LT 21

Proceedings of the

21st International Conference on

# LOW TEMPERATURE PHYSICS

Prague, August 8-14, 1996

CZECHOSLOVAK
JOURNAL
OF
PHYSICS

Vol. 46 - Suppl. 1996 Part S5

CZYPAO 46 (S5) 2425-2912 (1996) ISSN 0011-4626

Recognized by the
EUROPEAN PHYSICAL SOCIETY

Part S5
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Low temperature properties of solids II

Techniques and applications

LT 21 Proceedings of the 21st International Conference on Low Temperature Physics
Prague, August 8-14, 1996
Part S5 - LT Properties of Solids 2: Normal metals and insulators

# Specific heat of ferric chloride intercalated graphite

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## 1. INTRODUCTION

Ferric chloride $FeCl_3$, intercalated graphite is a highly anisotropic material [1]. The intercalant $FeCl_3$ molecule is sandwiched between the graphite layers and because of the staging phenomenon, which defines the stage index as the number n, of graphite layers between the intercalant, the c-axis period is stage dependent. As the stage increases, the distance between the intercalant magnetic layers increases, one intergraphite layer distance for $\Delta n=1$ allowing for a weakening of the magnetic interlayer interactions. Those interactions can be further screened due to the diamagnetic graphite layers. Therefore, with intercalation one can obtain either 3-d magnetic systems (low stages), or 2-d magnetic systems, (high stages).

The magnetic susceptibility of this system was reported elsewhere [2]. In high stages there is a distinct susceptibility maximum at about 1.8K, while in low stages the magnetic transition has a 3-d character. Here we report the measurement of the specific heat on a number of stages and their analysis.

## 2. EXPERIMENTAL

### 2.1 Sample preparation

The samples were prepared using the two zone method starting with highly ordered pyrolytic graphite (HOPG), and characterized by x-ray and volumetric methods [1].

### 2.2 Measurements

The specific heat measurements were carried out using both the ac [3] and the dc [4] methods. The ac method allows for continuous temperature scans which is appropriate near phase transitions, while the dc method gives a better absolute value of the specific heat.

## 3. RESULTS

The measured specific heat of stages 2, 3, 4,6 and 8 is shown in Fig. 1. The specific heat is normalized to the number of mole-atoms. This figure shows c/T plotted against T to enable us to determine the lattice specific heat from the high temperature behavior. The data is consistent with a lattice contribution proportional to $T^2$ in agreement with a 2-d lattice system. In this region, the specific heat is a decreasing function of stage. It was hard, with our precision, to separate the electronic from the lattice specific heat.

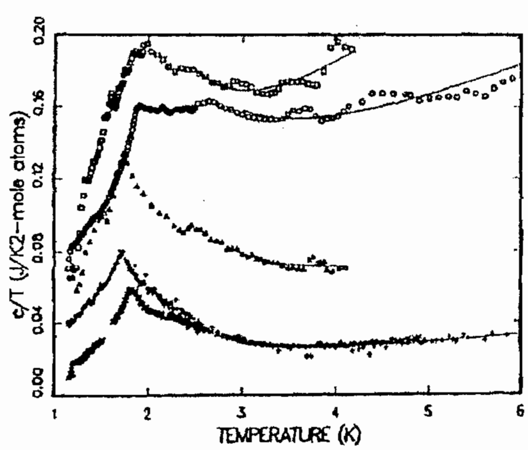


FIGURE 1. The specific heat divided by the temperature, c/T, graphed as a function of T. The magnitudes of the specific heat are in reverse order to the stage number. Stage 2 has the highest c and 8 the lowest. The points are for stages 2,3,4,6 and 8.

The magnetic specific heat is shown in Fig. 2. That was obtained by the subtraction of the lattice component from the total specific heat. One observes that for high stages there is a well defined peak while lower stages tend to rounded maxima. The lower stages exhibit a $T^3$ specific heat below the peak indicating three dimensional antiferromagnetism. In higher stages the power is somewhat higher with a measured exponent of 4.4 for stage 8.

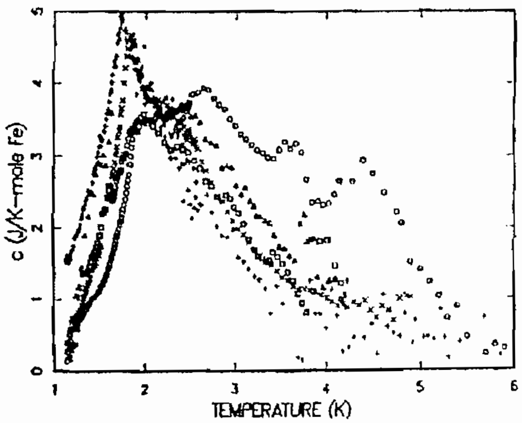


FIGURE 2. The magnetic specific heat as a function of temperature. High stages exhibit sharp peaks. Same symbols and stages as Fig. 1.

In general, the magnetic specific heat can be decomposed into a logarithmic divergent term in $|T-Tc|$ where Tc is taken as the temperature at the specific heat maximum, and a Schottky component. The former suggests a cooperative phase transition [5] while the latter is due to a multiple degenerate level system [6]. The Schottky component is dominant in the low stages while the logarithmically divergent component is dominant in the high stages. This decomposition is shown in Fig. 3 for stage 8 of ferric chloride intercalated graphite.

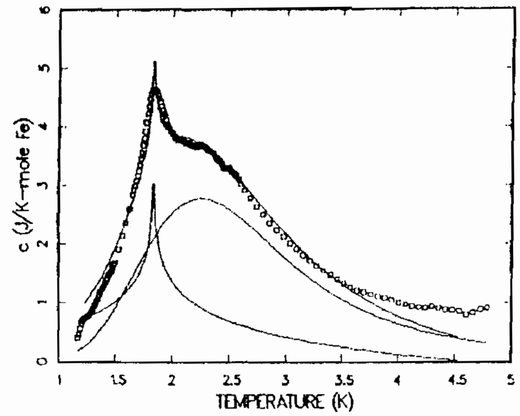


FIGURE 3. Decomposition of the specific heat of stage 8 into a Schottky anomaly and a logarithmically diverging component. Line through data is the sum of the two components.

## 4. CONCLUSIONS

The specific heat of $FeCl_3$ intercalated graphite indicates that all stages of the compound undergo a magnetic transition at or about 2K. The Magnetic component of the specific heat can be decomposed into two distinct parts which suggests that two kinds of ions are present in all the stages. The lower stages exhibit a greater admixture of the ions which undergo a Schottky type transition while in the higher stages indicate a logarithmic anomaly dominates.

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