Magnetic ordering of quasi-1 D S=1/2 Heisenberg antiferromagnet Cu benzoate at sub-mK temperatures

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Abstract

We have measured the ac susceptibility of quasi-1D S=1/2 Heisenberg antiferromagnet Cu benzoate at temperatures down to 0.2mK. A sharp susceptibility peak is observed at 0.8mK under an earth field. This fact indicates a 3D ordering of linear chains coupled by a weak magnetic interaction between chains.

Key words: 1D S=1/2 Heisenberg antiferromagnet; Cu benzoate; Néel ordering

1. Introduction

Magnetic properties of Cu benzoate trihydrate $Cu(C_6H_5COO)_2 3H_2O$ were studied by means of susceptibility, ESR[1]and specific heat[2] more than 20 years ago. The results show this compound consists of S=1/2 antiferromagnetic Heisenberg linear chains with the exchange interaction of $J = 8.6$ K. A recent specific heat measurement in high magnetic fields revealed the existence of an unexpected field-induced gap.[3][4] The gap formation was investigated on the basis of a field theoretical approach by Oshikawa and Affleck.[5][6] The Néel ordering of this compound is controversial. In the ESR experiment, the Néel ordering was claimed to exist at 0.76K.[7] On the other hand, the specific heat dose not show the phase transition.[2] To clarify the Néel ordered state, we have performed a magnetic measurement at sub-mK temperatures using a nuclear demagnetization refrigeration.

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2. Experiments

AC susceptibility was measured by an ac impedance bridge method, where a dc SQUID was employed as a null detector. The frequency of excitations field was 16Hz and the r.m.s. amplitude was about 1.4μT. The pick-up coil system was shielded by a Nb superconducting tube. A single crystal of Cubenzoate ($3 \times 5 \times 0.6\text{mm}^3$) was glued to a Ag plate with a conductive epoxy. The Ag plate was tightly fastened to a copper nuclear stage. Temperature was measured with a platinum NMR thermometer($< 15mK$) and a carbon resistance thermometer($> 15mK$) both calibrated against a 3He melting curve thermometer.

3. Results and discussion

The susceptibility under the earth magnetic field is shown in Fig.1. Two anomalies, the broad peak with complex structure around 2K and the sharp peak at 0.8mK, are seen. The origin of susceptibility anomaly around 2K is not clear yet but it dose not arise from the Néel order because the specific heat has no anomaly around 2K.[2] We make a rough estimate on the absolute value of χ by comparing the data around 2K

with Dender's.[3] The susceptibility of 0.5 emu/mole at 1mK is correspond to that of 0.1% of free spin with S=1/2. Such a large amount of impurities should not exist in the present sample. Therefore, it is concluded the low temperature susceptibility peak corresponds the Neel ordering. Fig. 2 shows low temperature part of susceptibility. The directions of temperature variation are shown as the arrows. The susceptibility exhibits no remarkable thermal hysteresis around T_N. The ratio of the Néel temperature to the intrachain exchange constant $k_B T_N/2JS(S+1)$, which gives the measure of one-dimensionality,[2] becomes on the order of 10^{-5}. We can conclude the extremely small ratio should be attributed not only to the high degree of one-dimensionality but also to a frustrated spin structure as pointed out by Oshima et al.[7]

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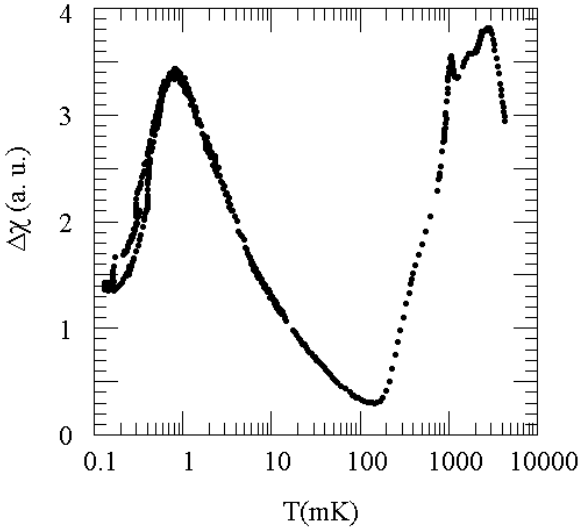

Fig. 1. Temperature dependence of the susceptibility in Cu benzoate. $\Delta\chi = \chi - \chi_0$, where χ_0 corresponds to the susceptibility when the bridge is balanced.

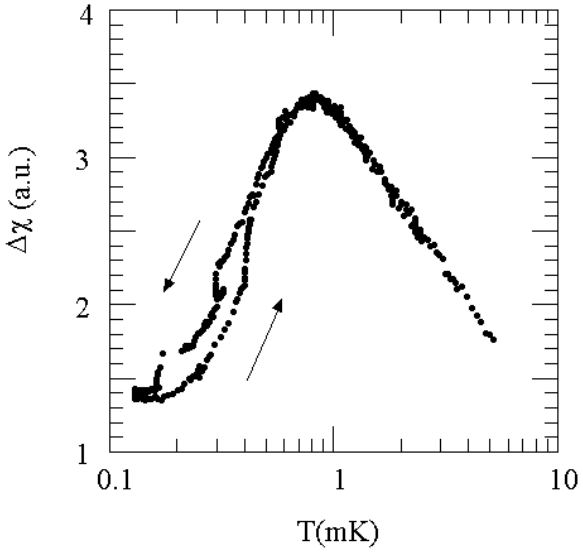

Fig. 2. Low temperature susceptibility of Cu benzoate.