nant such as U_{238}) in two ways. The deviation of the logarithm of each sample count from its least squares line was calculated and shown not to be preponderantly positive or negative near either the middle or the ends of the periods of measurement of the sample. The variances of these deviations were compared, using the F test, with the internally predicted variances. In only one of the four cases did the deviations show a significantly larger variance than that due to the counting statistics alone.

Using the larger variance in each case, the following four estimates of half-life were calculated:

Sample	*Counter A*	*Counter B*
I	24.14±0.10 days	24.04±0.07 days
II	24.13±0.04 days	24.09±0.04 days

There being no evidence of significant differences among these values they were averaged and the error of the mean (95 percent confidence interval limits) determined by propagation of the individual errors. The final value thus arrived at is 24.101±0.025 days. These data support Sargent's earlier data and give a tenfold decrease in the uncertainty of the half-life of uranium X_1.

* This document is based on work performed under Contract No. W-7405-Eng-26 for the Atomic Energy Commission by Carbide and Carbon Chemicals Corporation, at Oak Ridge, Tennessee.

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[2] B. W. Sargent, Can. J. Research **A17**, 103 (1939).

Angular Correlation of Successive Gamma-Ray Quanta. II*

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SINCE our first communication on this subject[1] the use of Kallmann scintillation counters has greatly increased the accuracy of the experiments. The approximately tenfold gain in efficiency over G-M counters permits useful coincidence counting rates about a hundred times greater than formerly. Figure 1 shows the angular correlation observed by this improved method for six radioactive substances indicated in the figure. The gamma-rays are, of course, emitted by the product nuclei Ni^{60}, Ti^{46}, Mg^{24}, Ba^{134}, Sr^{88}, and Pd^{106}, respectively, all of which are of even-even type and have presumably $J=0$ in the ground state. The abscissa in Fig. 1 is the angle θ between the directions of emission of the two successive gamma-rays and the ordinate is the ratio of the coincidence rate observed at the angle θ to that observed at $\theta=\pi/2$. The vertical lines indicate standard deviations for the points indicated. The errors for the other points are of comparable magnitude. All results are corrected for the finite angular resolution of the instrument, determined by observations on annihilation radiation.

The solid line in Fig. 1a represents the calculated[2] distribution for two quadrupole quanta and angular momenta $J=4$, 2, 0, respectively, for the three states involved. The solid line in Fig. 1b has the shape calculated[2] for two quadrupole quanta, $J=0$, 2, 0 but with the coefficients R/Q and S/Q only half as big as calculated from theory. The dotted line represents a distribution calculated by Ling[3] from a proposed disintegration scheme for Y^{88} by Peacock[3] considering interference between electric quadrupole and magnetic dipole radiation for $J=2$, 1, 0.

In every case investigated an anisotropic correlation was found. In every case except Y^{88} the probability is greatest for the two quanta to be emitted in opposite directions. The

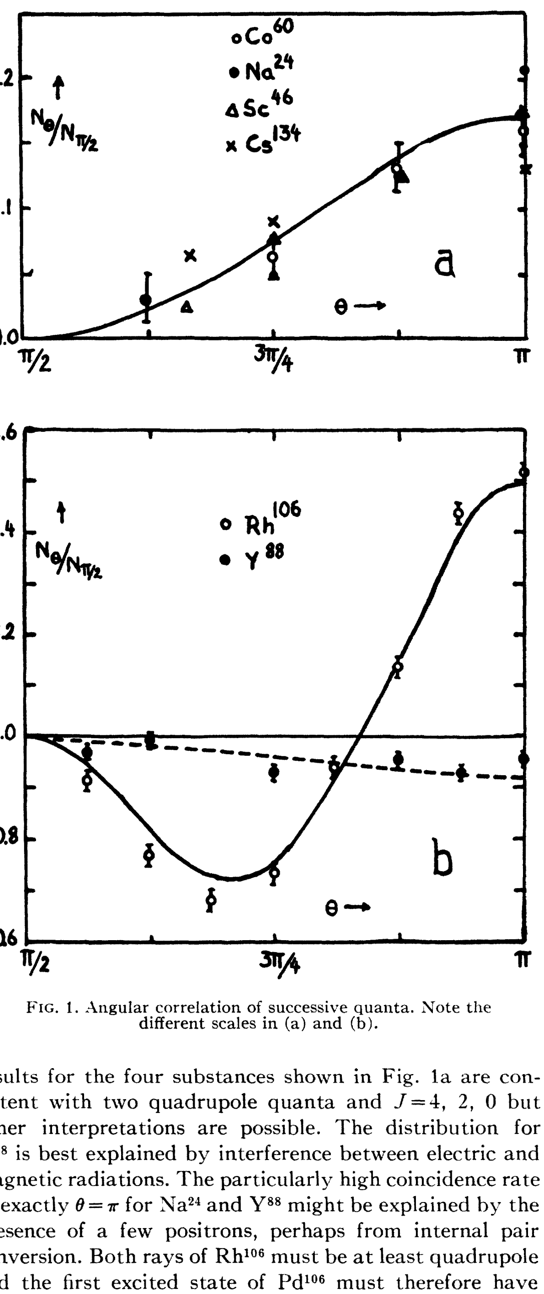

FIG. 1. Angular correlation of successive quanta. Note the different scales in (a) and (b).

results for the four substances shown in Fig. 1a are consistent with two quadrupole quanta and $J=4$, 2, 0 but other interpretations are possible. The distribution for Y^{88} is best explained by interference between electric and magnetic radiations. The particularly high coincidence rate at exactly $\theta=\pi$ for Na^{24} and Y^{88} might be explained by the presence of a few positrons, perhaps from internal pair conversion. Both rays of Rh^{106} must be at least quadrupole and the first excited state of Pd^{106} must therefore have

$J \geqslant 2$. The assignment $J=0$, 2, 0 to the three states concerned which is suggested by the shape of the curve could be accepted only if a reason could be found for the reduction of the coefficients by a factor of two. Obvious possibilities of instrumental causes were ruled out by appropriate tests. The possibility of interference by other gamma-rays seems unlikely because the curve remained unchanged by lead absorbers around the source. It is possible that the coefficients of the angular anisotropy are reduced by some perturbation destroying the constancy of the magnetic quantum numbers of the intermediate state, particularly the hyperfine structure interaction. However, a magnetic field of about 10^4 gauss did not affect the correlation in Rh^{106} or any of the other substances. The experiment was performed only with moderate precision, and may not be entirely conclusive. The assignment of J values to Pd^{106} is important because Peacock[4] has based a strong argument for the validity of Gamow-Teller selection rules on evidence that the second excited state does *not* have $J=0$.

A complete discussion of the experimental method and of the results and their interpretation will be given in a paper to be submitted soon for publication in this journal.

The sources, except Y^{88}, were obtained from Oak Ridge.

* Supported in part by the Office of Naval Research.
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[4] W. C. Peacock, Phys. Rev. **72**, 1049 (1947).

Correlation between Direction and Polarization of Successive Gamma-Ray Quanta*

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HAMILTON[1] has calculated the expected correlation between the polarization of one quantum and the direction of emission of the other for two successive gamma-rays. We have succeeded in observing this effect. The apparatus is shown schematically in Fig. 1. A, B, C represent the naphthalene crystals of three Kallmann counters. Counters A and B, connected in coincidence, form the polarimeter determining the polarization of γ_1, while γ_2 emitted simultaneously at the angle θ with respect to γ_1 is counted in counter C. If γ_1 experiences a Compton encounter in A, a scintillation is counted due to the recoil electron e. The scattered quantum γ_c is most likely to move in the plane perpendicular to the electric vector of γ_1; if γ_c is in or near the common midplane of A and B, it is very likely to cause a count in B because of the high efficiency of the Kallmann counter for soft quanta. Thus A and B define the "ϕ-plane" making an angle φ with the "θ-plane" formed by the two rays γ_1 and γ_2. Coincidences are most likely to occur between A and B when the electric vector of γ_1 is perpendicular to the ϕ plane. Exactly the same argument is valid if γ_1 strikes crystal B and γ_c enters A.

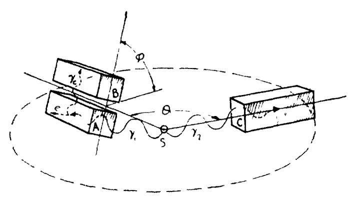

Fig. 1. The coincidence polarimeter.

The polarimeter was tested with gamma-rays of Co^{60} and Cs^{134} scattered through 90° by an aluminum scatterer. The observed difference in counting rate when the polarimeter was rotated through 90° indicated that for perfectly plane polarized radiation the ratio of the counting rates in the two perpendicular positions would be $D=2.1\pm0.3$. D measures the effectiveness of the polarimeter.

The actual experiments consisted of observing the triple coincidence rate $N(ABC)$ for $\varphi=0°$ and $\varphi=90°$ for various values of θ. The single counting rates and the twofold coincidences $N(AB)$, $N(AC)$, and $N(BC)$ were also counted to correct for slight asymmetries due to the difference in the effective value of θ in the two positions and to evaluate the chance coincidence rate. $\varphi=90°$ corresponds to the electric vector of γ_1 being in the θ-plane and the counting rate $N(ABC)$ in this position is denoted by $N_{\|}$. The counting rate for $\varphi=0°$ is denoted by $N_{\perp}$. Typical values of $N(ABC)$ are between 5 and 15 c.p.m. It follows from the Klein-Nishina formula that the polarimeter should be most efficient for low energy gamma-rays. Also strong polarization effects are expected in general when[1] the angular correlation between the gamma-rays is very anisotropic. Thus our first significant results have been obtained with Rh^{106}, which shows very anisotropic angular correlation[2] and emits rather soft gamma-rays.[3] Figure 2 shows the ratio $N_{\|}/N_{\perp}$ as a function of θ.

The dotted line is calculated from Hamilton's paper[1] (Eq. 12b) on the assumption that both quanta are electric quadrupole. The experimentally observed coefficients[2] of the angular correlation were used in the calculations. The eeffectiveness of the polarimeter was assumed to be that determined as described above, i.e., $D=2.1$. The solid line

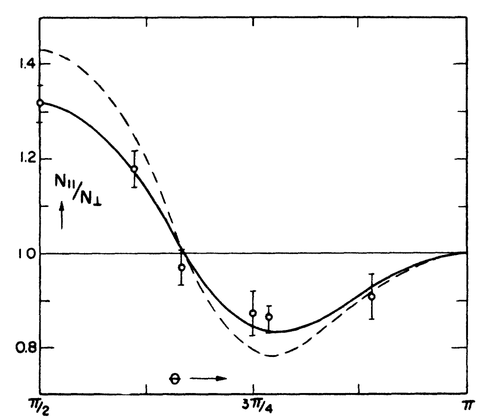

Fig. 2. Polarization of Rh^{106} gamma-rays. Solid line: $D=1.76$. Dotted line: $D=2.1$.