MAGNETIC LINE-WIDTH OF THE IV-COMPOUND YbCu2Si2

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MAGNETIC LINE-WIDTH OF THE IV-COMPOUND \(\text{YbCu}_2\text{Si}_2\) †

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Résumé.- Le spectre de puissance des niveaux Zeeman 4f magnétiques sur les ions fluctuants du Yb a été mesuré en fonction de la température par diffraction diffuse magnétique de neutrons. Une largeur de raie \(\Gamma/2\approx 7\) meV quasiélastique, presque indépendante de la température a été détectée. Pour la première fois, les mesures ont été étendues, dans cette expérience, à la spectroscopie de perte d'énergie à \(k_B T<\Gamma/2\).

Abstract.—The power spectrum of the magnetic 4f Zeeman-levels on the fluctuating Yb-ions was measured as a function of temperature by diffuse magnetic neutron scattering. A nearly temperature independent quasielastic line width \(\Gamma/2\approx 7\) meV was detected. In this experiment, the measurements were extended, for the first time, to the energy loss spectroscopy at \(k_B T<\Gamma/2\).

It has been established previously by measurements of the diffuse magnetic neutron scattering cross-section of CePd$_3$ /1/ and Ce$_x$Th$_{1-x}$ alloys /2/ that in the so-called valence fluctuation phase the 4f Zeeman-levels relax spontaneously and nearly independent of temperature at a rate of about \(10^{-13}\) s. It was not possible to establish unequivocally the existence of this relaxation near \(T=0\) in these first experiments, because they were performed by measuring the energy gain of the neutron and therefore suffered from severe intensity problems at \(k_B T<\Gamma/2\). We report here the first such measurements on a Ytterbium fluctuation valence compound in both energy gain and energy loss.

The problem with energy gain measurements is demonstrated in figure 1. If one assumes a temperature independent Lorentzian power spectrum, the energy dependence of the scattering cross-section at a given momentum transfer \(Q\) has the form of \(F(\omega)\) as shown in the upper left of figure 1. In the high temperature approximation \((k_B T>\Gamma/2)\) \(F(\omega)\) approaches a Lorentzian with an intensity proportional to \(k_B T\). In this case, energy loss and energy gain spectroscopy can both measure the width \(\Gamma/2\). However, at \(k_B T<\Gamma/2\) the scattering goes to zero on the energy gain side, because there are no excitations in the sample to give energy to the neutron. Thus in order to establish the existence of the Lorentzian power spectrum near \(T=0\), energy loss spectroscopy has to be performed with incoming neutron energy \(E_0\) larger than \(\Gamma/2\).

The measured spectrum will then correspond to the hatched area under the heavy line. This spectrum originating from a broad quasielastic Lorentzian can be clearly distinguished from the usual inelastic line spectra (see also C. Balseiro and A. Lopez /3/).

As before /1/ along with those on the intermediate valence (IV)-compound \(\text{YbCu}_2\text{Si}_2\) we have performed measurements on a diamagnetic compound \(\text{LaCu}_2\text{Si}_2\) and a compound with a stable 4f-shell \(\text{TbCu}_2\text{Si}_2\), in order to separate inelastic phonon scattering and to contrast the normal Korringa behaviour of the line width for a stable 4f-shell against the large temperature independent width of...
IV-compound. Figure 2 shows the energy gain spectra at room temperature (measured by TOF method). The hatched area is the elastic nuclear incoherent scattering and exhibits the instrumental resolution at \( h\omega=0 \) by its width. In figure 2a the scattering intensity around \(-15 \text{ meV} \) fulfilled a \( Q^2 \)-dependence and is due to phonon scattering. The drawn out line in figure 2b is a fit of the diffuse magnetic scattering according to

\[
S(Q,\omega) = \frac{1}{2} \left( \frac{\mu B}{\hbar} \right)^2 P^2(Q) \chi(T) \times \frac{\hbar \omega}{1-e^{-\hbar \omega/\mu B}} \times P(\hbar \omega)
\]

(1)

Here is \( P(Q) \) the local magnetic 4f-form factor, \( \chi(T) \) the static susceptibility and \( P(\hbar \omega) \) the power spectrum, e.g. a Lorentzian. In a time-of-flight experiment the value of the momentum transfer \( Q \) varies with energy transfer \( h\omega \) for a constant scattering angle \( 2\theta \). The fit includes the incoherent scattering. The additional intensity over the fit is due to phonon scattering. (The original fit was performed on a difference spectrum of \( \text{YbCu}_2\text{Si}_2 \) and \( \text{LaCu}_2\text{Si}_2 \).) In the power spectrum \( P(\hbar \omega) \) we have assumed one quasielastic magnetic line (dashed) and one inelastic magnetic line (dotted) centered at \( 12 \text{ meV} \) with a nearly temperature independent width \( \Gamma/2=(15 \pm 5) \text{ meV} \). The width of the quasielastic line obtained from such fits is plotted as a function of temperature down to 30 K in figure 4a (circles). Figure 3 shows energy loss spectra of the same systems at 5 K. The energy \( E_0 \) of the incident neutrons was 12.5 meV. Fits on the basis of formula (1) yield line widths plotted in figure 4a (triangles).

The values of \( \Gamma/2 \) are consistent with the fluctuation energy of 6.5 meV derived from the static susceptibility \( 1/4 \) or the width of the zero bias anomaly derived by tunnelling spectroscopy \( 1/5 \) on the same compound.

\[ \text{Fig. 3: Energy loss spectra of YbCu}_2\text{Si}_2 \text{and LaCu}_2\text{Si}_2 \text{for } 2\theta=14^\circ \text{ at } 5 \text{ K; } E_0=12.5 \text{ meV.} \]

\[ \text{Fig. 4b shows the temperature dependence of the line width of TbCu}_2\text{Si}_2. \]

\[ \text{Fig. 4: Quasielastic line widths of YbCu}_2\text{Si}_2 \text{and TbCu}_2\text{Si}_2 \text{plotted against temperature.} \]

As previously for \( \text{CePd}_4 \) we now observed a very large nearly temperature independent line width in \( \text{YbCu}_2\text{Si}_2 \), which at 30 K is 60 times wider than the magnetic line of the stable valence compound \( \text{TbCu}_2\text{Si}_2 \). The existence of the Lorentzian spectrum at \( T<<\Gamma/2 \) is quite convincingly demonstrated by comparison of figure 3a with figure 1. This measurement establishes more firmly than before the fact that the large \( \Gamma/2 \) for IV-compounds is a property of the ground state.

References


