Study of the magnetocaloric scaling factor $f(T,p)$ in GdAl$_2$ and NdAl$_2$ under hydrostatic pressure

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The magnetocaloric effect (MCE) can be characterized by a field induced isothermal change in magnetic entropy or adiabatic change in temperature of a magnetic system with second or first order transitions. One important issue of the MCE is to study the scaling and universality of their isothermal and adiabatic potentials. Other issue is to study the evolution of the MCE potentials with magnetic field and temperature. Focusing on the first case, for the H-dependent isothermal entropy change, from the critical scaling theory, the isothermal entropy change $-\Delta S(T)$ follows a simple power law (considering $H_i = 0$ and $H_f = H$) with exponent defined as $n(T,H) = d\ln(\Delta S)/d\ln(H)$ which suggests performing derivatives to obtain the exponent for temperatures around the critical one. This power law can be extended to all range of temperatures with the exponent dependent of external variables. If one writes $\Delta S = f(T,p)H^n$, then the cooling power $q(H)$, i.e. the amount of heat transferred between cold and hot reservoirs in one ideal refrigeration cycle, can be obtained by integration in the range of temperatures. Here $f(T,p)$ corresponds to a new scaling function as considered by Smith (Phys. Rev. B 90, 2014, 104422) and we intend to study their behavior in GdAl$_2$ (theoretically) and NdAl$_2$ under hydrostatic pressure from experimental data. If the factor $f(T,p)$ is insensitive to the $\Delta H$-change then the ratio $q(H1)/q(H2)$ depends mainly on $H^n$. It was verified from calculations of the GdAl$_2$-like compound. For the NdAl$_2$ compound under pressure, the scaling of $f(T,p)$ is excellent for the range $80 \text{ K} < T < 120 \text{ K}$ and pressures of 1.3 and 8.3 kbar.