D1.6 MAGNETIC PROPERTIES OF CEROUS MAGNESIUM NITRATE IN THE MILLIDEGREE REGION. George O. Zimmerman* and D. J. Abeshouse,* Physics Dept., Boston University,† Boston, Mass. 02215, USA, and E. Maxwell and D. Kelland, MIT Francis Bitter National Magnet Laboratory,‡ Cambridge, Mass. 02139, USA.

The low temperature magnetic properties of CMN [Cerous Magnesium Nitrate $Ce_2Mg_3(NO_3)_{12} \cdot 24H_2O$] are of interest because it has been widely used as a thermometer and coolant in low temperature investigations. We have measured its properties concentrating on the region below 0.010°K. The samples were a 1 x 1 powder cylinder, a powder sphere, and a single crystal sphere. Low temperatures were achieved by one stage adiabatic demagnetization from about 1.1°K with fields as high as 100 kG.

Fig. 1 shows the $\frac{S}{R}$ vs. T* data obtained for the 1 x 1 powder cylinder (in which it is assumed that the demagnetizations are isentropic). Solid circles represent the values of S calculated from

$$\frac{S}{R} = \int_0^{\frac{\pi}{2}} [\ln 2 \cosh x - x \tanh x] \sin\theta \, d\theta$$

with $x = \frac{(g_\perp \sin\theta)\beta H}{2kT}$ where $g_\perp = 1.84$ and θ is the angle between the crystal axes, where β is the Bohr magneton, k is Boltzmann's constant, H is the initial field, and T is the initial temperature. For purposes of comparison, the open circles are obtained assuming that the entropy at 1.1°K obeys the equation

$$\frac{S}{R} = \ln 2 \cosh x - x \tanh x$$

with $x = \frac{g_\perp \beta H}{2kT}$, where we assumed $g_\perp = 1.84\sqrt{\frac{2}{3}}$. The solid curve is drawn through the solid circles and the broken curve through the open circles. One feature of this graph is that the magnetic temperature T* exhibits a minimum at a T* of about 2.30 mdeg. K. corresponding to a maximum in the inphase component of susceptibility χ' at low temperatures.

Fig. 2 is a plot of the susceptibility for a single crystal as a function of time after demagnetization referred to χ_m, the susceptibility at the maximum. The circles denote the inphase component of χ', in arbitrary units. The crosses are the values of the out of phase component, χ'', referred to the value at t = 0. In some runs it was noted that χ'' also went through a maximum, however at a lower temperature than the χ' maximum. The maximum susceptibility occurred at T* between 2.30 mdeg. K. and 2.70 mdeg. K. depending on the sample, the higher temperatures applying to the powder sphere sample.

Fig. 3 shows our $\frac{S}{R}$ vs. T* values for the powder sphere, (circles, with the open and solid circles having the same significance as in Fig. 1) for the crystal sphere (triangles) and the data of Hudson and Kaeser (crosses). The full and broken lines are the curves of Fig. 1. Our values of T* are lower than those of Hudson and Kaeser. For the same $\frac{S}{R}$, the T* values of the powder sphere appear greater than those of the crystal sphere, and the powder cylinder values overlap those of the crystal sphere at low $\frac{S}{R}$. Our data is in better agreement with Daniels and Robinson[2] and with Frankel, Shirley, and Stone[3] than with that of Hudson and Kaeser.

Some problems arise with powders which are absent in the case of single crystals. Since CMN is highly anisotropic, some grains in the powder will be effective in cooling during adiabatic demagnetization while others will be passive or only partially effective. The latter will have to be cooled by conduction which is, of course, poor at low temperatures, especially across boundaries. To reduce thermal boundary resistance between grains, we prepared our cylindrical samples by adding a few drops of water to the powder, thus fusing the crystallites at the boundaries and then cryopumping off the excess water. In order to estimate the extent to which the demagnetization of the powder was non-isentropic due to heat conduction between the grains, we successively magnetized and demagnetized our sample adiabatically several times without any indication of excessive irreversibility.

We observed a very large increase in χ'' at temperatures below 0.1°K where it becomes comparable with χ' at a frequency of 35 cps.

Specific heat measurements are currently underway for the purpose of establishing a T - T* relation below 10 mdeg. for the powder cylinder and sphere, a problem of considerable topical interest.[4, 5, 6]

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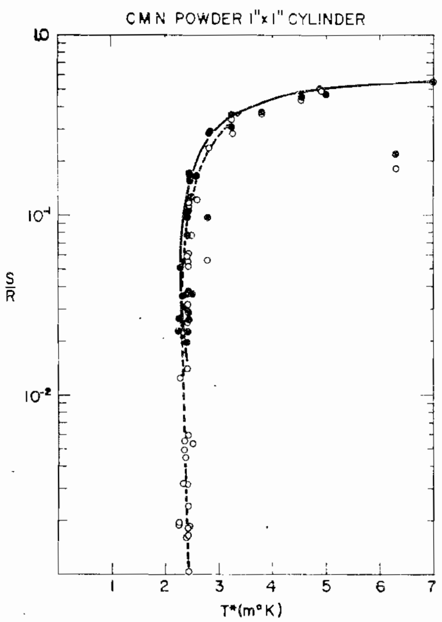

Fig. 1

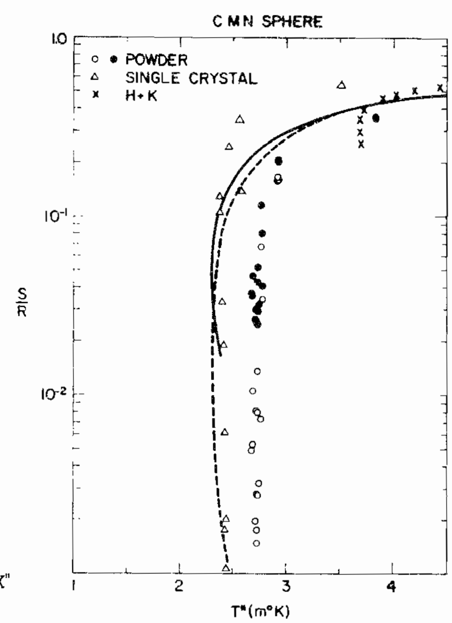

Fig. 3

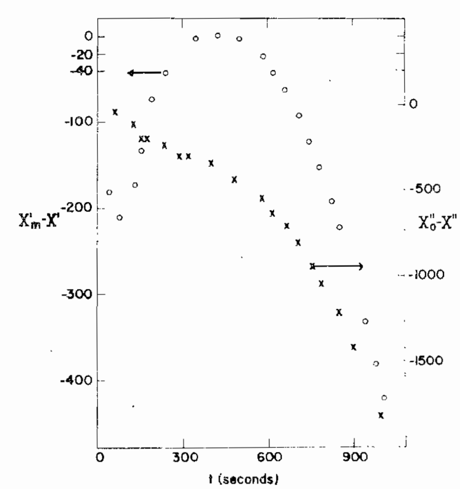

Fig. 2