(a) "Weak field" ($I-J$ coupling unbroken)

$$G_k^r=(2k+1)\sum_{F,F'}(2F+1)|W(I_BJkF|F'I_B)|^2\sum_{m,m'}|C_{F'm'kr}{}^{Fm}|^2\times\frac{1}{1-i\omega_{Fm,F'm'}\tau}. \quad (3)$$

I_B and J stand for the angular momentum of the intermediate state and the electronic shell, respectively; F is the total angular momentum of the atom; W and C are Racah and Clebsch-Gordon coefficients, respectively.[2] For the case of vanishing external magnetic field (3) reduces to

$$G_k{}^r=\sum_{FF'}(2F+1)(2F'+1)|W(I_BJkF|F'I_B)|^2\frac{1}{1+(\omega_{FF'}\tau)^2}. \quad (3a)$$

We have discussed this expression in a previous letter.[3]

(b) "Strong field" ($I-J$ coupling broken)

$$G_k{}^r=(2k+1)\sum_{m,m'}|C_{I_Bm'kr}{}^{I_Bm}|^2(1-i\omega_{mm'}\tau). \quad (4)$$

If the magnetic moment J of the shell is zero, we obtain

$$\omega_{mm'}=r\omega=r\mu H/I_B\hbar=rg\mu_kH/\hbar \quad (5)$$

(μ, g = magnetic moment and g factor of the intermediate nuclear level; μ_k = nuclear magneton). Then the sum in (4) can be evaluated:

$$G_k{}^r=1/(1-ir\omega\tau). \quad (6)$$

If we take the external magnetic field H perpendicular to the plane of the two quanta, Eq. (2) becomes particularly simple and useful for application:

$$W(\vartheta,H)=\Sigma_r\,[b_r/(1-ir\omega\tau)]e^{ir\phi} \quad (7)$$

where ϑ is the angle between the two quanta. The magnetic field induces an attenuation and a phase shift. For $\omega\tau\ll1$, this results essentially in a rotation of the symmetry axes through the classical precession angle $\phi=\omega\tau$. If the two counters cannot distinguish between the two particles, the attenuation factor becomes real:

$$G_k{}^r=\frac{1}{2}\left\{\frac{1}{1-ir\omega\tau}+\frac{1}{1+ir\omega\tau}\right\}=\frac{1}{1+(r\omega\tau)^2}. \quad (8)$$

Therefore a measurement of $G_k{}^r$ with equally sensitive counters gives only the magnitude, but not the sign, of the nuclear g factor.

For $\omega\tau\gg1$, for both strong and weak fields, the relationship is simplified to a minimum correlation:

$$G_k{}^r=\delta_{0r}. \quad (9)$$

In this case the angular correlation is symmetric about the axis of the magnetic field. If then the direction of one particle coincides with that of the magnetic field, the angular correlation remains uninfluenced.

$$W=\Sigma_k\,a_kP_k(\cos\vartheta). \quad (10)$$

Thus the a_k of Eq. (2) are seen to be the coefficients of Legendre polynomials in the case of an unperturbed correlation.

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The Determination of the Magnetic Moment of an Excited Nuclear Level (Cd^{111}, 247 kev)

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The possibility of determining the g factor of the intermediate nuclear state on a $\gamma-\gamma$-cascade by measuring the influence of a magnetic field on the angular correlation has recently been discussed by several authors.[1,2] Using an external magnetic field on a source of $In^{111}\rightarrow Cd^{111}$, we have now established experimentally the existence of this effect, and have determined the magnitude and sign of the magnetic moment of the intermediate nuclear level.

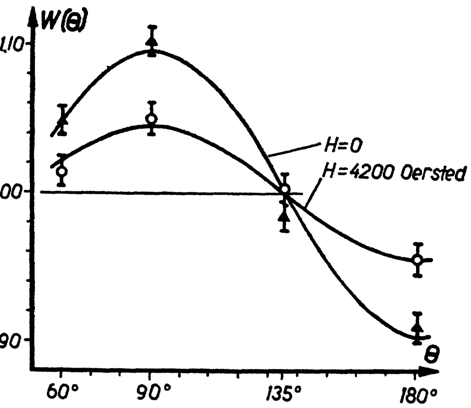

FIG. 1. Angular correlation, $W(\theta)=1+b_2'\cos2\theta$, of Cd^{111}. Magnetic field perpendicular to the plane of the two γ-rays.

The $\gamma-\gamma$-cascade of Cd^{111} is well known;[3] the measured angular correlation in sources of maximum anisotropy[4,5] follows closely the function[6]

$$W(\theta)=1+A_2\cos^2\theta\quad\text{with}\quad A_2=-0.20\pm0.01. \quad (1)$$

The intermediate level is assumed to be a $d_{\frac{5}{2}}$ state[3] and has a half-life of about 8.5×10^{-8} sec.

The general relationships for the influence of an external magnetic field upon the angular correlation of two successive nuclear radiations has been calculated by Alder.[7] For the case in which a magnetic field H is perpendicular to the plane of the two successive γ-rays, and each counter is sensitive to only one γ-ray, Alder finds the correlation function to be given by

$$W(\theta,H)=\Sigma_r\,[b_r/(1-ir\omega\tau)]e^{ir\theta}, \quad (2)$$

where θ is the angle between the two γ-rays, τ is the mean life of the intermediate state, and $\omega=gH\mu_k/\hbar$ is the classical precessional velocity of the nucleus in the magnetic field H.

In the case of Cd^{111}, the correlation function in the absence of a magnetic field can be well fitted by the function (1); the highest term in the development (2) thus is $r=2$. Equation (2) then becomes

$$W(\theta,H)=1+\frac{b_2}{1+(2\omega\tau)^2}\{\cos2\theta\mp2\omega\tau\sin2\theta\}, \quad (3)$$

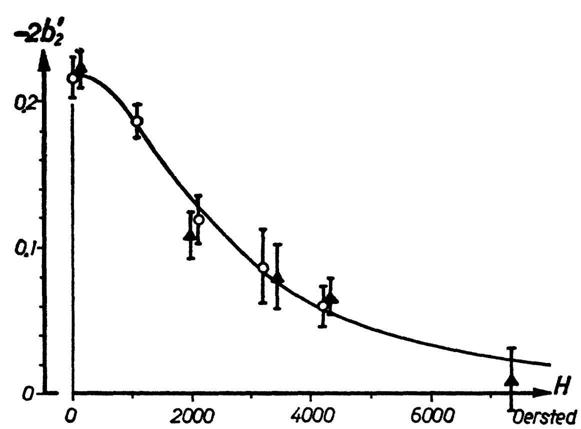

FIG. 2. Anisotropy b_2' as a function of the magnetic field strength H.

where the sign of the $\sin 2\theta$-term refers to the direction of the magnetic field. If, in addition, both counters are equally sensitive for both γ-rays, the term $\sin 2\theta$ vanishes, leaving

$$W(\theta, H) = 1 + b_2' \cos 2\theta, \quad \text{where} \quad b_2' = b_2/[1+(2\omega\tau)^2]. \qquad (4)$$

The experimental arrangement consisted of two scintillation counters and a small magnet, with the field perpendicular to the plane of the equally sensitive counters. The measured values of the angular correlation for two different values of the field strength are shown in Fig. 1.

Each measurement was corrected for the finite resolving time of the coincidence circuit and for the finite solid angle subtended by the counters. The corrected anisotropy b_2' is shown in Fig. 2 as a function of the field strength H. The solid line, fitted by the method of least squares, represents the function (4) with $|g| = 0.34$.

The sign of the magnetic moment has also been determined by measuring the coincidence rate with $\theta = 135°$ for positive and for negative external magnetic field, the two γ-rays being differentiated by means of different absorbers in front of the two counters. A number of measurements conclusively showed that $g < 0$. Measurements with fixed direction of the magnetic field, but with change of the absorbers, gave the same result and exclude the effect of possible differences between the two channels.

As a final result, we have therefore

$$g \text{ (247 kev-level)} = -(0.34 \pm 0.09).$$

The negative sign confirms the assignment[3] of $d_{\frac{5}{2}}$ for the 247-kev level and excludes $d_{\frac{3}{2}}$. Together with the measurement of the conversion coefficients and the angular correlation, it gives the unique spin assignment 7/2, 5/2, ½ for the three nuclear states involved in this cascade.[6]

With this assignment, the magnetic moment becomes

$$\mu(d_{\frac{5}{2}}) = -(0.85 \pm 0.22)\mu_k.$$

This value for the $d_{\frac{5}{2}}$ excited state fits well in the group of the odd neutron nuclei with $d_{\frac{5}{2}}$ ground state (Mg^{25}, Mo^{95}, Mo^{97}, Yb^{173}).

Further measurements are in progress and the detailed report will appear in *Helvetica Physica Acta.*

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$P-N$ Transition of an Oxide-Coated Cathode

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P-TYPE conduction was found for a (BaSr)O cathode in an oxygen atmosphere, in opposition to N-type conduction in high vacuum. Figures 1 and 2 show the results of conductivity and Hall-coefficient measurements for a wide range of oxygen pressure (from 10^{-6} to 10^{3} mm Hg). These two types of conduction are almost symmetrical, and the conductivity curves contain definite minima. It can be easily understood from these two figures that the "$P-N$" transition occurs at these minima.[1]

The "F-center" model is applicable to this case as well as to the case of alkali halides; the equilibrium between the (BaSr)O and oxygen atmosphere determines the number of lattice vacancies of oxygen ions and barium ions, which supply the conduction electrons and positive holes, respectively. Coexistence of a considerable

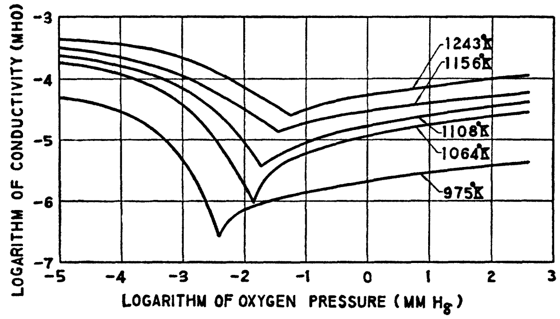

Fig. 1. Electrical conductivity *versus* oxygen pressure at five values of the temperature. The mixture of $BaCO_3$ and $SrCO_3$ held between the platinum electrodes was decomposed to (BaSr)O in high vacuum, and the purified oxygen was introduced to the tube, the conductivity being measured at each equilibrium point.

number of these two kinds of vacancies may occur at intermediate oxygen pressures. This causes the recombination of electrons and positive holes, so that the conductivity decreases rapidly in this region. At the $P-N$ transition points the numbers of these two kinds of vacancies are nearly equal, and the (BaSr)O shows the characteristics of an insulator or at least an intrinsic semiconductor.

The activation energies of the conductivity are 16 cal in high

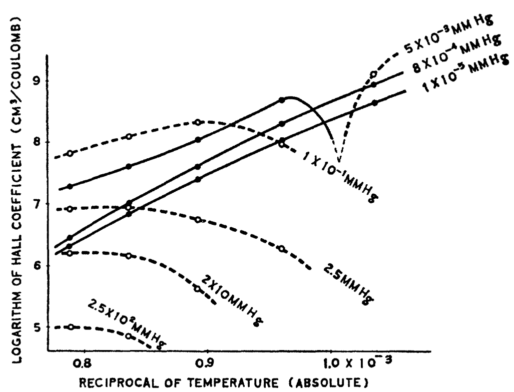

Fig. 2. Logarithm of $|R|$ *versus* reciprocal of temperature at seven values of the oxygen pressure. The solid lines show negative Hall coefficients, and the dotted lines show positive ones.

vacuum[2] and 10 cal in oxygen at high pressure. In the region between these two cases, the $\log\sigma$ *vs* $1/T$ curves are fairly complicated and there are one or more kink points on them,[1] as is conceivable from the shape of the three-dimensional structure of the relation connecting $\log\sigma$, $\log P$, and $1/T$.

It must be taken into consideration, however, that the magnetic properties of (BaSr)O are peculiar. As is shown in Fig. 2, the Hall-effect is extraordinarily large for this kind of ionic crystal. Also the variation of conductivity with magnetic field has, as is shown

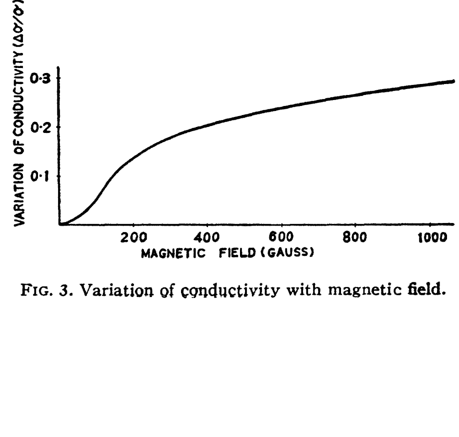

Fig. 3. Variation of conductivity with magnetic field.