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Journal
Physics Letters A, 30(3)

ISSN
0375-9601

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Publication Date
1969-10-01

DOI
10.1016/0375-9601(69)90904-9

MAGNETIC SUSCEPTIBILITY OF Ce AND Pr IN SrB_6 AND YB_6 *

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Received 27 August 1969

Magnetic susceptibility data suggest that the crystal field splittings of the 4f levels of Ce and Pr impurities are larger in metallic YB_6 than in isostructural and semiconducting SrB_6, contrary to what might be expected.

The alkaline earth and most of the rare earths form hexaborides whose structure may be pictured as a CsCl-type lattice with the cesium replaced by the metal, the chlorine by a B_6 octahedron. Theory [1] and experiment [2] agree that divalent metals form semiconducting hexaborides, trivalent metals electrically conducting hexaborides with one conduction electron per unit cell.

Fig. 1 is a Curie-Weiss plot of the magnetic susceptibility of Ce impurities in SrB_6 and YB_6, corrected for the host susceptibility. This correction is relatively large above about 150°K and therefore only the room temperature point has been taken at higher temperatures.

The cubic crystalline field at the metal atom site is expected to split the $J = \frac{5}{2}$ ground state of the cerium impurity into a quartet and a doublet. An analysis of the data similar to that given in ref. 3 finds the doublet lowest with a doublet-quartet splitting of 350°K for Ce in YB_6 and 20°K for Ce in SrB_6.

The susceptibility of CeB_6 is very similar to that for Ce in YB_6, except for an ordering peak near 3°K [4]. Nickerson and White have analyzed CeB_6 susceptibility data taken above 80°K using a model with temperature dependent exchange [5]. They find a splitting of 320°K, not very different from our value.

Fig. 2 is the same plot as fig. 1 with Pr replacing Ce. An analysis in terms of crystal field splittings is more complicated here. We merely

* Research sponsored by the Air Force Office of Scientific Research, Office of Aerospace Research, United States Air Force, under AFOSR grant number AF-AFOSR-631-67.

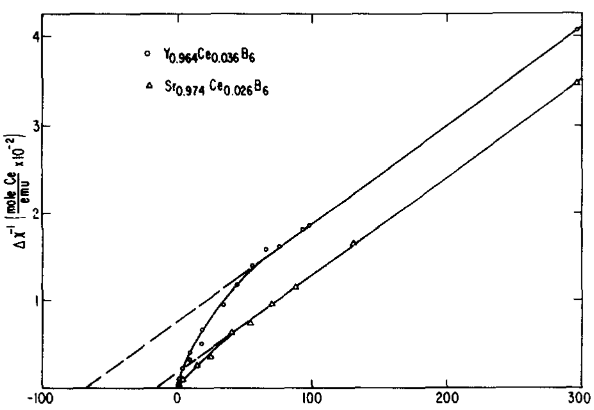

Fig. 1. Curie-Weiss plots of the magnetic susceptibility of Ce in YB_6 and SrB_6.

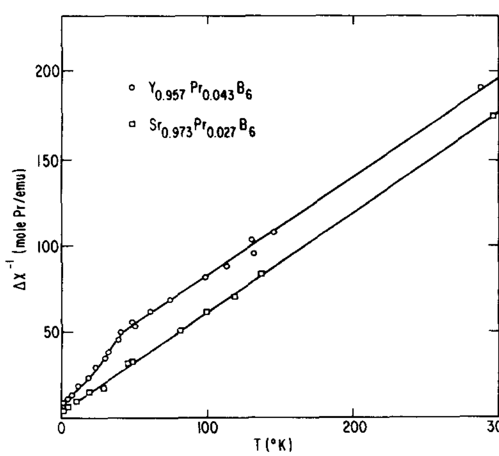

Fig. 2 Curie-Weiss plots of the magnetic susceptibility of Pr in YB_6 and SrB_6.

point out that it appears from fig. 2 that the splittings are larger in YB_6 than in SrB_6. We also note that the susceptibility of PrB_6 is very similar to that of Pr in YB_6 [4]. The data shown suggest that the ground state of the Pr ion is a singlet.

Static Stark fields are expected to be larger in the semiconductor than in the metal. It seems, therefore, that some other interaction is involved here. Such an interaction might involge the d-orbitals present in YB_6 but not in SrB_6. Another possibility is that the difference in nuclear charge screening on the magnetic impurity between the metal and the semiconductor significantly alters the radius of the 4f level, these levels being not strongly bound in Ce of Pr.

It appears that the 4f electron of Ce in YB_6 [6] as well as in CeB_6 [4] occupies a virtual bound state. Such does not appear to be the case for Pr. Judging from the similarity of the situations of Ce and Pr impurities considered here, it seems that the large effects in YB_6 are not a direct consequence of the presence of a virtual bound 4f level.

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MODULATION AND FAST DECAY OF PHOTON-ECHOS IN RUBY *

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Received 30 August 1969

Observations are reported on concentration effects, Cr-Al modulation and fast decay in photon-echo relaxation measurements in ruby, performed by the direct echo-signal versus time method.

We have made direct observations [1] of photon-echo relaxation of the states based on the R_1 line in ruby at liquid helium temperature and in fields up to 5 kG. The observed decay times are considerably faster than those previously measured by an indirect temperature-variation method and shorter than those predicted by phonon processes [2]. The decay times are independent of temperature in the range 2.2 to 4.2°K but decrease with increasing Cr concentration, indicating that Cr-Cr interactions are important in photon-echo decay. Superposed on these decay curves are strong echo modulations [3,4], which we observe only when the applied field is inclined to the sample optic axis.

We used previously described [5] experimental apparatus and a 1.5 m confocal spherical mirror delayline to generate the second pulse delays, τ_s. We found, when care is taken to adjust the delayline for unit magnification, that incremental changes of τ_s (in 10 nsec steps) from 30 nsec to 300 nsec could be made reproducibly and quickly in a single experimental run at fixed sample temperature. Variation of intensity due to multiple reflections over the range of τ_s was less than 15% and had a neglibible effect on the results.

Fig. 1 shows a logarithmic plot of photon echo signal versus pulse separation τ_s for several sample concentrations at 2.7 kG field. For the case of the external magnetic field accurately aligned parallel to the sample optic axis, the solid lines representing exponential decays are rea-

* Supported in part by Advanced Research Projects Agency, and monitored by U.S. Army Research Office, Durham.

** General Telephone and Electronics Fellow.

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