method of cold working, fragmentation is most severe. A simple experiment in which the surface layers of a cold worked copper rod were gradually removed by etching in weak nitric acid shows this actually to be the case. Figure 2 gives the percentage change in susceptibility as a function of the percentage reduction in *diameter* caused by etching. Here χ is the initial value of susceptibility in the cold worked condition and $\Delta\chi$ is the difference between the "etched" and "initial cold worked" values. Clearly most of the change in χ is caused by the heavily fragmented surface layers, and on removal of these layers the susceptibility reverts very nearly to its original value for the annealed metal.

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Polarization Correlation of Successive Gamma-Ray Quanta

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RECENT successful experiments[1] on the angular correlation of γ-quanta emitted in successive nuclear transitions are in sufficient accord with theory[2, 3] to make it worth while to inquire into what additional information can be gotten from this type of measurement. L. Madansky of this laboratory has suggested the possibility of detecting a polarization correlation between successive quanta by use of the photoelectric or Compton effect as analyzers, and is setting up apparatus to measure it.

The purpose of this note is to state what the theory predicts for such correlations and to point out that, aside from its intrinsic interest, the measurement of polarization correlation can be a useful tool in nuclear spectroscopy because, unlike the directional correlation, it provides a means of distinguishing between the electric and magnetic multipole character of the γ-transition and hence of determining the parity of the nuclear states.

The formalism for the calculation of polarization correlation differs in only one respect from that for the angular correlation,[2, 3] namely, one has to specify the polarizations of the two quanta rather than average over them. One finds for the case of anti-parallel quanta, the first being a 2^{l_1}-pole transition between nuclear states of angular momentum quantum numbers J' and J, the second a 2^{l_2}-pole transition between nuclear states J and J'', that the probability of the polarizations of the two quanta, being at an angle φ with respect to each other, may always be expressed in the form:

$$W(\varphi)=1+A\cos 2\varphi. \tag{1}$$

Here $A=2N/D$ with

$$N=\sum_n\left({}^{J'}_{n+1}\middle|Y_{l_1}^{-1}\middle|{}^{J}_{n+2}\right)\left({}^{J'}_{n+1}\middle|Y_{l_1}^{1}\middle|{}^{J}_{n}\right)\times\left({}^{J}_{n+2}\middle|Y_{l_2}^{1}\middle|{}^{J''}_{n+1}\right)\left({}^{J}_{n}\middle|Y_{l_2}^{-1}\middle|{}^{J''}_{n+1}\right), \tag{2}$$

and

$$D=\sum_n\left[\left|\left({}^{J'}_{n-1}\middle|Y_{l_1}^{-1}\middle|{}^{J}_{n}\right)\right|^2+\left|\left({}^{J'}_{n+1}\middle|Y_{1}^{1}\middle|{}^{J}_{n}\right)\right|^2\right]\cdot\left[\left|\left({}^{J}_{n}\middle|Y_{l_2}^{-1}\middle|{}^{J''}_{n+1}\right)\right|^2+\left|\left({}^{J}_{n}\middle|Y_{l_2}^{1}\middle|{}^{J''}_{n-1}\right)\right|^2\right],$$

the summation being over the $(2J+1)$ magnetic quantum numbers of the intermediate state J. The $Y_l^{\pm1}$ are spherical harmonics; their matrix elements are given by Condon and Shortley[4] for $l=1, 2$ and may be obtained by group theory methods for arbitrary l.

TABLE I. $|A(J)|$ for dipole-dipole transitions.

	$\Delta J=-1$	$\Delta J=0$	$\Delta J=1$
$\Delta j=-1$	$\frac{1}{7}$	$\frac{(2J-1)}{(6J+7)}$	$\frac{J(2J-1)}{(14J^2+33J+20)}$
$\Delta j=\ \ 0$	$\frac{(2J+3)}{(6J-1)}$	$\frac{(2J-1)(2J+3)}{(8J^2+8J-1)}$	$\frac{(2J-1)}{(6J+7)}$
$\Delta j=\ \ 1$	$\frac{(J+1)(2J+3)}{(14J^2-5J+1)}$	$\frac{(2J+3)}{(6J-1)}$	$\frac{1}{7}$

The coefficient A in (1) is always real and its sign is given by:

$$\text{sign of } A=(-1)^{l_1+l_2+J'-J''}+1+\delta, \tag{3}$$

where $\delta=1$ if both multipoles are electric or magnetic, 0 if one is electric, the other magnetic.

As an example, consider the $\gamma-\gamma$ transitions in Co^{60} and Sc^{46}. Deutsch and co-workers[1] identify these as quadrupole-quadrupole $(l_1=l_2=2)$ transitions between nuclear states $J'=4$, $J=2$, $J''=0$. Hence here the sign of A is positive if both multipoles are electric or magnetic, and negative otherwise. Accordingly, in the first case one should observe a maximum coincidence rate when the polarizations are parallel $(\varphi=0)$; in the second case the maximum occurs for perpendicular polarizations $(\varphi=\pi/2)$. The magnitude of A is 2/7 so that the ratio of Wmax. to Wmin. is 1.8, which can be used as an additional experimental check on the assignment of multipole orders and quantum numbers. It should be remarked, however, that A has the magnitude 2/7 for any quadrupole-quadrupole $J+2$, J, $J-2$ transition irrespective of J.

In Table I, the absolute values of A as a function of J are listed for dipole-dipole transitions between states $J'=J-\Delta j$, J, $J+\Delta J=J''$. Similar tables for higher multipoles to complement those of Hamilton[2] are in preparation. The sign of A is given by (3) with $l_1=l_2=1$.

Comparison of this table with Table I of Hamilton,[2] shows that the magnitude of A is roughly twice that of the corresponding parameter R/Q for the angular correlation. Hence, whenever the angular correlation is easily measurable, one may also expect an appreciable polarization correlation. On the other hand, since the form of the polarization distribution (1) is the same for all multipoles, the main value of the polarization data will be to supplement the angular correlation data which do distinguish the various multipoles orders.

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