

## Specific Heat Studies on Filled Skutterudites $\text{Sm}(\text{Ru},\text{T})_4\text{P}_{12}$

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$\text{SmRu}_4\text{P}_{12}$  shows a metal-insulator (M-I) transition at 16.5 K [1-3]. The M-I transition for  $\text{SmRu}_4\text{P}_{12}$  is supposed to have a close relation to an antiferromagnetic ordering [2]. The specific heat at zero field shows a  $\lambda$ -type peak anomaly at the M-I transition temperature [1], which is indicative of a second order transition. However, the specific heat measurements at magnetic fields reveal that this M-I transition occurs in two successive steps [1,3]. These two successive transitions are suggested to correspond to an orbital and an antiferromagnetic ordering. The mechanism of the M-I transition of  $\text{SmRu}_4\text{P}_{12}$  is still unclear. In order to elucidate this M-I transition, the specific heat measurements of  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$  and  $\text{Sm}(\text{Ru}_{0.9}\text{Rh}_{0.1})_4\text{P}_{12}$  have been carried out.

Figure 1 (a) shows a magnetic contribution to the specific heat divided by temperature  $C_{\text{mag}}/T$  and the magnetic entropy  $S_{\text{mag}}$  of  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$ . The  $C_{\text{mag}}/T$  curve at zero field exhibits a  $\lambda$ -type peak anomaly at 16 K. The magnetic entropy change reaches to  $R \ln 4$  at 16 K. Therefore, it is reasonable that  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$  has a  $\Gamma_{67}$  ground state. The Seebeck coefficient and magnetic susceptibility measurements reveal that an antiferromagnetic and an M-I transition occur at the same temperature. This behavior is very similar to that of  $\text{SmRu}_4\text{P}_{12}$ . However, the temperature dependence of the specific heats at magnetic fields of  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$  is different from that of  $\text{SmRu}_4\text{P}_{12}$ , i.e. the  $C_{\text{mag}}/T$  curve of  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$  shows one  $\lambda$ -type peak anomaly (see Fig. 1 (b)).

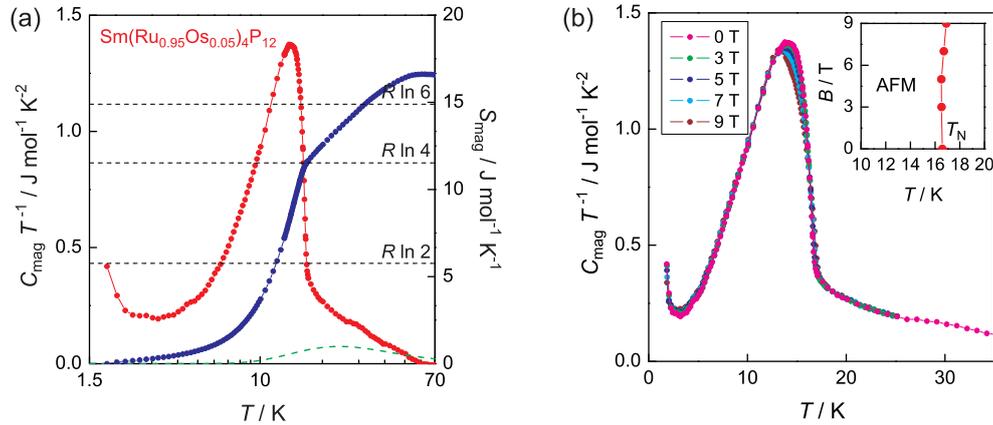


Figure 1: (a) Magnetic contribution to the specific heat divided by temperature  $C_{\text{mag}}/T$  and the magnetic entropys  $S_{\text{mag}}$  of  $\text{Sm}(\text{Ru}_{0.95}\text{Os}_{0.05})_4\text{P}_{12}$ . (b)  $C_{\text{mag}}/T$  at magnetic fields of  $\text{Sm}(\text{Ru}_{0.9}\text{Rh}_{0.1})_4\text{P}_{12}$ . The inset shows the  $B$ - $T$  phase diagram.

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