Neutron diffraction studies of CeAl2 at low temperature
B. Barbara, J. Boucherle, J. Buevoz, M. Rossignol, J. Schweizer

To cite this version:

HAL Id: jpa-00218892
https://hal.archives-ouvertes.fr/jpa-00218892
Submitted on 1 Jan 1979

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.
Neutron diffraction studies of CeAl₂ at low temperature

B. Barbara (*), J. X. Boucherle (**) , J. L. Buevoz (°), M. F. Rossignol (*) and J. Schweizer (**°)

(*) Laboratoire Louis-Néel, C.N.R.S., 166X, 38042 Grenoble Cedex, France
(**) D.R.F.-D.N., Centre d'Etudes Nucléaires, 85X, 38041 Grenoble Cedex, France
(°) Institut Laue-Langevin, 156X, 38042 Grenoble Cedex, France

Résumé. — Des mesures de neutrons polarisés sur CeAl₂ montrent que le magnétisme est essentiellement dû à des ions Ce³⁺ et mettent en évidence un couplage anormal entre les spins de Ce et la polarisation des électrons de conduction. D'après les mesures de neutrons sur poudre et sur monocristal nous avons démontré que la structure magnétique est modulée sinusoïdalement jusqu'à T_N/10, résultat incohérent avec la dégénérescence de Kramers. Ces deux points particuliers peuvent être reliés au comportement Kondo à haute température.

Abstract. — Polarized neutron measurements on CeAl₂ show that the magnetism is essentially due to a Ce³⁺ ion and indicate an anomalous coupling between the Ce spins and the polarization of conduction electrons. From powder and single crystal neutron measurements we have demonstrated that the magnetic structure is sinusoidally modulated down to T_N/10, a result which is incompatible with Kramers' degeneracy. These two particular results can be related to the high temperature Kondo behaviour.

1. Introduction. — At high temperature, CeAl₂ is known to be a Kondo compound [1]. In this paper we summarize the results of neutron diffraction studies carried out in Grenoble, which clarify the nature of the magnetism in CeAl₂ at low temperature.

2. Individual behaviour of cerium atom. — Polarized neutron diffraction allows to access to the magnetization densities. Such experiments have been done on CeAl₂ at T = 1.5 K on the ferromagnetic component induced by an applied field of 48 kOe using the facilities of the diffractometer D5 at the I.L.L. For a field applied along the [011] axis, the magnetic amplitudes show a substantial and unusual dispersion which can be explained by the anisotropy of the 4f form factor : a calculation based on a Ce³⁺ model, including crystal and exchange fields [2] shows a very good agreement with the experiment (figure 1). Thus it is obvious that the greatest part of the magnetism is due to a Ce³⁺ moment.

However the systematic deviations observed at low sin θ/λ are very interesting. The calculated values of the form factor are smaller than the observed ones. This is due to a polarization of conduction electrons as shown previously in the isomorphous compound NdAl₂ [3]. But in CeAl₂, contrary to the results obtained for the other RA1₂ compounds [3-5] and more generally for rare earth metal and alloys [6], this polarization tends to increase the Ce³⁺ moment. Since J = L – S the spins S and e of Ce and conduction electrons are opposite corresponding to a negative constant 3 in the coupling Hamiltonian \(-2J(Se).

This result is a direct measurement of the negative resonant coupling introduced to describe the Kondo effect in cerium compounds [7].

3. Collective behaviour of cerium moments. — Taking into account the localized magnetism on the Ce³⁺ ions, it is possible to throw some light on their collective behaviour by studying the magnetic struc-
ture at low temperature. Given the negative results of many experiments performed on classical powder neutron diffractometer, we have used the ultra-sensitive multidetector powder diffractometer D1B of the I.L.L. Numerous very weak extra lines were observed at 1.9 K. They were indexed by means of a unique propagation vector $\mathbf{k} = 1/2 + \tau, 1/2 - \tau, 1/2$, with $\tau = 0.112$. Their intensities allow to show that all the moments are along the [111] axis and sinusoidally modulated. The experimental maximum value of the moment (0.89 $\mu_B$) is in good agreement with a calculation [8], assuming a $T_\gamma$ doublet as crystal field ground state [9]. Such a ground level should lead, at low temperature, to an antiphase structure [10] which cannot be detected here due to:

- the weakness of the moment which does not allow to see higher order satellites,
- the relatively high value of the temperature: at 1.9 K ($\sim T_N/2$) the thermal effect cannot be completely neglected [11].

A study [12] on a single crystal down to 0.4 K ($\sim T_N/10$) has confirmed the powder results: the sinusoidally modulated structure (figure 2) remains frozen as shown by the absence of higher order satellites and the invariance of $\tau$ value (figure 3) down to 0.4 K. The resulting reduction of most of the Ce moments is incompatible with a $T_\gamma$ Kramers doublet and implies a non magnetic ground level [12].

4. Conclusion. — Three important points stand out in these neutron studies:

- a magnetic ordering exists in CeAl$_2$ below 3.8 K,
- the stable modulation of the moment implies a singlet as ground state [11]. Such a ground state cannot arise from crystal field for a Kramers’ ion, but can be due to a coupling with conduction electrons.
- this coupling constant $\tilde{\lambda}$ is negative which is a necessary condition for the existence of a Kondo singlet [13].

Numerous theoretical studies [14-17] are in progress to explain the coexistence of magnetic ordering and Kondo effect in CeAl$_2$.

References