Magnetic Saturation and Apparent Molecular Fields of $MnCl_2 \cdot 4H_2O$

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PREVIOUS measurements[1] of magnetic moments of substances with small interionic interactions have demonstrated the applicability of the free spin Brillouin function up to over 99.5 percent saturation. Experimental investigation in the helium range of copper sulfate pentahydrate[2] above and copper chloride dihydrate below the Néel (antiferromagnetic transition[3]) temperature has shown nonsuperposition of the magnetic moment isotherms with M plotted against H/T. The departure of the moment from a Brillouin function (using the applied field,[4] H_0, in the argument of the function) has been attributed to molecular fields[5] seen by the paramagnetic ion. The purpose of this investigation is to measure approximately such molecular fields. Substances, such as $CuSO_4 \cdot 5H_2O$, with Néel temperatures below 1°K are difficult to investigate because of the determination and maintenance of the temperature; on the other hand, high Néel temperatures imply molecular fields which may be large compared with the available applied fields, i.e.,

$$\mu H_m \approx k T_N, \tag{1}$$

where μ is the atomic moment in Bohr magnetons, H_m is the molecular field, k is the Boltzmann constant, and T_N is the Néel temperature.

Manganous chloride tetrahydrate was chosen because the Néel temperature as determined by specific heat measurements[6] is 1.6°K in zero magnetic field. The apparatus for measurement of moments is the same as used in previous studies.[1] A sphere of small crystals was studied. The results are shown in Fig. 1. It is seen that practical saturation is achieved for 58 000 gauss and 1.3°K, as indicated by the nearly vanishing slope. From the point representing the saturation moment, one may now construct a Brillouin function. The approximate molecular field is obtained as follows. An arbitrary test point is chosen on either of the five magnetic moment isotherms. From this arbitrary point, one follows a constant moment line to the Brillouin function where the value of H/T is read. The value obtained by multiplying this value of H/T by the temperature corresponding to the isotherm chosen is taken as the effective field H_{eff}. Employing this method, one finds that the ratio between the apparent molecular field contribution ($H_0 - H_{\text{eff}}$) and the magnetic moment is a constant for all T to within ±10 percent over a wide range, corresponding to quadrupling H/T. Using this ratio and extrapolating the apparent molecular field contribution to saturation, one obtains ~14 000 gauss as the apparent molecular field, in rough agreement with Eq. (1).

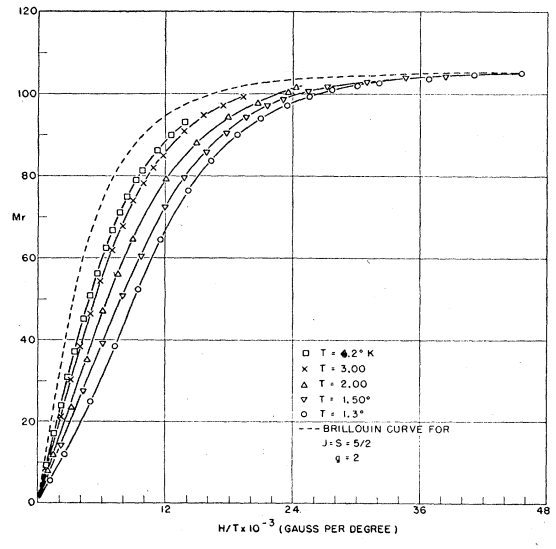

FIG. 1. A plot of relative magnetic moment (M_r) *vs* H/T for manganous chloride tetrahydrate for various temperatures. The broken line is a Brillouin function fitted at saturation.

With our results and neutron diffraction data such as obtained by Shull and Smart[7] to determine the array of sublattices, it would be possible to use the modified Van Vleck[8] method to calculate the antiferromagnetic exchange integral. However, if one assumes a simple model, where the molecular field is γM_0, and if one takes 5 Bohr magnetons as the saturation moment (M_0) per ion, one can compute γ. Now, from the Van Vleck[8] relation,

$$\gamma = zA/Ng^2\beta^2, \tag{2}$$

where N is the number of ions per cm³, $g(=2$ for $J=S)$ is the Landé factor, β is the Bohr magneton, and z is the number of nearest neighbors, one estimates energy density (zA) to be ~10^6 ergs/cm³, $A/2$ being the exchange integral.

The interpretation of the results of this investigation, in which manganous chloride tetrahydrate is magnetized up to saturation, enables one to explain the dispersion in the magnetic moment isotherms on the basis of the estimated molecular fields and suggests a means of calculating antiferromagnetic exchange integrals. A more detailed analysis will be presented later.

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A Proposed Experiment to Detect the Free Neutrino*

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THE success of the neutrino hypothesis[1,2] in explaining the observed facts of beta-decay provides reasonably convincing evidence for the existence of the neutrino. Nevertheless, the observation of an effect produced by a neutrino at a location other than its place of origin would be interesting because (1) any doubts as to its existence would be resolved, and (2) further information as to its properties and place in the nature of things might be obtained. It is with these aims in mind that we have developed the following technique which we plan to apply to the problem of detecting the free neutrino.

The neutrinos produced in the beta-decay of fission fragments[3] in a powerful chain reacting pile are to be allowed to pass through a large volume (10-ft³) liquid scintillator. The protons in the scintillator have a cross section of about 10^{-44} cm² for conversion by the fission fragment neutrinos to neutrons with the emission of a positron. It seems feasible to obtain some tenths such events per minute in the detector. Loading the scintillator solution with boron or cadmium compounds and counting the neutron capture gamma-pulse in delayed coincidence with the positron and annihilation radiation pulse assists in an important way in the reduction of background. Also necessary to the reduction of background in our experiment is the use of thick boron paraffin shielding, massive composite lead-steel shields, and Geiger tube anticoincidence umbrellas, the latter to discriminate against double pulses arising from μ-meson decay, stars, etc.