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ULTRALOW INTERACTION TEMPERATURES AND CRYSTAL FIELD EFFECTS FOR Gd IMPURITIES IN YPd₃ AND CePd₃ †

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Résumé.- La susceptibilité magnétique des impuretés de Gd montre que le comportement des ions est indépendant jusqu'à 10 mK si la concentration est inférieure à 0.15% dans YPd₃ et inférieure à 0.5% dans CePd₃. On peut expliquer ces résultats dans un modèle de champ cristallin.

Abstract.- The magnetic susceptibility of Gd impurities shows single ion behaviour down to 10 mK at concentrations below 0.15 % in YPd₃ and below 0.5 % in CePd₃. The data can be fitted with crystal field theory.

The search for single ion behaviour of magnetic impurities in metals has led to experiments with extremely dilute alloys at temperatures in the millikelvin range. Most of this work /1/ has been concerned with 3d impurities, and it is now established that impurity-impurity interactions mask single ion effects in this temperature range at concentrations as low as a few ppm.

Interactions between 4f impurities in metals are generally one, or in exceptional cases, more than two orders of magnitude smaller. For instance, from the interaction temperature of GdPd₃ (T_N = 7K) /2/ one estimates 7 mK per 1000 ppm of Gd in the diamagnetic metal YPd₃. Moreover, for the same concentration of Gd in CePd₃, this low interaction temperature is expected to be reduced even further because of the disruption of the long range RKKY interactions caused by the valence fluctuations in this host.

We have made measurements of the low field (50 mgauss) susceptibility of such alloys form 6 K down to 10 mK. Figure 1 shows Curie behaviour for three Gd concentrations in YPd₃ from 3 K down to 150 mK. Below that temperature we observe a smooth reduction of the susceptibility from the Curie law, which is, within the scatter, independent of concentration for the 500 and 200 ppm alloys. The temperature of about 25 mK at which the 5000 ppm alloy deviates from the low concentration data, indicates ordering of the expected magnitude.

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Gd in YPd₃. However, EPR experiments on these systems indicate crystal field effects with \( b_4 = 20 \) gauss, \( b_4 \gg b_6 \), and the \( \Gamma_7 \) doublet being the ground state for Gd in both YPd₃ and CePd₃. Stimulated by this finding, we have fitted our low field data with crystal field theory and found good agreement for the parameters indicated in figure 3.

In particular, we can fit the data in CePd₃ with the same scheme and parameters as found by EPR \( (b_4 = +2.7 \text{ mK \& 20 gauss}) \). However, the same data can also be fitted with \( b_4 = -3.5 \text{ mK} \) in YPd₃ on the other hand, the data can only be fitted with negative \( b_4 \), namely \(-6.1 \text{ mK}\).

It appears that the crystal field fits are as good as the Curie-Weiss fits. The Stark splittings obtained by these fits are in the range usually observed for metals by EPR, i.e. a factor of three to ten smaller than in insulators.

We wish to point out that crystal field effects of similar size as the one we observe here on \( 4f^7 \) ions in metals should be expected for the \( 3d^5 \) ions \( Mn^{2+} \) and \( Fe^{3+} \) in metals as well. Previous data on \( CuMn, ZnMn, MgMn, \) etc., as far as they could be analyzed with single ion behaviour, might be interpreted similarly on the basis of crystal field effects, rather than the Kondo effect. Clearly EPR data on such systems are desirable.

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References

/3/ Elschner, B. et al, private communication. The crystal field notation is that used by A. Abragam and N. Bleaney, Electron Paramagnetic Resonance of Transition Ions (Clarendon, Oxford, 1970)