Karlsruher Institut für Technologie
Institut für Theorie der Kondensierten Materie

Übungen zur Theorie des Magnetismus Sommersemester 16

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1. f^2-ions in a cubic field (6 Punkte)

We consider here a simplified version of an f^2-ion in a cubic field. We assume that the ground state is the singlet state $|\Gamma_1\rangle = \sqrt{\frac{7}{12}}|0\rangle + \sqrt{\frac{5}{24}}(|4\rangle + |-4\rangle)$, and the first excited state is the triplet Γ_4 with its states $|\Gamma_4^0\rangle = \sqrt{\frac{1}{2}}(|4\rangle - |-4\rangle)$ and $\Gamma_4^{\pm} = \sqrt{\frac{7}{8}}|\pm 1\rangle + \sqrt{\frac{1}{8}}|\mp 3\rangle$, where $|m\rangle$ is a $J = 4$ and $J^z = m$ state.

(a) Determine the temperature dependence of the susceptibility. What is the effective paramagnetic moment is the high-temperature regime?

(b) Consider the effect of a strong magnetic field at $T = 0$. What is the saturation moment at very high fields? Is is the same as the effective moment at high temperatures? Taking the crystal field splitting $\Delta = 7\,\mathrm{meV}$ found for PrSb, what is the moment induced by an external field of 10 T?

(c) Schottky anomaly: Plot the specific heat as the function of temperature.

2. A toy model of the metamagnetic transition (4 Punkte)

Here, we consider an f^2-configuration in a tetragonal field. We only keep the four singlet states $|\Gamma_{t1}\rangle = \sqrt{\frac{1}{2}}(|4\rangle + |-4\rangle)$, and $|\Gamma_{t2}\rangle = \sqrt{\frac{1}{2}}(|4\rangle - |-4\rangle)$, and $|\Gamma_{t3}\rangle = \sqrt{\frac{1}{2}}(|2\rangle + |-2\rangle)$, and $|\Gamma_{t4}\rangle = \sqrt{\frac{1}{2}}(|2\rangle - |-2\rangle)$. The state $|\Gamma_{t1}\rangle$ has been simplified by assuming there is no contribution of $|0\rangle$. Now, we switch on a magnetic field in the z-direction.

(a) Determine the magnetization curve at $T = 0$.

(b) Determine the temperature dependence of χ^z.