CONF-8704171--1
BNL 39823

Paper number: 117 BNL--39823 Y. Yamaguchi

DE87 010789

MAGNETIC EXCITATIONS IN AN ITINERANT ELECTRON ANTIFERROMAGNET Cr_2As

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Abstract

Spin wave excitations in an itinerant electron antiferromagnet Cr_2As was measured using neutron spectroscopy. Magnon dispersion is linear to the reciprocal lattice vector for small q, and the slope is 125 and 185 meVÅ along c- and a-axis, respectively. The slope is about two times larger than the value predicted from the molecular field theory.

Running title: Magnetic exciations in Cr_2As

Key wods: Cr_2As, Antiferromagnet, Spin wave, Neutron spectroscopy

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There is a series of intermetallic compounds that are composed of 3d-transition elements and arsenic or antimony with tetragonal crystal structure of Cu_2Sb type. One of the point of interest is that there are many kinds of magnetic structure in this group of compounds. For example, Mn_2Sb is a ferrimagnet [1], and Cr_2As [2], Mn_2As [3] and Fe_2As [4] are all antiferromagnets while their magnetic structures differ from one another.

Among them Cr_2As, T_N=393 K, is interesting in two points. One is concerning to the magnetic interaction between Cr atoms, which occupy two kinds of sites as shown in Fig. 1 [2]. We can see from the magnetic structure shown in Fig. 1 that the isotropic exchange interactions cancel out between site-I and II chromium. There exists only anisotropic exchange interaction between them. It is interesting to know the character of the anisotropic exchange interaction by measureing the spin wave dispersion relation.

The other interesting point is the smallness of the magnetic moments in Cr_2As. The values are 0.40 ± 0.08 and $1.34 \pm 0.06\ \mu_B$ for Cr(I) and Cr(II), respectively [2]. We imagine from these values that Cr(I) is in the metallic chromium state surrounded by eight chromium and four arsenic atoms. In the other hand Cr(II) is thought to be in a localized electron state as it is surrounded by four chromium and five arsenic atoms. In the other words, Cr_2As is a system of coexisting of itinerant and localized 3delectrons.

A specimen of about 0.3 cm^3 grown by the Bridgman method was used for the neutron scattering experiments. Its mosaic spread was 30'. The experiments were carried out on the H4M spectrometer at the Brookhaven HFBR. Constant-energy scans were used with final neutron energy of 14.7 and 30.5 meV. The monochromator and anlyzer were pyrolitic graphite, and also a filter of pyrolitic graphite was used to remove higher order contamination. The sample was mounted with a [100] axis vertical. The inelastic scattering measurements were made at 293 K around reciprocal lattice points of (0, 0, 2.5), (1, 0, 1.5) and (1, 0, 0.5). Typical scans are shown in Fig.2.

The observed spectra are convolution of the neutron scattering cross-sections with the instrumental resolution of the spectrometer. As there is no theoretical prediction for the magnetic excitation in Cr_2As, we approximate the cross section in the Van Hove formula similar to Cowley et al. [5].

$$S(q,E) \propto (n(E)+1) \cdot \Gamma_q E / \{(E^2 - E_q^2)^2 + \Gamma_q^2 E^2\},$$

where E is the energy transfer and n(E) is the Bose-Einstein factor. E_q is the spin wave excitation energy for a wave vector q and is assumed to be

$$E_q = cq$$

where c is the slope of the spin wave. Γ_q is the damping for a wave vector q.

Parameters in the cross section were determined by least square fitting of the convolution to the observed spectra by the method of Cooper and Nathans [6].

Thus obtained E_q curve is linear to q in small q region and deviates slightly to the lower energy side for large q, The slope of the spin wave for small q was obtained to be 125±10 and 185±10 meVÅ in c- and a-direction, respectively.

The slope of the spin wave dispersion is about two times large compared with the prediction from the molecular field theory using the values of the Neel temperature and the magnetic moments.

We could not resolve the exchange interactions from the spin wave dispersion curve, since we had not been able to obtain the data for the whole region of the Brillouin zone because of the steepness of the spin wave dispersion.

The damping parameter Γ_q was also obtained for each constant-energy scan. Although the experimental error was large for this parameter, Γ_q seems to be approximated in an equation

$$\Gamma_q = \Gamma_0 + \Gamma_1 \cdot q$$

with $\Gamma_0 \sim 4$meV and $\Gamma_1 \sim 60$ meVÅ in the c-direction. The largeness of the damping parameter is common for the itinerant electron antiferromagnets [5].

This work was carried out under the U.S.-Japan Cooperative Neutron Scattering Program. Work at Brookhaven National Laboratory was supported by the Division of Materials Sciences, U.S. Department of Energy, under contract DE-AC02-76CH0016.

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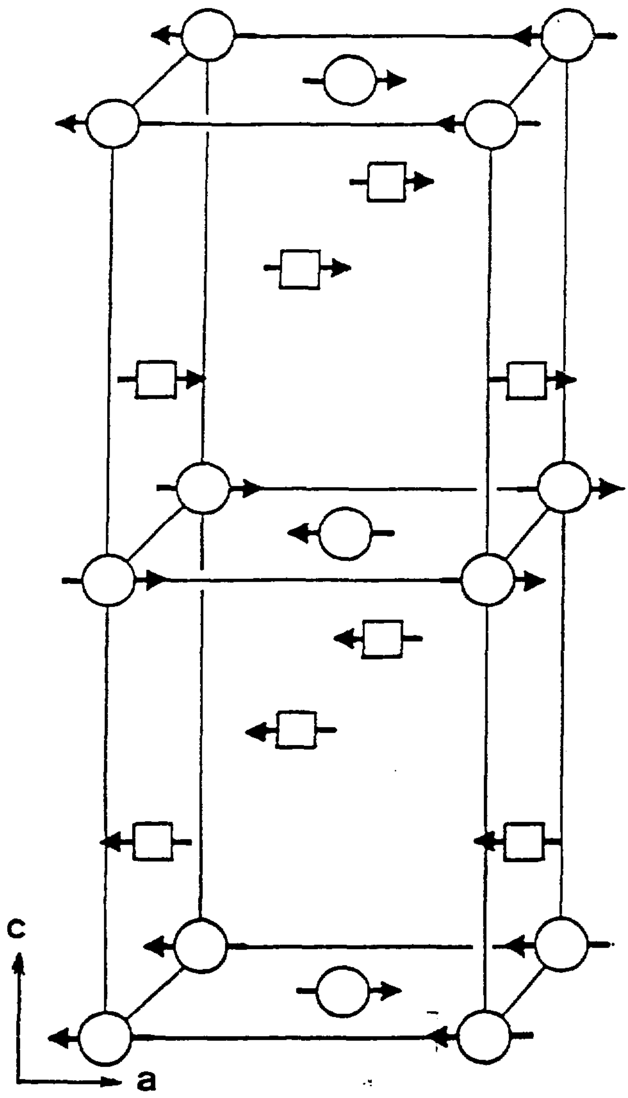
Figure Captions

Fig.1. Magnetic structure of Cr_2As. Circle and square indicate Cr(I) and Cr(II), respectively. Only metal atoms are shown.

Fig.2. Constant-energy scans along c-direction around (0, 0, 2.5). The solid lines are fits of spin wave cross section.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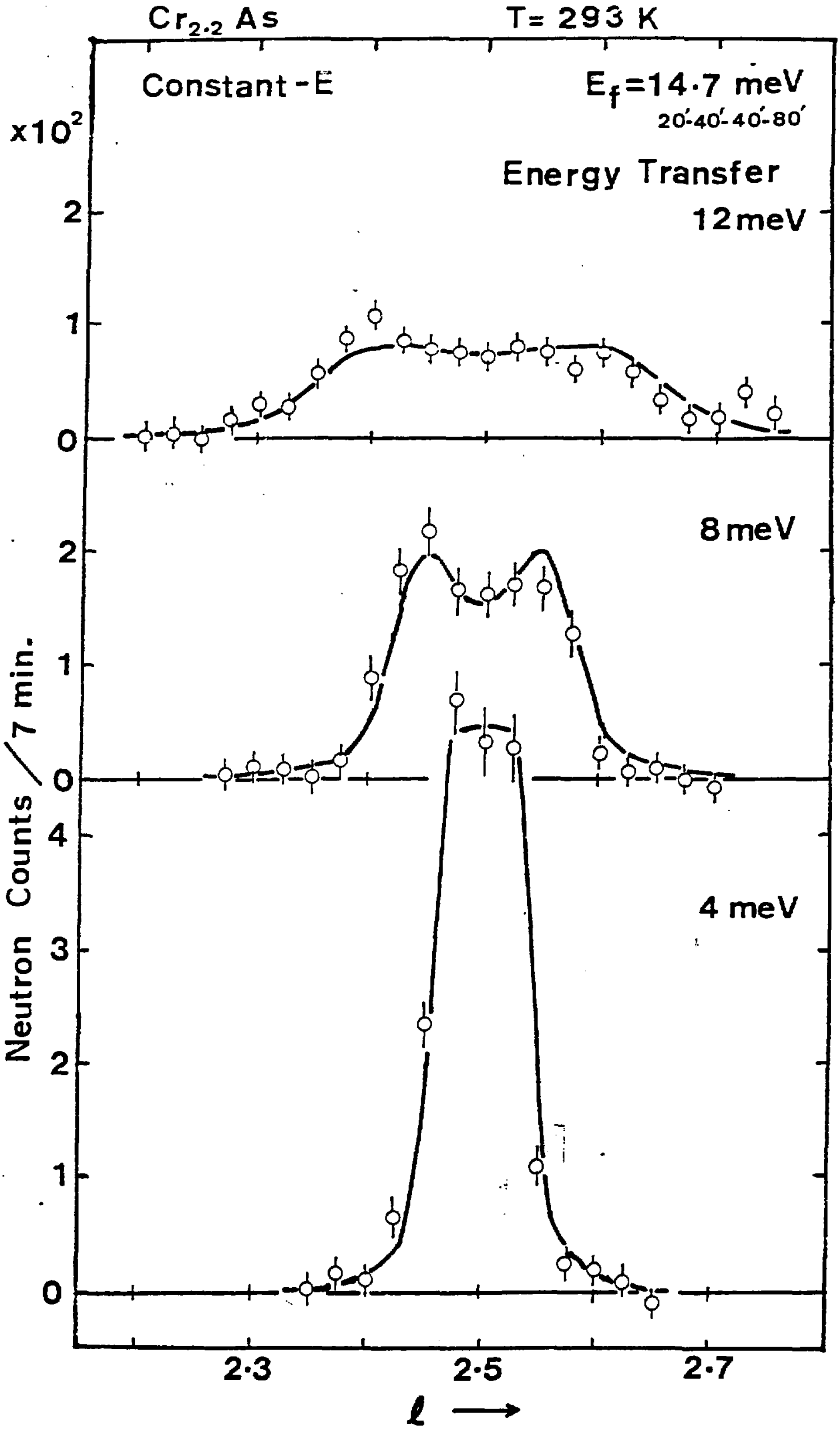

Cr2.2 As
T= 293 K
Constant-E
Ef=14.7 meV
20'-40'-40'-80'
x10²
Energy Transfer
12 meV
8 meV
4 meV
Neutron Counts / 7 min.
0
1
2
3
4
2·3
2·5
2·7
ℓ →