Unusual magnetic phase diagram and magnetic structure of the field-induced phases in Ce_2RhIn_8

Our recent high-field specific-heat measurements on a single crystal of Ce_2RhIn_8 grown in Oarai revealed unusual magnetic phase diagrams, including field-induced phases for magnetic fields applied along both principal crystallographic directions (the c and *a* axes). Motivated by these observations, we carried out low-field specific-heat and magnetization measurements with the field applied along the [110] direction. Unexpectedly, the resulting phase diagram differs significantly from that observed for fields along [100]. Moreover, our first neutron-diffraction experiment with the field applied along [110] uncovers a magnetic structure more complex than previously established, even in zero field. We further track the evolution of this structure across the field-induced phases.

The antiferromagnetic heavy-fermion compound Ce_2RhIn_8 belongs to the same family as, and shares several similarities with, the well-studied prototypical material $CeRhIn_5$, which exhibits a unique behavior under applied magnetic field [1]. Ce_2RhIn_8 crystallizes in a tetragonal structure and undergoes an antiferromagnetic (AFM) transition at a Néel temperature of T_N = 2.8 K [2]. Single-crystal neutron diffraction has established a commensurate magnetic structure with propagation vector **Q** = (1/2, 1/2, 0) and a staggered magnetic moment of $0.55\mu_B$ [3].

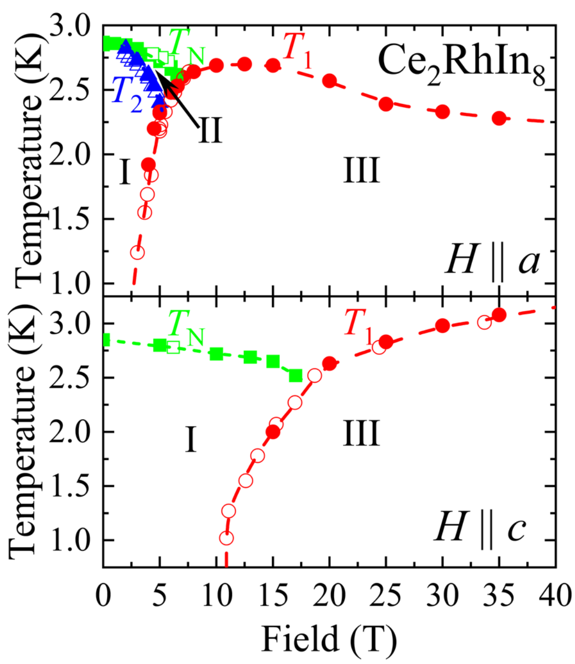

Fig. 1 Magnetic phase diagram of Ce_2RhIn_8 obtained from specific-heat measurements performed as a function of temperature (solid symbols) and magnetic field (open symbols) for the field applied along the *a* (upper panel) and c (lower panel) axis. Lines are a guide for the eye.

Recently, we performed specific-heat measurements on a high-quality single crystal of Ce_2RhIn_8 grown in Oarai, in magnetic fields up to 35 T applied along both principal crystallographic directions. The resulting phase diagrams are shown in Fig. 1. When the magnetic field is applied along the *a* axis, two additional field-induced AFM phases are observed, in agreement with previous reports. One of these phases is confined to a small region of the field–temperature phase diagram. The other, which develops above ≈2.5 T, is remarkably robust: its transition temperature increases with increasing field, reaches a maximum at ≈12 T, and subsequently decreases, although it tends to saturate toward the highest fields of our measurements.

For a field applied along the c axis, T_N initially decreases with field, as expected for a typical antiferromagnet. Surprisingly, an additional phase emerges above ≈10 T, which is likely of the same origin as the phase observed above 2.5 T for the other field orientation. This phase is also unusually robust: its transition temperature continues to increase up to 35 T, where it exceeds the zero-field T_N. These results were published in Ref. [4].

To understand the origin of the field-induced phases, it is essential to determine their magnetic structure by neutron diffraction. However, such measurements under magnetic field are only feasible when the field is applied along the [110] direction. For this reason, we performed low-field specific-heat and magnetization measurements with the field applied along this direction. Surprisingly, the resulting phase diagram (Fig. 2) differs strongly from that for the field applied along the [100] direction (the *a* axis). For comparison, in $CeRhIn_5$, the phase diagrams are identical for fields applied along the [100] and [110] directions.

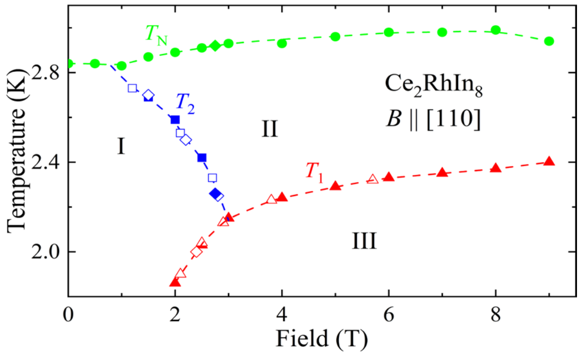

Fig. 2 Magnetic phase diagram of Ce_2RhIn_8 obtained from specific-heat (circles, squares, and triangles) and magnetization (diamonds) measurements performed as a function of temperature (solid symbols) and magnetic field (open symbols) for the field applied along the [110] direction. Lines are a guide for the eye.

Once the low-field magnetic phase diagram for the field along [110] was established, we performed in-field neutron diffraction experiments at JAEA–Tokai. Quite surprisingly, even in zero magnetic field (phase I), we observed an incommensurate wave vector **Q** = (0.46, 0.46, 0) in addition to the previously reported commensurate vector **Q** = (0.5, 0.5, 0). However, at zero field, the commensurate phase is dominant. The situation reverses in phase III, where the intensity of the incommensurate Bragg peak exceeds that of its commensurate counterpart. Finally, in phase II, the commensurate phase is suppressed, leaving only the incommensurate phase.

We also attempted to extend the phase diagram to higher fields using pulsed-field magnetization measurements at the ISSP, University of Tokyo. Unfortunately, this experiment was unsuccessful, as no anomalies were detected at high fields. However, specific-heat measurements in fields up to 36 T are planned at LNCMI–Grenoble to extend the phase diagram for the field along [110] to higher fields. Finally, we plan to perform NMR measurements at JAEA–Tokai to provide further insight into the field-induced phases, particularly for fields applied along the [100] and [001] directions, which are inaccessible to neutron diffraction.

This work was performed in collaboration with D. Aoki, A. Miyake, and A. Nakamura (Tohoku University), and K. Kaneko, Y. Hirose, and C. Tabata (JAEA-Tokai).

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Keywords: heavy fermion, magnetic properties, neutron diffraction
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