direct radiation. The approximate Compton response of the crystal for the 141-kev gamma-ray was obtained by critically absorbing the x-ray with Sn and Cu.

The intensity of the x-ray has been corrected for the escape of iodine K x-rays from the surface of the crystal. This correction was obtained from computations made for a collimated beam of gamma-radiation entering normal to the surface of a semi-infinite crystal of NaI. A further correction was applied to the intensity of the x-ray for fluorescent yield in the K-shell.[2]

The intrinsic efficiency of the crystal for the γ-ray was based on measurements of the total broad beam absorption cross section of NaI with a scintillation spectrometer. Edge effects have been accounted for by integration over the crystal for a given geometrical arrangement. The ratio of the K x-ray intensity to the gamma-ray yields the experimental value: $\alpha_K=0.46\pm0.02$.

Theoretical K-shell conversion coefficients were obtained by extrapolation of the values of Rose *et al.*[3] For magnetic dipole radiation $\beta_1{}^K=0.457$ and for electric quadrupole radiation $\alpha_2{}^K=0.428$. Since these values do not make an assignment conclusive, a measurement of the K/L conversion ratio was made by measuring the intensity of the conversion electrons in coincidence with β^- rays between 250–350 kev on anthracene. A tentative value of 5 ± 1 was obtained. Theoretical values for the K/L conversion ratio were obtained by using the K-shell values of Reitz[4] and L-shell values of Gellman *et al.*[5] From a plot against Z^2/E, for $E2$ radiation $N_K/N_L=2.7$ for $Z=49$, and 1.3 for $Z=84$. For $M1$, the values are 6.8 and 6.0, respectively. Comparison of the experimental value for the K/L conversion ratio, together with the value for α_K, would seem to indicate that this transition is a mixture of $M1$ and $E2$ radiation, $M1$ predominating.

* On loan from American Cyanamid Company, National Reactor Testing Station.

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The Anomalous Paramagnetism of Copper Sulfate Pentahydrate

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THE low temperature and high field investigations of paramagnetic ions increase understanding of their quantum behavior (such as adherence to or departure from Brillouin functions), and provides information for the practical problem of producing extremely low temperatures by paramagnetic cooling and determining these temperatures through a knowledge of magnetization behavior.

The Brillouin function for free spins has been shown to be applicable (with almost negligible deviation) up to saturation[1] for iron ($^6S_{5/2}$ state for free ion) ammonium alum[1] and chromium ($^4F_{3/2}$ state for free ion) potassium alum in which specific case the orbital moment is quenched by the crystalline electric field.

However, for copper sulfate pentahydrate, ballistic measurements[1] indicate a pronounced departure of the moment (reproducible to 0.5 percent) of a solid sphere from any Brillouin or other unique function of H/T, Fig. 1. H/T is known to better than 1.5 percent. It is seen that the four magnetic moment isotherms do not superimpose and show a systematic dispersion. These results are in qualitative agreement with the dispersion of calculated magnetic moment isentropes of Geballe,[2] since isothermal and isentropic moments approach each other in the limit of zero field.

The magnetic moment can be calculated[3] from a partition function, provided that the energy levels are known. Thus, a limitation of temperature independent energy levels to a first power dependence on the magnetic field is a necessary condition for the applicability of Brillouin functions. A departure from any Brillouin function can therefore be expected if there are sufficiently large terms in which H occurs in any power besides the first in the energy levels or if the energy levels are sufficiently temperature dependent. Such conditions can arise from various types of interaction as has been shown by several authors.[4] They used Hamiltonians containing terms for the contribution of the crystalline field, spin-orbit interaction, nuclear spin-electron spin interaction, and the like, from which energy levels were calculated.

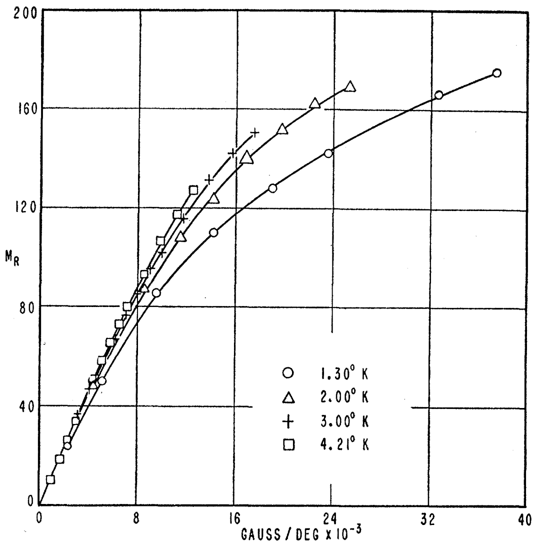

FIG. 1. Plot of relative magnetic moment for a sphere of copper sulfate pentahydrate against the ratio of applied magnetic field to absolute temperature. The four isotherms are for 4.21°, 3.00°, 2.00°, and 1.30°K.

We are unable to account theoretically for the observed variation from the Brillouin function. However, interionic interaction (such as may give rise to antiferromagnetism) and the action of the crystalline electric field through appropriate coupling mechanisms may prove sufficient to account for the observed deviations. Further study of this salt is being carried out to approach nearer to saturation and to make more precise comparisons of experiment and theory.

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Angular Correlation of Gamma-Rays in Ti^{48}†

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THE angular correlation function has been determined for the cascaded gamma-rays of 1.32 and 0.99 Mev in Ti^{48}. The source used was a sample of V^{48} prepared by deuteron bombardment of titanium dioxide. A careful chemical separation[1] performed after bombardment effectively removed the considerable quantity of impurities formed; in addition, the correlated gamma-rays were identified by verifying that they followed the 16-day half-life of V^{48}. The arrangement of the scintillation counters used is shown schematically in Fig. 1. The coincidence circuit comprised a fast component to provide a time resolution of 8×10^{-9} second and a slow (0.2 microsecond rise-time) amplifier and integral discriminator for energy selection.

The V^{48} nuclide decays by positron emission, so that in addition to the two nuclear gamma-rays from Ti^{48} there are two 0.5-Mev

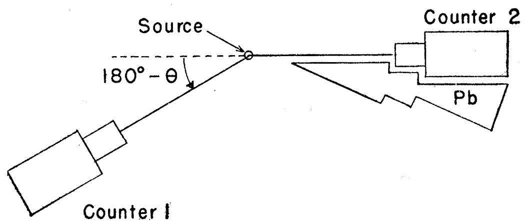

FIG. 1. Arrangement of counters for angular correlation measurements.

annihilation quanta produced in the source container in a large fraction of the decay events. These quanta are uncorrelated in angle with the subsequent gamma-rays, with the result that if care is not taken to discriminate against them, they wash out the correlation. The points marked with triangles in Fig. 2 show the resulting essentially isotropic distribution. Adjusting the discriminators to reject most of the annihilation photons reveals the angular correlation between the two nuclear gamma-rays (circles in Fig. 2). The 180° annihilation peak persists, but is considerably reduced. The experimental points are in good agreement with the distribution $1+(1/8)\cos^2\theta+(1/24)\cos^4\theta$, which holds for spin assignments 0–2–4 for the ground state and first two excited states of Ti^{48}. Ticho *et al.*,[2] using a scintillation spectrometer, have set an upper limit on the number of 2.31-Mev cross-over gamma-rays of 0.5 percent of the 1.32-Mev quanta; of the possible parity assignments for the first and second excited states, this value excludes only odd-even. Hence, while the angular correlation requires that both gamma-transitions must be quadrupole, the low intensity of the cross-over ray excludes only the possibility that they be both magnetic. Present information on the decay scheme of V^{48} is shown in Fig. 3. The K-capture-to-positron ratio[3] (0.72) for the decay of the V^{48} ground state, together with the value 6.1 of $\log(f_{\text{total}}t)$ indicates[4] that the transition to the second excited state of Ti^{48} is allowed, so that the spin change involved cannot be greater than ± 1; but a spin of 3 for V^{48} is ruled out by the lack of transitions to the first excited state of Ti^{48}: hence, the spin of the ground state of V^{48} must be either 4 or 5.

The value[4] 5.4 of $\log ft$ for the beta-decay of Sc^{48} to the 2.31-Mev state of Ti^{48} precludes a spin change of more than 1 unit. The values 2 and 4 for the spins of the two excited states of Ti^{48}, and the absence of beta-transitions to either the ground state or first excited state[5] establishes that the ground-state spin of Sc^{48} cannot be less than 4 nor more than 5. On the basis of negative results in a

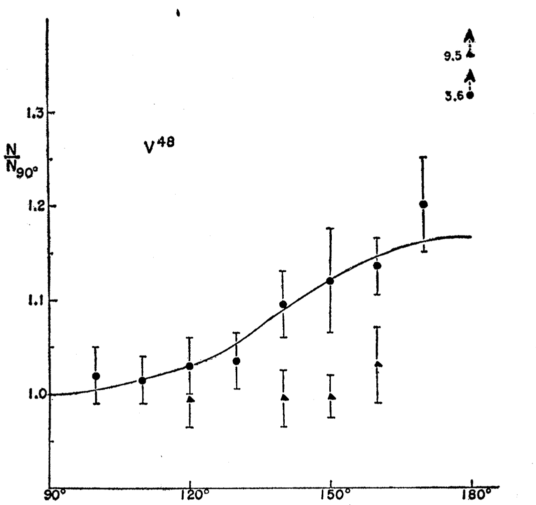

FIG. 2. Angular correlation of Ti^{48} gamma-rays. The points marked with triangles show the uniform distribution due to annihilation radiation background.

search[6] for beta-decay of Ca^{48} to the ground state of Sc^{48}, Jones and Kohman set a lower limit to the partial half-life for single beta-decay of Ca^{48} at 2×10^{16} years; the corresponding $\log ft$ has a minimum value of about 25 (where f is computed from the expression for allowed transitions), appropriate to a Sc^{48} ground-state spin of about 5. It is entirely possible, however, that a small transition matrix element could permit a spin of 4 for the ground state of Sc^{48} to be consistent with the observed minimum half-life for single beta-decay of Ca^{48}.

Shell model considerations indicate that the Sc^{48} ground state should have even parity. If, as seems likely, the Sc^{48} beta-decay is allowed, then the second excited state of Ti^{48} will also have even

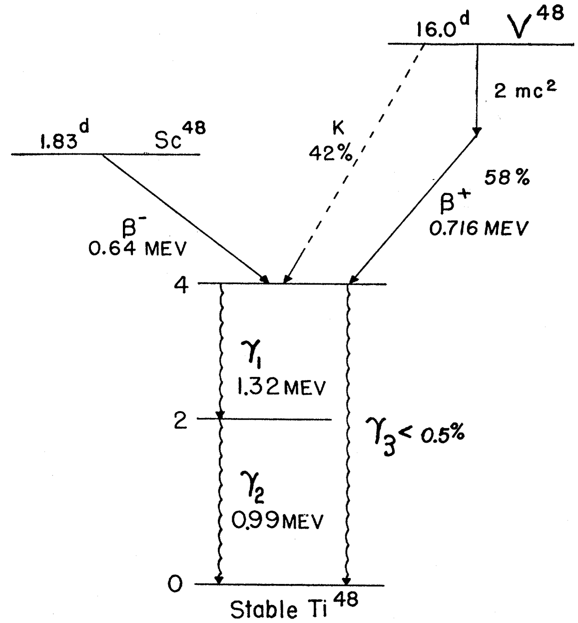

FIG. 3. Decay schemes of Sc^{48} and V^{48}.

parity, with the consequence as remarked earlier that the intermediate state in Ti^{48} can have only even parity. The same parity assignment will hold for the ground state of V^{48}.

To summarize: the results that follow directly from experimental evidence are that the spins of the ground state and first two excited states of Ti^{48} are, respectively, 0, 2, 4; the parities of the two excited states may be anything except the combination odd, even, respectively; for both Sc^{48} and V^{48}, the spin of the ground state is either 4 or 5. Of a more speculative nature are proposed assignments that are at least consistent with all the evidence at hand: even parity for the two excited states of Ti^{48} and the ground states of V^{48} and Sc^{48}, and a spin of 5 for the latter.

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Radioactive Decay of Indium 114

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IN the decay of In^{114} a 50-day isomeric transition from the 0.192-Mev level to the ground state is followed by a 72-second beta-transition to the ground state of Sn^{114}. In addition to this dominant mode of decay, K-capture occurs in a few percent of the disintegra-