MAGNETIC PROPERTIES OF Ce (Zn_{1-x}Cu_x)₂ SINGLE CRYSTALS

J. Voiron, P Morin, D. Gignoux, R. Aleonard

► To cite this version:

J. Voiron, P Morin, D. Gignoux, R. Aleonard. MAGNETIC PROPERTIES OF Ce (Zn_{1-x}Cu_x)₂ SINGLE CRYSTALS. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-419-C8-420. 10.1051/jphyscol:19888191 . jpa-00228346

HAL Id: jpa-00228346

<https://hal.science/jpa-00228346>

Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

MAGNETIC PROPERTIES OF $\text{Ce}(\text{Zn}_{1-x}\text{Cu}_x)_2$ SINGLE CRYSTALS

J. Voiron, P. Morin, D. Gignoux and R. Aleonard

Laboratoire Louis Néel, C.N.R.S., 166X, 38042 Grenoble Cedex, France

Abstract. – We present magnetization measurements performed on CeZn_2 and $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ single crystals along the *a*, *b* and *c* directions of the orthorhombic structure between 1.5 K and 300 K. Evolution of magnetic properties in the $\text{Ce}(\text{Zn}_{1-x}\text{Cu}_x)_2$ series is discussed considering crystalline electric field, magnetic interactions and Kondo effect.

CeZn_2 and CeCu_2 crystallize in the same orthorhombic CeCu_2 -type (Imma group space) structure. Their magnetic properties are highly anisotropic but quite different. CeZn_2 orders antiferromagnetically [1] around 7 K with the magnetic moments in the *b*-direction. It is characterized by Ising type behaviour in the ordered state: the magnetization curves, with the field applied along the *b* direction, exhibit three steps and because of the huge anisotropy, magnetizations along the *a* and *c* axes are very small [2]. On the other hand, CeCu_2 orders antiferromagnetically at 3.5 K [3] and neutron diffraction experiments suggest a very long-range antiferromagnetic structure [4]. However the easy axis is in the *a* direction and a metamagnetic-like behaviour has been observed at 1.5 K. Resistivity measurements [1, 3] have shown that Kondo effect is present in these two compounds. We have undertaken to study the evolution of the magnetic properties in the $\text{Ce}(\text{Zn}_{1-x}\text{Cu}_x)_2$ series and we present magnetizations of CeZn_2 and $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ single crystals measured along the *a*, *b* and *c* axes at various temperatures between 1.5 K and 300 K.

Magnetization measurements in CeZn_2 along *b* in increasing and decreasing fields are reported in figure 1. They show the existence of five different phases *versus* applied magnetic field. The critical fields are respectively $H_{c1} = 22.5$ kOe, $H_{c2} = 44$ kOe and $H_{c3} = 72$ kOe in agreement with the results of reference [1]. However, an additional phase is observed between $H'_{c2} = 40$ kOe and H_{c2} at 4.2 K but only in decreasing field at 1.5 K (Fig. 1) because of the large hysteresis. Effectively our measurements show the existence of a hysteresis for H_{c1} ($=1.7$ kOe at 1.5 K) and H_{c2} (4 kOe) but no hysteresis for H_{c3} .

Magnetization curves of a single crystal of $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ performed along the three directions of the orthorhombic structure present a quite different behaviour (Fig. 1). The easy axis is the *a* direction as in CeCu_2 and the values of the magnetization along the three axes appear to be similar to those of CeCu_2 . For example, the values of the magnetization measured at 4.2 K in a field of 60 kOe are $1.09 \mu_B$ and $1.19 \mu_B$ for the *a*-axis, 0.60 and $0.72 \mu_B$ for the *b*-axis and 0.18 and $0.20 \mu_B$ for the *c*-

Fig. 1. – The magnetization of CeZn_2 measured at 1.5 K along the *b*-axis by increasing and decreasing field ($\circ$) and the magnetization of $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ measured at 1.5 K along the *a*, *b* and *c* axes ($\times$).

axis for $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ and CeCu_2 , respectively [3]. However, the metamagnetic-like behaviour observed at 1.5 K in CeCu_2 [4] has not been observed along any of the axes of $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$.

Temperature dependences of the reciprocal susceptibility of CeZn_2 and $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ measured along the *a*, *b* and *c* axes are shown in figures 2 and 3, respectively. The anisotropy of the susceptibility is very large in the whole range of temperatures, reflecting the orthorhombic crystal structure. The thermal variation of the low field susceptibility of CeZn_2 along the *b*-axis presents a maximum at 7 K, which is the signature of the magnetic order. In contrast no such a maximum has been observed in the thermal dependence of the susceptibility of $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ compound. Contrary to CeZn_2 and CeCu_2 , $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ does not order magnetically down to 1.5 K. The paramagnetic Curie temperature θ_p and the effective moments μ_{eff} have been deduced for each direction from the linear part of $\chi^{-1}(T)$ at high temperature and are listed in table I, with those of CeCu_2 [5]. Properties of the $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ sample appear more similar to those of CeCu_2 than those of CeZn_2 .

The paramagnetic susceptibilities of our two samples

Fig. 2. - Temperature dependence of inverse magnetic susceptibility of CeZn_2 along the a, b and c axes and calculated curves.

Fig. 3. - Temperature dependence of inverse magnetic susceptibility of $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ along the a, b and c axes and calculated curves.

Table I. - The effective magnetic moment μ_{eff} and the paramagnetic Curie temperatures θ_p in CeZn_2 , $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ and CeCu_2 .

$H_{\parallel}$	CeZn_2		$\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$		CeCu_2 (Ref. [5])	
	$\mu_{\text{eff}} (\mu_B)$	θ_p (K)	$\mu_{\text{eff}} (\mu_B)$	θ_p (K)	$\mu_{\text{eff}} (\mu_B)$	θ_p (K)
a	2.68	- 34	2.58	+ 12.4	2.45	+ 17
b	2.47	+ 30	2.49	- 23.5	2.36	- 25
c	2.36	- 260	2.78	- 163	2.70	- 270

are analysed using the usual expression

$$\chi^{-1}(T) = \chi_{\text{CF}}^{-1}(T) - \lambda \quad (1)$$

$\chi_{\text{CF}}(T)$ is the crystal field susceptibility obtained from the usual Hamiltonian in orthorhombic symmetry:

$$\mathcal{H}_{\text{CF}} = B_2^0 O_2^0 + B_2^2 O_2^2 + B_4^0 O_4^0 + B_4^2 O_4^2 + B_4^4 O_4^4 \quad (2)$$

where B_l^m and O_l^m are crystal field parameters and Stevens operators respectively. λ is the exchange term arising from magnetic interactions and takes also into account Kondo interactions.

The best agreement between calculated and measured curves is obtained for the following sets of parameters: $B_2^0 = 13.7$ and 8.3 K, $B_2^2 = 0$ and -9.1 K, $B_4^0 = -0.25$ and -0.2 , $B_4^2 = -3.8$ and -1.1 K, $B_4^4 = -3.8$ and 0 K and $\lambda = -19$ and -31 mole/e.m.u. for CeZn_2 and $\text{Ce}(\text{Zn}_{0.75}\text{Cu}_{0.25})_2$ respectively. The deduced crystal field level scheme is reported in figures 2 and 3. The high temperature susceptibility is well described and the shape of $\chi(T)$ curves at low temperatures is well reproduced but with a constant shift of all the curves (except for the a-axis of CeZn_2). Uncertainties can proceed at high temperature (especially for the c-axis, the susceptibility of which is small) from the contribution of the matrix susceptibility which has not been subtracted. Differences observed at low temperature can be attributed to a smaller Kondo temperature at low temperature than at high temperature, since the effective Kondo temperature is decreased in presence of the crystalline field [6] and depends on the degeneracy of the ground state level. A smaller Kondo temperature will drive a smaller λ parameter in our fit and consequently a much better agreement (except for the a-axis of CeZn_2).

Substitution of only 25 % of Zn by Cu thus changes drastically the magnetic properties of CeZn_2 and yields properties more similar to those of CeCu_2 . The stability of the peculiar metamagnetic properties of CeZn_2 is probably limited to a narrow range of concentration. The Ising behaviour in CeZn_2 should be due to a delicate balance between exchange interactions and Kondo effect in a compound with a large uniaxial anisotropy due to crystal field.

- [1] Debray, D., Sougi, M. and Meriel, P., *J. Chem. Phys.* **56** (1972) 4325.
- [2] Yamashita, M., Kurisu, M., Kadomatsu, H., Oguro, I. and Fujiwara, H., *J. Phys. Soc. Jpn* **56** (1987) 32.
- [3] Onuki, Y., Machii, Y., Shimizu, Y., Komatsubara, T. and Fujita, T., *J. Phys. Soc. Jpn* **54** (1985) 3562.
- [4] Gratz, E., Bauer, E., Barbara, B., Zemirli, S., Steglich, F., Bredl, C. D. and Lieke, W., *J. Phys. F* **15** (1985) 1975.
- [5] Takayanagi, S., Onuki, Y., Komatsubara, T., *J. Phys. Soc. Jpn* **55** (1986) 2384.
- [6] Okiji, A., Kawakami, N., *J. Magn. Magn. Mater.* **54-57** (1986) 327.