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MAGNETIC ORDER IN THE Yb INTERMEDIATE VALENT SYSTEM
R_{0.14}Yb_{0.36}In_{0.5}Cu_{2}(R = Eu, Gd)

I. Felner (1'), I. Nowik (1') and Y. Yeshurun (2')

(1') Racah Institute of Physics, The Hebrew University, Jerusalem
(2') Department of Physics, Bar-Ilan University, Ramat-Gan, Israel

Abstract. – The system Yb_{1-x}In_{x}Cu_{2} exhibits a first order valence phase transition of the Yb ion. Partial substitution of Yb by Eu or Gd increases and decreases the valence phase transition temperature respectively. While the divalent Eu exhibits spin glass phenomena (T_G (0) ~ 20 K), the trivalent Gd stays paramagnetic down to 4.2 K.

The systems Yb_{1-x}In_{x}Cu_{2} of cubic Laves phase structure exhibit a sharp Yb valence phase transition at T_v ~ 50 K [1]. The properties of this transition were studied in great detail by many experimental techniques [2-5]. It was shown that pressure decreases T_v and “negative pressure” obtained by chemical substitution of Yb by La or Cu by Ag increases T_v [3-5].

External magnetic fields also decrease T_v [5]. It is expected that substitution of Yb by strongly magnetic ions may have a double effect on the valence phase transition, due to the different size of the introduced ion and due to its magnetic interactions. In order to test these ideas we have studied two similar systems Eu_{0.14}Yb_{0.36}In_{0.5}Cu_{2} and Gd_{0.14}Yb_{0.36}In_{0.5}Cu_{2}. Since the Eu in this system is divalent, this is obvious from the high temperature magnetic susceptibility and from Eu^{151} Mossbauer spectroscopy [4], its single ion magnetic properties are identical to those of Gd^{3+} (S=7/2 ground state). Thus we have here two systems in which Yb was substituted by ions of identical magnetic properties but they strongly differ in their valency and in their ionic size, Eu^{2+} is larger than Gd^{3+}.

The experimental magnetic susceptibility data show that Eu^{2+} being larger than Yb^{2+} increases T_v, while Gd^{3+} being smaller than Yb^{2+} decreases T_v. Though the single ion properties of Eu^{2+} and Gd^{3+} are similar the exchange interactions among the ions in the two systems are extremely different. While Gd_{0.14}Yb_{0.36}In_{0.5}Cu_{2} is paramagnetic down to helium temperatures, Eu_{0.14}Yb_{0.36}In_{0.5}Cu_{2} becomes magnetically ordered in a spin glass configuration with T_G (0) ~ 20 K. This indicates that the band structure of the system is strongly affected by the extra conduction electron difference in the two systems and thus also the RKKY exchange mechanism is strongly affected. The experimental dependence of T_G of the Eu system on external magnetic field does not agree with any simple power law formula.

The compounds were prepared by standard methods described earlier [1]. They were X ray analysed to show that they are of single phase of the Laves phase structure. The a lattice parameter at room temperature for Yb_{0.5}In_{0.5}Cu_{2} is 7.142 Å and for the Eu and Gd substituted samples: 7.162 Å and 7.172 Å respectively. The magnetic susceptibility was measured using a SQUID magnetometer in the temperature range of 4.2 to 200 K in fields from 20 Oe to 2 kOe. The magnetic susceptibility curves in low fields are shown in figures 1 and 2 for the Eu and Gd systems respectively. The figures also contain the behaviour of the inverse susceptibility which behave linearly at high temperatures and exhibit a break at the temperature at which the Yb ion changes valency (T_v). Below T_v the Yb ions being nonmagnetic contribute very little to the susceptibility. Above T_v they contribute the full paramagnetic contribution of Yb^{3+}. From these figures it is clear that T_v is about 70 K and 15 K for the Eu and Gd systems respectively. This huge difference is probably due to the large difference in ionic size of Eu^{2+} and Gd^{3+}.

Fig. 1. – Magnetic susceptibility and inverse susceptibility of Eu_{0.14}Yb_{0.36}In_{0.5}Cu_{2}.

Fig. 2. – Magnetic susceptibility and inverse susceptibility of Gd_{0.14}Yb_{0.36}In_{0.5}Cu_{2}.
relative to Gd$^{3+}$, though the different ionicity may also contribute.

From figure 2 it is clear that the Gd system is paramagnetic down to 4.2 K. On the other hand the Eu system exhibits a spin glass magnetic phase transition. The magnetic susceptibility depends on the cooling procedure. The zero field cooled curve at low temperatures is below the field cooled curve. The temperature at which they meet is defined as $T_G(H)$. We observe in figure 3 that $T_G$ decreases as the external magnetic field, $H$, is increased, as it should for a spin glass system. In figure 4 we plot $T_G$ as a function of $H$. In many spin glass systems $T_G(0) - T_G(H)$ follows a simple power law. This is not the case in the present system, probably due to the mixed valent character of the system. In ordinary rare earth intermetallic compounds Gd has the highest ordering temperature. Here Gd does not order and Eu does, indicating again the unique character of the mixed valent system.

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Fig. 3. – Field cooled and zero field cooled magnetic susceptibility curves of Eu$_{0.14}$Yb$_{0.36}$In$_{0.5}$Cu$_2$. The arrows indicate $T_G$.

Fig. 4. – The dependence of the spin glass transition temperature $T_G$ on external magnetic field.

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