TABLE I. Measured and corrected hfs intervals of the metastable $^2P_{\frac{3}{2}}$ state of Ga^{69} and Ga^{71}.

	Ga^{69} (Mc/sec)	Ga^{71} (Mc/sec)
	Measured	
$F=0\leftrightarrow F=1$	128.27730±0.00020	203.04340±0.00020
$F=1\leftrightarrow F=2$	319.06706±0.00020	445.46960±0.00020
$F=2\leftrightarrow F=3$	634.90183±0.00020	766.69580±0.00020
	Corrected	
$F=0\leftrightarrow F=1$	128.27650±0.00030	203.04133±0.00040
$F=1\leftrightarrow F=2$	319.06373±0.00050	445.46566±0.00060
$F=2\leftrightarrow F=3$	634.90597±0.00060	766.70181±0.00080

where the uncertainty is the root-sum-square of the uncertainties in each of the terms of the equations which yield the interaction constants in terms of the intervals.

The data cannot be explained by the mechanism of off-diagonal terms in the interaction matrix giving rise to octupole-like $(\mathbf{I}\cdot\mathbf{J})^3$ terms, since $(ab)^{69}/(ab)^{71}$ and $(b^{69})^2/(b^{71})^2$ are greater than unity, and c^{69}/c^{71} is less than unity. To within the quoted uncertainty, $a^{69}/a^{71}=c^{69}/c^{71}$.

Schwartz has evaluated the nuclear octupole moment, Ω, and finds

$$\Omega^{69}=(0.107\pm0.02)\times10^{-24}\text{ nuclear magneton cm}^2,$$

and

$$\Omega^{71}=(0.146\pm0.02)\times10^{-24}\text{ nuclear magneton cm}^2.$$

Here, as in the corrected intervals, the quoted uncertainty includes the experimental error and the uncertainty in theoretical evaluation.

The results and experimental procedure will be presented in greater detail in a later paper.

The interest and encouragement of Professor J. R. Zacharias during the investigation are gratefully acknowledged.

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[1] Previous measurement by P. Kusch and G. E. Becker, Phys. Rev. **73**, 584 (1948).
[2] N. F. Ramsey and H. B. Silsbee, Phys. Rev. **84**, 506 (1951).
[3] We are indebted to C. Schwartz for the calculation of the interval corrections.
[4] For the interaction Hamiltonian, as well as an explicit definition of the constants *a*, *b*, and *c*, see Jaccarino, King, Satten, and Stroke, Phys. Rev. **94**, 1798 (1954). For gallium, the definition of *b* given should be taken with opposite sign.

Scattering of Gamma Rays by Nucleons*

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THE cross section for the scattering of photons of energy $\hbar\omega$ by any nonrelativistic, bound system in which the number of particles is conserved has been shown[1] to be proportional to ω^4 for wavelengths large compared to the dimensions of the system if the Thomson scattering and scattering by the static magnetic moment are neglected. The proof depends only on the gauge invariance of the Schrödinger equation, not at all on the detailed distribution of currents and charges in the system. It is natural to raise the question of whether the same theorem may be established for other systems, for example, if the nucleon is treated as a structured system in which the number of pions is not a good quantum number.

It turns out that it is possible to extend the theorem to a much more general class of bound systems, the only condition on the system other than gauge invariance being that its wave function must be normalizable. The proof follows closely that given by Sachs and Austern.[1] It makes use of the condition of gauge invariance in the form

$$e^g H_m\{\mathbf{A}\}e^{-g}=H_m\{\mathbf{A}+\text{grad}G\},$$

where $H_m\{\mathbf{A}\}$ is the Hamiltonian of the matter field in the presence of an external electromagnetic field having vector potential $\mathbf{A}$, $G(\mathbf{r})$ is an arbitrary function which in fact may be any electromagnetic field operator that commutes with $\mathbf{A}$, and

$$g=(ie/\hbar c)\int G(\mathbf{r})\rho(\mathbf{r})d^3r,$$

where $\rho(\mathbf{r})$ is the charge density operator of the matter field.

A calculation of the scattering of gamma rays by nucleons by Sachs and Foldy[2] based on nonrelativistic, no-recoil, pseudoscalar meson theory led to a result contrary to the above-stated result. It was found that the scattering amplitude contained a spin-dependent term proportional to the frequency at long wavelength, and that this term was not related to the static magnetic moment.[3] This contradiction has to do with the fact that the unrenormalized nonrelativistic meson theory does not lead to a normalizable state vector as is required to establish the theorem. In fact, the results of SF were finite by virtue of a cancellation between infinite integrals, and in particular, the questionable term resulted from that cancellation. Such cancellations are usually ambiguous and some convergence procedure must be established to eliminate the ambiguity.

The problem has been reconsidered by one of us (RHC) on the basis of a pseudovector interaction containing a finite source. The finite source theory has been made gauge invariant by introducing the necessary line currents. The state vector is then normalizable and all relevant integrals are finite. If the source size is allowed to become small without limit, the scattering amplitude differs from that obtained by SF simply by the elimination of the term that violates the general theorem.

The corrections to SF have been obtained as a function of energy to energies well above pion threshold by this convergence procedure. A further, and important, correction to SF, namely the inclusion of the absorptive part of the scattering, has also been introduced in these calculations. For the purpose of comparison with the results of SF, the newly calculated total scattering of gamma rays by neutrons is shown in Fig. 1 along with

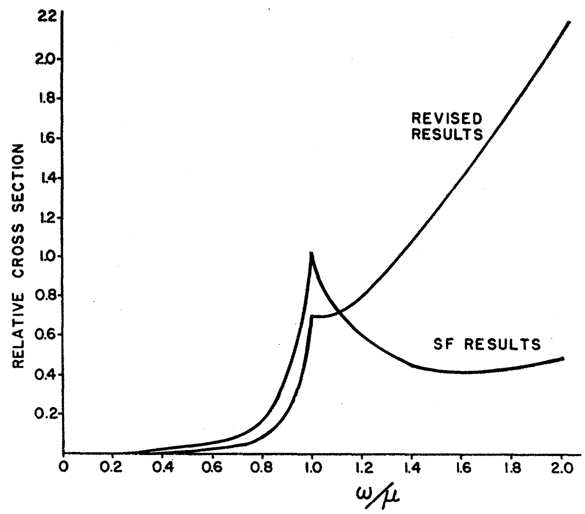

FIG. 1. Total cross section for scattering of gamma rays by neutrons calculated in weak-coupling, no-recoil, pseudoscalar meson theory. Results obtained by SF (see reference 2) are also given for comparison. The energy is given in units of the pion mass, the absolute cross section is proportional to g^4, and the above values are given in units of the Thomson cross section for $g^2/\hbar c = 0.116$.

the old results. The neutron was used for this purpose since the shape of the curve is independent of the choice of coupling constant. That is not the case for the proton because of the interference between Thomson and mesonic scattering. It is to be borne in mind that this is a weak coupling calculation carried only to order g^4 in the meson-nucleon coupling.

The energy dependence of the total cross section of the proton shows an equally important change from the curve obtained by SF, as does the differential cross section. These results will soon be submitted for publication along with a detailed discussion of both the general arguments and the method of calculation.

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† National Science Foundation Predoctoral Fellow.

[1] R. G. Sachs and N. Austern, Phys. Rev. **81**, 705 (1951).
[2] R. G. Sachs and L. L. Foldy, Phys. Rev. **80**, 824 (1950). Referred to as SF.
[3] The fact that this term probably should not occur has been pointed out to the authors by Foldy, Kroll, and Goldberger in discussions at Brookhaven National Laboratory.

Nuclear Spin of Np^{239}†

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MICROGRAM quantities of Np^{239}, a 2.3-day beta-gamma activity, were produced by a neutron irradiation of uranium in a high-flux pile. The chemistry used to separate the neptunium from the uranium was an extraction of the Np^{+4} ion into a TTA (thenoyltrifluoroacetone) benzene phase. The intense radiations of the neptunium produced enough peroxide to interfere with the separation, however, sufficient Np^{239} was obtained to conduct the experiment. The Np^{239} was also radiochemically identified and assayed.

The Np^{239} was evaporated on a $\frac{1}{4}$-inch graphite electrode and arced at 15 amperes dc. Neptunium-237, a graphite blank, and an iron arc were photographed for comparison. The spectra were photographed in the second and third order on a 21-foot Paschen-Runge mount with a 30 000-line/inch grating.

The hyperfine pattern of Np^{239} showed two lines and, thus, a spin of $I=\frac{1}{2}(h/2\pi)$ can be assigned to this isotope. The Np^{237} comparison spectrum showed the six-component flag pattern as reported by Tomkins.[1]

The neptunium line at 3999.5A was the best-resolved and widest line observed. The distances from the centers of the first and last components of the line are in the ratio of 1 to 6.9 ($\pm$0.1) for Np^{239} to Np^{237}.

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[1] F. S. Tomkins, Phys. Rev. **73**, 1214 (1948).

Possible Existence of a New Hyperon*

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AN unusual event has been found in a stack consisting of 42 Ilford G-5 400-μ stripped emulsions flown for $6\frac{1}{2}$ hours at approximately 100 000 ft from Goodfellow Air Force Base, Texas (41°N geomagnetic latitude). The event is shown in Fig. 1. Particle K_2 comes to rest in the emulsion and gives rise to a star containing 5 visible prongs. Of these 1, 2, and 3 are protons of 1.0, 5.5, and 0.5 Mev, respectively. Track No. 4 is a 29-Mev alpha particle, and the light track L