$ in an applied field of 19 kOe.

As seen in Fig. 1, the χ_M^{-1} versus-T curve for $PrPb_3$ deviates from Curie–Weiss behavior below 10°K. This deviation can be attributed to the influence of the cubic crystal field on the Pr^{3+} ($5f^2$, $J = 4$) ions. The cubic crystal field splits the lowest J multiplet of Pr^{3+} into a singlet, two triplets and a doublet as shown in the inset of Fig. 2. From the values of χ_M^{-1} the crystal field energy splitting was estimated considering the crystal field potential to be pure fourth order (*6*, *7*). The influence of exchange was also taken into account using the expression $1/\chi = 1/\chi_0 - \lambda$, where χ_0 is the susceptibility in the absence of exchange and λ is the molecular field constant. The best agreement between the experimental and theoretical curves was obtained for a total crystal field splitting of about 80°K and $\lambda_M = -5.5$ (See Fig. 2). This leads to a Γ_1, Γ_4 separation of about 20°K.

Figure 1 also reveals the nonlinear behavior of χ_M^{-1}-versus-T curve for $SmPb_3$. The deviation from Curie–Weiss behavior is due to the existence of low lying multiplet ($J = 7/2$) lying about 1500°K above the ground multiplet ($J = 5/2$) (*8*).

The χ_M^{-1}-versus-T curves for $EuPb_3$ and $GdPb_3$ are presented in Fig. 3 together with the magnetization temperature curves for temperatures below 30°K. Weak maxima are observed at 17 and 22°K

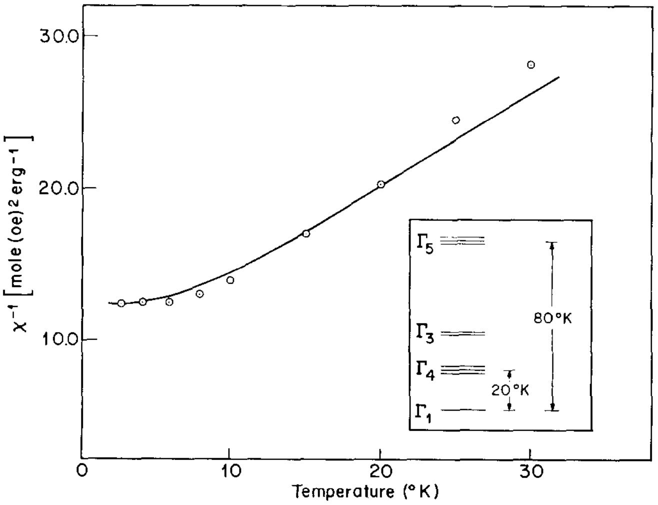

FIG. 2. Inverse susceptibility versus temperature for $PrPb_3$. The solid line indicates calculated values (see text); points represent experimental values.

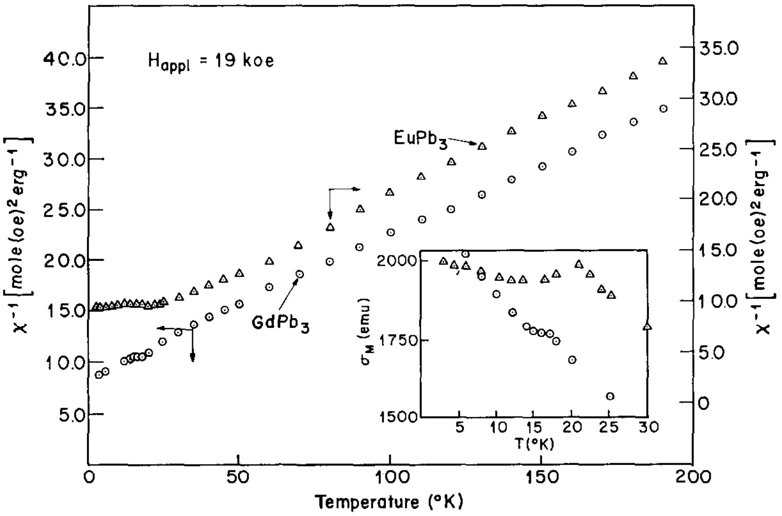

FIG. 3. Temperature dependence of inverse susceptibility and magnetization of $EuPb_3$ and $GdPb_3$ in an applied field of 19 kOe.

for $GdPb_3$ and $EuPb_3$, respectively, suggesting the formation of antiferromagnetic phases at these temperatures. The χ versus T behavior of $GdPb_3$ below the weak maximum closely resembles that of $GdIn_3$ observed by Buschow *et al.* (*9*).

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