

ESRF

Experiment title:
Magnetic Circular Dichroism in CeRh₃B₂.

Experiment
number:
HE363

Beamline:
ID12A

Date of experiment:
from:02/04/98 to:07/04/98

Date of report:
30/08/98

Shifts:
18

Local contact(s):
A. Rogalev

Received at ESRF:
02 SEP. 1998

Names and affiliations of applicants :

J.-P. Kappler and W. Grange, IPCMS, Strasbourg
E. Dartyge, LURE, Bât 209d, Orsay
P. Haen and P. Lejay, CRTBT, Grenoble
A. Rogalev, ESRF, Grenoble

Report: To be published in **Physica B** (1998)

Magnetic Circular Dichroism in CeRh₃B₂

W. Grange¹, J.-P. Kappler^{1,2}, E. Dartyge², P. Haen³, P. Lejay³, A. Rogalev⁴

¹IPCMS-GEMME, 23 rue du Loess, 67037 Strasbourg

²LURE, B.P. 34, 91898 Orsay

³CRTBT, B.P. 166, 38042 Grenoble

⁴ESRF, B.P. 220, 38043 Grenoble

Abstract

We report a magnetic circular dichroism study at the Ce-2*p* core level x-ray absorption spectra on the ferromagnet CeRh₃B₂. The Ce-*L*_{2,3} spectra on a single crystal are compared to that obtained on CeRu₂Ge₂ and CeFe₂, taken as reference systems. The shape of the circular dichroism signal, that witnesses the 4*f* hybridisation, support the delocalised picture of the 4*f* electrons in CeRh₃B₂.

1- Introduction

The study of the ternary boride CeRh₃B₂ is of great importance because of its exceptional ferromagnetic state. One of the most surprising feature is that the Curie temperature is unusually large (T_c= 115 K) for a Ce compound without 3*d* magnetic constituents [1]. Magnetisation measurements show that the saturation moment is only about 0.5-0.4μ_B/f.u [2]: this is much smaller than the free-ion value and has been attributed to large crystal effects and/or a Kondo type interaction [3,4].

The structural properties of CeRh₃B₂ seem also anomalous: CeRh₃B₂ crystallises in a distorted hexagonal *p6/mmm* CeCo₃B₂-like structure, with *a*= 5.484 Å and *c*= 3.087 Å; this latter value is the shortest never observed in intermetallic Ce compounds. The linear thermal expansion is large and highly anisotropic : along the *a* axis the expansion is nearly temperature dependent whereas along the *c* axis the expansion is three time larger than in an usual metal [5].

To precise the role played by the 4f and 4d electrons in the magnetic properties of CeRh_3B_2 , we present in this paper x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) experiments at the Ce and Rh $L_{2,3}$ edges. The comparison of the spectra with those obtained from some reference systems evidence the itinerant behaviour of the 4f electrons.

2- Results and discussion

The Ce and Rh $L_{2,3}$ XAS measurements were carried out at the ESRF beam-line ID 12A in the total fluorescence detection mode.

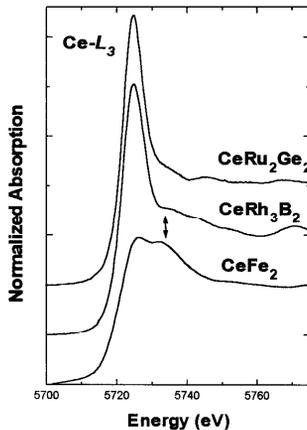


Fig. 1- $\text{Ce-}L_{2,3}$ edges in CeRh_3B_2 , CeRu_2Ge_2 and CeFe_2 (from ref. 8). The arrow indicates the position of the $4f^0$ contribution.

The XMCD signal was monitored by keeping the helicity of the incoming x-rays fixed and flipping the direction of the applied magnetic field. The XAS spectra presented here are recorded with the incoming light parallel to the direction of the applied magnetic field (2T) and perpendicular to the c axis, *i.e.* parallel to the easy axis of the magnetisation, at $T = 10\text{K}$.

As a first approach in the understanding of the magnetic properties of CeRh_3B_2 , one could expect that the high Curie temperature result from the Rh- $4d$ electrons. However, our own XMCD experiments performed at the Rh- $L_{2,3}$ edges exclude this assumption ($M_{\text{Rh}} \leq 0.004\mu_B$). This result is in agreement with both valence-band photoemission and recent polarised neutron diffraction measurements [6].

We now discuss results obtained from measurements at the Ce- $L_{2,3}$ and show that the character of the $4f$ states are intermediate to that found in strong localised and well delocalised Ce compound.

In highly correlated systems the Ce- $L_{2,3}$ absorption edges may present a satellite located at about 10 eV above the main white line. This structure can be interpreted either as a "shake up" or the signature of a $4f^0$ configuration in the ground state (the 4f electrons interact strongly with the $2p$ core holes leading to $2p^5 4f^0 5d^{n+1}$ and $2p^5 4f^1 5d^{n+1}$ final states [7]). The interpretation of the satellite is far from trivial; however the Ce- $M_{4,5}$ edges also show a weak satellite. This suggests that the structure (not observed for trivalent Ce compounds such as CeRu_2Ge_2) results from a $4f^0$ configuration. Consequently, the $5d-4f$ hybridisation is certainly non negligible in

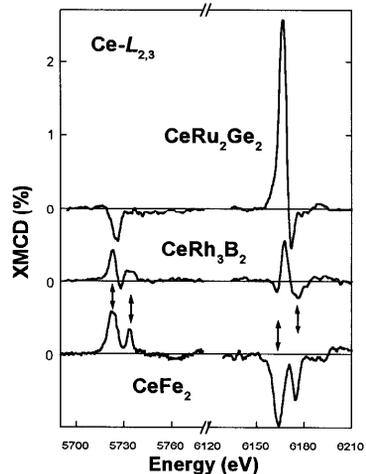


Fig 2. XMCD at the Ce- $L_{2,3}$ edges for CeRu_2Ge_2 , CeRh_3B_2 and CeFe_2 (from ref. 8). Normalised absorption unit corresponds to 1 % of the edge.

CeRh_3B_2 . Figure 2 illustrates the XMCD response at the Ce- $L_{2,3}$ edges for CeRu_2Ge_2 ($T_c = 8\text{K}$), CeRh_3B_2 ($T_c = 110\text{K}$) and CeFe_2 ($T_c = 220\text{K}$). The presence of signal reveals the existence of a $5d$ polarisation. The large palette of magnetic signals observed shows that the $5d$ XMCD is very sensitive to the Ce ground state. For CeRu_2Ge_2 , where the $4f^1$ localised character is undisputed, the XMCD signals are characterised by a negative (positive) signal at the L_3 (L_2). The signs of the integrated intensity are opposite to that expected from the one-particle model.

Moreover, the branching ratio (+2), is far away from the -1 value expected by the $L_{2,3}$ edges band structure and corresponding to a pure spin contribution. Such dichroic signals, always observed for well localised $4f^1$ systems, are taken as a reference for weak Kondo temperature systems [8,9]. In contrast, for CeFe_2 both the sign and the branching ratio of XMCD are in accordance with the one-particle model, in agreement with the small Ce- $4f$ moment contribution and then with the itinerant $5d$ band character, without orbital contribution. The unusual XMCD observed in CeRh_3B_2 , which can be interpreted as a combination of that observed in CeFe_2 and CeRu_2Ge_2 , demonstrates the importance of the $4f$ hybridisation in the peculiar properties of CeRh_3B_2 . Indeed, the arrows in Fig. 2 illustrate the possible correspondence of the main XMCD structures of CeFe_2 and those of CeRh_3B_2 .

3- Conclusions

In conclusion, the XMCD signals in CeRh_3B_2 suggest that the $4f$ does not reach the high degree observed in CeRu_2Ge_2 due to $5d$ - $4f$ hybridisation. This result is in agreement with the additional features observed in Ce- $M_{4,5}$ absorption edges.

References

- [1] S.K. Dhar *et al.*, *J. Phys. C* **14** L321 (1981).
- [2] M. Kasaya *et al.*, *J. Magn. Magn. Mater.* **76&77**, 347 (1988).
- [3] K. Yamaguchi *et al.*, *Phys. Rev.* **B46**, 9845 (1992).
- [4] K. Yamaguchi *et al.*, *Phys. Rev.* **B51**, 13952 (1992).
- [5] A.C. Lawson, A. Williams and J. G. Huber, *J. Less-comm Met.* 136 87 (1987).
- [5] E.V. Sampathkumaran *et al.*, *Phys. Rev.* **B31**, 3185 (1985).
- [6] J.A. Alonso *et al.*, *J. Magn. Magn. Mater.* in press (1998).
- [7] J. Röhler, in *Handbook of the Physics and Chemistry of Rare Earths* (North Holland, Amsterdam, 1987)
- [8] Ch. Giorgetti *et al.*, *Phys. Rev.* **B48**, 12732 (1993).
- [9] M. Arend *et al.* *Phys. Rev.* **B57**, 2174 (1998).