Letters to the Editor

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Experimental Beta-Gamma-Angular Correlation

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THE number of gamma-rays emitted by a nucleus into unit solid angle has been measured as a function of angle with the preceding coincident beta-ray. Scintillation counters were used, the gamma-sensitive counter consisting of a 1-cm thick clear anthracene crystal subtending 0.13 steradian at the source. The beta counter active element is a 50 mg/cm² sheet of anthracene cleavings mounted with collodion on the face of an RCA 5819 photo-multiplier. The beta-counter subtends an angle of 0.07 steradian at the source, having efficiency 100 percent for beta- and 1 percent for gamma-rays. The beta-counter is fixed with respect to the source, the surrounding tank being evacuated to avoid loss of correlation by scattering. The sources are sufficiently thin (0.01 to 0.1 mg/cm²) so that no appreciable beta-scattering arises in the source.[1] Detailed tests indicate that the correlation measured is that existing at the atom in question. A coincidence resolving time of 0.04 microsecond is available from a simple modified Rossi pair.

Measurements are taken at 20 positions, giving 10 points of the correlation curve between 45° and 180°. For the most part, 20,000 counts are taken for each activity, and a $1+b\cos^2\theta$ function fitted by least squares to the experimental points. The observed beta-gamma-coincidence rate at each point is divided by the gamma-single rate at that point to allow for the shadow of the source holder, etc.

The resulting values for b and their standard deviations (induced through the least squares process by the finite number of counts) are listed in Table I.

In no case was any anisotropic correlation observed, larger than the statistical error. According to the theory[2,3] the only general way of obtaining spherical correlation is either for the beta-ray to be permitted or for the spin of the residual nucleus (after the beta-decay) to be 0 or $\frac{1}{2}$. Typical values of the coefficient b range from 0.10 to 0.80 when these selection rules are not fulfilled.

For the isotopes Na^{24}, Co^{60}, and Au^{198} the spin of the intermediate nucleus is known to be non-zero,[4] and the beta-ray is classified as forbidden by Konopinski.[5] This suggests an inconsistency in the beta-ray theory, since the resulting angular correlations should be readily observable.

It is not known to what cause to ascribe the lack of correlation. The probability that these results are due to the operation of the selection rules in all cases, i.e., allowed betas or zero intermediate spins, is very small—of the order of 1 percent.[6,7] A large class of possible causes are made improbable by the fact that many gamma-gamma-correlations have been observed,[4] substantiating a considerable part of the theory.

Further experiments are under way on more test cases of the theory; these are forbidden beta-transition followed by a single gamma-ray to an even-even ground state.

Grateful acknowledgment is made of helpful discussions with Professor E. Fermi and Dr. C. N. Yang.

A fuller account of these investigations will be published in this journal.

TABLE I. Coefficient b in the function $1+b\cos^2\theta$ fitted by least squares to the experimental points.

Isotope	b
Na^{24}	$-0.02\ \pm0.02$
Co^{60}	-0.003 ± 0.01
Ru^{103}	$+0.025\pm0.025$
Ru^{105}	-0.002 ± 0.009
Cd^{115}	$+0.02\ \pm0.02$
Ir^{192}	-0.004 ± 0.03
Au^{198}	$+0.006\pm0.01$

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[1] Pile irradiation of the sources, and some of the measurements were carried out at the Argonne National Laboratory. I should like to thank the staff of the Argonne Laboratory for their help and cooperation.
[2] D. L. Falkoff, Ph.D. Thesis, University of Mich. (1948).
[3] C. N. Yang, Phys. Rev. **74**, 764 (1948).
[4] L. Brady and M. Deutsch, Phys. Rev. **74**, 1541 (1948).
[5] E. J. Konopinski, Rev. Mod. Phys. **15**, 209 (1943).
[6] In addition to the work reported here on the beta-gamma-problem, M. L. Wiedenbeck and K. Y. Chu inform me (August 10, 1949) that they have found no anisotropic correlation to 4 percent in Na^{24}, K^{42}, Co^{60}, Au^{198}, Cs^{134}, and I^{131}.
[7] Also Na^{24} and Co^{60} at 90° and 180° by Grace, Allen, and Halban, Nature **164** (Sept. 24, 1949).

Hyperfine Structure and Nuclear Moment of Pb^{207}

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THE recent radiofrequency induction measurement[1] of the nuclear magnetic moment of Pb^{207} makes possible an additional confirmation of the effect of finite nuclear radius on the electron-nuclear magnetic interaction constant.[2,3] The theory is tested by comparing the nuclear moment calculated from the spectroscopically determined interaction constant of a single s electron with the directly measured moment. For the one-electron spectrum Pb IV there are no measurements of hyperfine structure splittings of s levels. However a_{6s}, the interaction constant for the $6s$ electron of Pb IV, has been deduced from the levels of Pb III using the measurements of Crooker[4] and Crawford, making allowance for interconfiguration perturbations.[5] It is found that all the hyperfine structure splittings of the $6s6d$, $6s7d$, $6s8s$, $5d^96s6p$, $6s7p$, $6s5f$ configurations are fitted by $a_{6s}=2.60\ \text{cm}^{-1}$. It is believed that this interval factor is accurate within $\pm0.05\ \text{cm}^{-1}$.

The Goudsmit-Fermi-Segrè formula is

$$g(I)=\frac{a_{6s}\cdot 3n^{*3}\cdot 1837}{8R\alpha^2Z_iZ_0^2\kappa(\frac{1}{2},Z_i)(1-d\sigma/dn)}$$

where the symbols have the usual meanings.[6,7] For $5d^{10}6s$ of Pb IV, $n^*=2.268$ and the Fermi-Segrè correction factor $(1-d\sigma/dn)$ from a Rydberg-Ritz formula[3] is 1.16, and $\kappa=2.38$. Then $g(I)=0.99(4)$ and since $I=\frac{1}{2}$, μ for $Pb^{207}=0.49(7)$ nuclear magnetons.

The value obtained by the nuclear induction measurement,[1] $\mu=0.588\pm0.001$ nuclear magnetons, is 18 percent higher than the spectroscopic value. It has been shown for thallium[3] that the correction due to the finite volume occupied by the nuclear electric charge, with approximately uniform charge density, increases the spectroscopic value by about 15 percent. The same, or a slightly larger, correction is to be expected for lead. A further correction in the same direction of about 3 percent probably should be added because the magnetic moment is distributed through the nuclear volume. Thus for lead as well as thallium, lanthanum and caesium the correction for the finite volume of the nucleus brings the spectroscopic values of the magnetic moment into agreement with the induction measurement.

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[1] W. G. Proctor, Phys. Rev. **76**, 684 (1949).
[2] J. E. Rosenthal and G. Breit, Phys. Rev. **41**, 459 (1932).
[3] M. F. Crawford and A. L. Schawlow, Phys. Rev. **76**, 1310 (1949).
[4] A. M. Crooker, Can. J. Research **A14**, 115 (1936).
[5] J. N. P. Hume, Ph.D. Thesis, Toronto (1949).
[6] S. Goudsmit, Phys. Rev. **43**, 636 (1933).
[7] E. Fermi and E. Segrè, Zeits. f. Physik **82**, 729 (1933).