Specific Heat of Normal Conducting UPt_3 Revisited

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Abstract

Using a high-quality single crystal with very high superconducting transition temperature we have measured specific heat of UPt_3 in the temperature range from 0.3 K to 16 K and in magnetic fields up to 8 T. The focus of this work lies in the normal state properties where, apart from the heavy fermion behaviour, in neutron scattering experiments magnetic correlations have been found to set in at 6 K. However, this ordering has so far not been confirmed in measurements of thermodynamic properties. For the first time we observe a peak in specific heat at 6.7 K, which shifts to 3.2 K in 3 T, independent of field direction. We discuss its origin and possible explanations either in terms of the magnetic correlations or impurity contributions.

Key words: heavy fermion systems; magnetism; specific heat

1. Motivation

In the group of heavy fermion systems UPt_3 plays a singular role for the diversity of its phase diagram. Of particular interest is its unconventional superconductivity that manifests itself by internal phase lines and, e.g., a double peak structure of the specific heat [1]. The origin of the unconventional superconductivity is believed to be an interplay of Cooper pairing with the magnetism of the strongly correlated conduction and f electrons. An onset of magnetic correlations was found in neutron scattering near 6 K [2,3]. They are very weak and so far have not been reproduced in thermodynamic experiments [4], although any ordering should manifest itself in specific heat easurements. According to theory [5] it is believed that long-range static ordering of these correlations is responsible for a number of remarkable effects seen below 20 mK [6–9].

After even better single crystals have become available [10], we have again measured specific heat in the normal conducting state.

2. Experimental Details

The sample used in this study has been produced and characterised as described in reference [10]. The transition to superconductivity occurs at 551 mK with a width of 5.7 mK. The residual resistivity ratio in the c direction is 892. Here we are using a 3.10 mg piece which broke away from the needle-like sample "HA-c" of references [9,11].

To measure the heat capacity we use a commercial Oxford Instruments MagLab system which employs the relaxation method and reaches temperatures T down to 300 mK and magnetic fields B up to 8 T. The sample is glued with grease to the measuring chip that contains heater and thermometer and is weakly linked to the thermal bath. The chip heat capacity and grease specific heat are known from previous experiments. The amount of grease used has been weighed and the addendum contribution subtracted accordingly.

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3. Results

Figure 1 shows the total measured heat capacity. In addition to the raw data (addendum not subtracted) the total addendum contribution is shown with a solid line. The dashed line represents the grease, which is uncertain to 15% in its absolute magnitude. This uncertainty however plays no role compared to the high sample heat capacity. On the low T side of figure 1 the superconducting transition is visible, which is clearly split into two peaks. Towards higher T there is a linear section due to the Fermi liquid of the conduction electrons and a slight curvature due to electronic correlations and phonons.

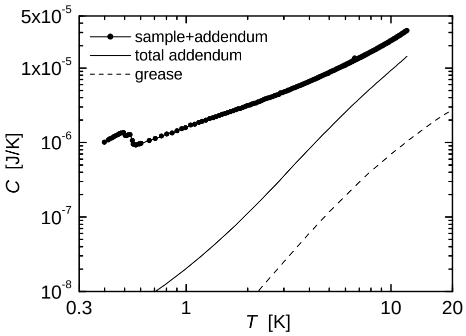

Fig. 1. Total measured heat capacity. The addendum (solid line) and grease (dashed line) contributions are also shown.

A small peak is present between 6 K and 7 K. This peak evolves very prominently when plotted in detail as in figure 2. Its temperature ($T = 6.67$ K) coincides exactly with the onset of correlations in neutron diffraction in [3]. The scale in this graph is converted to the molar specific heat of the sample with the addendum subtracted. The dotted line interpolates the underlying Fermi liquid behaviour.

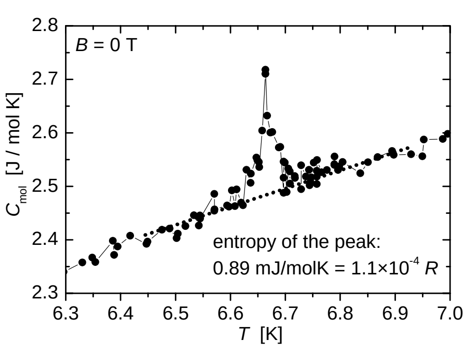

Fig. 2. Peak of the UPt_3 specific heat at 6.7 K. The dotted line is a guide to the eye.

4. Discussion

Integration of the difference between the measured value and the dotted line (fig. 2) yields the entropy associated with the peak. It turns out to be 0.89 mJ/molK, or 1.1×10^{-4} times the gas contant R. This indicates the weakness of the effect and corresponds to the weakness of the neutron signal. However, an impurity concentration of 10^{-4} would be compatible with the residual resistivity ratio and superconducting transition temperature [10,12]. On the other hand, a collective ordering of the impurities at a single, well defined temperature seems improbable.

We also followed the magnetic field dependence of the peak both applying B parallel and perpendicular to the c axis. In both cases we observe a significant suppression with field and can follow it only up to 3 T.

A more detailed analysis of the B dependence and the origin will be the subject of a future publication.

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