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

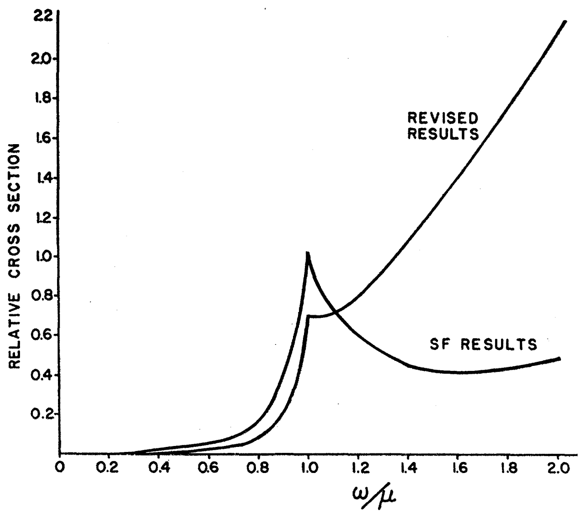

FIG. 1. Total cross section for scattering of gamma rays by neutrons calculated in weak-coupling, no-recoil, pseudoscalar meson theory. Results obtained by SF (see reference 2) are also given for comparison. The energy is given in units of the pion mass, the absolute cross section is proportional to 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}†

JOHN G. CONWAY AND RALPH D. MCLAUGHLIN
Radiation Laboratory, University of California, Berkeley, California
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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 (± 0.1) for Np^{239} to Np^{237}.

We wish to acknowledge the help of Dr. J. C. Wallmann and Professor B. B. Cunningham, and also the Health Chemistry Department of the Radiation Laboratory, particularly D. Martin, Jr., J. E. Anderson, and T. C. Parsons. We are also indebted to Professor F. A. Jenkins of the Department of Physics of the University of California for the use of the spectrograph and to Dr. G. H. Higgins for the radiochemical assay.

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Possible Existence of a New Hyperon*

Y. EISENBERG†
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York
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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

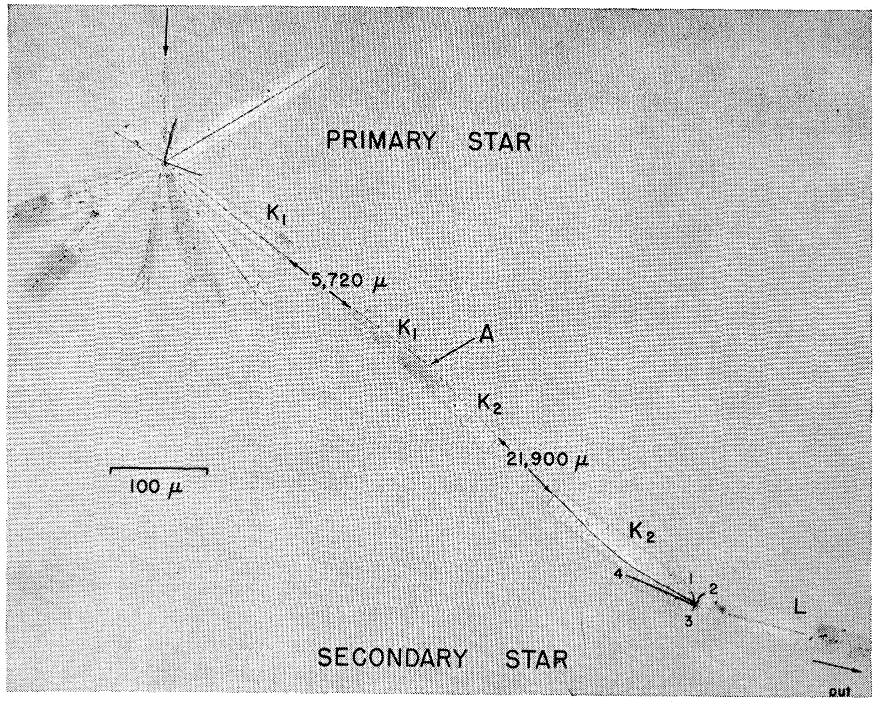

FIG. 1. A microphotograph of the event observed.

has been identified by scattering *vs* ionization measurements as an L (π or μ) meson of kinetic energy 33±4 Mev. Track L leaves the stack after 12 000 μ, therefore the sign of the charge of the particle is unknown. The total visible energy of this sigma star (including the rest mass of the π meson, and not counting binding energies) is 209±4 Mev, therefore it must have been induced by the capture of a heavy meson. Indeed, the mass of K_2 as determined by the scattering *vs* residual range measurements (using the constant sagitta method)[1] from the point A to the sigma star turns out to be $M(K_2)=940\pm200\ m_e$. Also the ionization *vs* residual range curve of K_2 is the expected one for a particle of mass about 1000 m_e (see Fig. 2). We consider, therefore, that the identification of K_2 as a heavy negative meson is established.

In the following K_2 back to its origin it was found that 21 900 μ before the capture star it suffered a 10° deflection (point A in Fig. 1). The part of the track before A is labeled K_1. K_1 originates in a $5+11_p$ star produced by a fast charged particle of energy about 30 Bev (estimated by the angular distribution of the meson shower).

The ionization of K_1 (which crossed 3 different plates from point A to the primary star) is about 10±4 percent above the expected ionization of a K meson having the range of K_2, as determined by extrapolating the ionization-range measurements of K_2 into the region before point A (see Fig. 2). Random nearby background tracks crossing the same emulsions were also grain-counted and failed to show any systematic change in grain density among these plates. This difference in grain density by itself would not have been considered significant. However, the scattering of K_1 turns out to be 3.3 times smaller than the expected scattering of a K meson of the same range. The calculated mean scattering angle of a K meson (mass 965 m_e) between the point A and the primary star is $\bar{\alpha}_{\text{calc}}=0.259°/100\ \mu$, whereas the observed value is $\bar{\alpha}_{\text{obs}}=0.078\pm0.017°/100\ \mu$. The cell length chosen was 170 μ and the scattering values obtained for the 3 plates were 0.087, 0.067, and 0.081°/100 μ, respectively. The probability of such a difference in the scattering to happen by chance is extremely small.

The three facts mentioned above, namely, (1) the 10° deflection, (2) the ratio of 1.1±0.04 between the grain density of K_1 and K_2, and (3) the difference of 0.181±0.017°/100 μ between the scattering of K_2 and the expected value if $K_2=K_1$, suggest that this is perhaps an example of a decay in flight of a negative hyperon, Y_1^-. The possibility that K_1 and K_2 are both the same particle, a negative hyperon which gives rise to a sigma star (the scattering of K_2 yielding a mass value smaller than that of a hyperon due to the steepness of the tracks and the slight distortion in the emulsions) is excluded since, as mentioned before, the grain-density range measurements of K_2 agree very well with the expected ones for a meson of mass ~1000 m_e (see Fig. 2).

There is no particle which is known to decay into a K meson. Therefore, if this is a decay process it must be either an alternate mode of decay of a known particle, or a decay of a new unknown particle. If one assumes that this is a two-body decay, the following

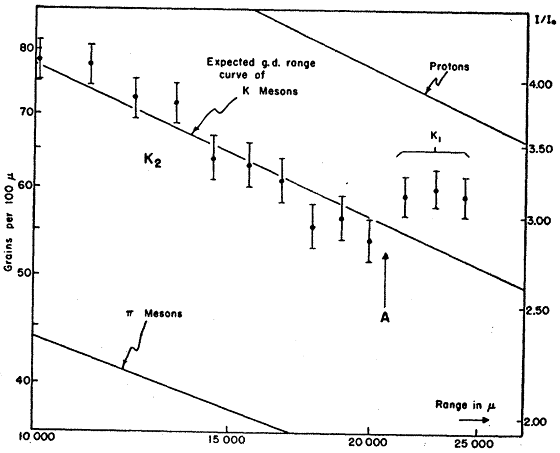

FIG. 2. Grain density *vs* range measurements (log-log scale) of K_2. Solid lines: expected curves for protons, K mesons, and π mesons. (Note: the three points of K_1 are plotted as a function of their distance from the endpoint of K_2. Therefore, it is not the correct grain density-range plot of K_1.)

may be argued. From the relative grain density, the velocity of K_2 is about 1.05 times the velocity of Y_1. Since the angle of deflection is only 10°, the Q value of the decay $Y_1 \rightarrow K_2+$neutral is about 5 Mev no matter what the neutral particle is. Therefore, the mass of Y_1^- will essentially be the mass of K_2 plus the mass of the neutral particle. The known hyperons, Λ^-, Ω^-, have masses equivalent to 1200 and 1320 Mev, respectively. $Y_1^- \rightarrow K_2^- + n$ would require $M(Y_1)=1440$ Mev, and $Y_1^- \rightarrow K_2^- + K^0$ would require $M(Y_1)=1000$ Mev. Thus the possibility of an alternate two-body mode of decay of a known hyperon is ruled out.

If it is a three-body decay process, nothing can be said about the Q value. But, even in this case, it seems unlikely to be an alternate three-body decay scheme of a known hyperon because of the following argument. The scheme $Y_1^- \rightarrow K_2^- + n$ (or Λ^0)+neutral+Q can be discarded since it gives for the mass of Y_1^- at least 1440 Mev, which is much over the masses of the known hyperons. If $Y_1^- \rightarrow K_2^- + K^0$ (or π^0)+neutral+Q, by a proper choice of Q and the neutral particle, one can make the mass of Y_1^- agree with the mass of Λ^- or Ω^-. But, by assuming the last decay scheme, we are admitting the possibility that hyperons, which may be regarded as a combination of nucleons and mesons, especially since they are produced at cosmotron energies[2] much below the nucleon production threshold, are capable of disintegrating into mesons only. That would mean annihilation of a nucleon in the decay process, which we do not like to believe possible.

On the assumption that Y_1 is a new particle, we obtain:

$$\text{if } Y_1^- \rightarrow K_2^- + n + Q, \text{ then } M(Y_1) \approx 2830\ m_e;$$
$$\text{if } Y_1^- \rightarrow K_2^- + \Lambda^0 + Q, \text{ then } M(Y_1) \approx 3160\ m_e.$$

A search for a Λ^0 particle in the direction determined by the second of the above schemes failed to yield positive results. The chances of finding the Λ^0, if it existed, were about 25 percent. The direct mass measurements of Y_1 by scattering *vs* ionization gave $M(Y_1) = (3200^{+1200}_{-500})$ electron masses. Either one of the above schemes agrees with the observed mass of Y_1. All errors quoted in the discussion are standard statistical errors.

The author is greatly indebted to Professor G. Cocconi for many helpful discussions and suggestions during the analysis of this event.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at the Weizmann Institute of Science, Physics Department, Rehovoth, Israel.
[1] Biswas, George, and Peters, Proc. Indian Acad. Sci. **38**, 418 (1953).
[2] Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. **93**, 861 (1954).

Measurement of the Spin and Gyromagnetic Ratio of C^{13} by the Collapse of Spin-Spin Splitting

VIRGINIA ROYDEN
Varian Associates, Palo Alto, California
(Received July 29, 1954)

A PRECISE and interesting measurement of the ratio of the resonance frequency of C^{13} to that of H^1 has been obtained in the course of some experiments on indirect spin-spin interactions between nuclei in molecules.[1–3] The multiplet structure in the nuclear resonance of a given nucleus caused by spin-spin interaction with another nucleus of like or different atomic species can be reduced to a single line by irradiating the second nucleus with an rf magnetic field of its own resonance frequency.[4,5]

The transmitter section of a standard nuclear induction probe was modified so that it tuned to both 30 Mc/sec and 7.5 Mc/sec simultaneously. The proton spectrum of CH_3I enriched with 51 percent C^{13} was observed at 30 Mc/sec under "slow passage" conditions with the high-resolution spectrometer.

The oscilloscope trace showed three peaks, of which the central one was caused by those protons attached to C^{12} (Fig. 1). The two outer proton peaks were separated by 11 milligauss from the central peak as a result of the spin-spin interaction between C^{13} and its companion H^1 nuclei. The number and relative amplitudes

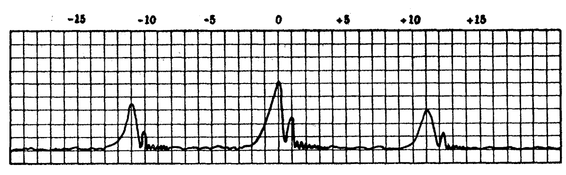

FIG. 1. Proton spectrum at 30 Mc/sec of CH_3I enriched with 51 percent C^{13}. The two outside lines are split by the spin-spin interaction between C^{13} and H^1.

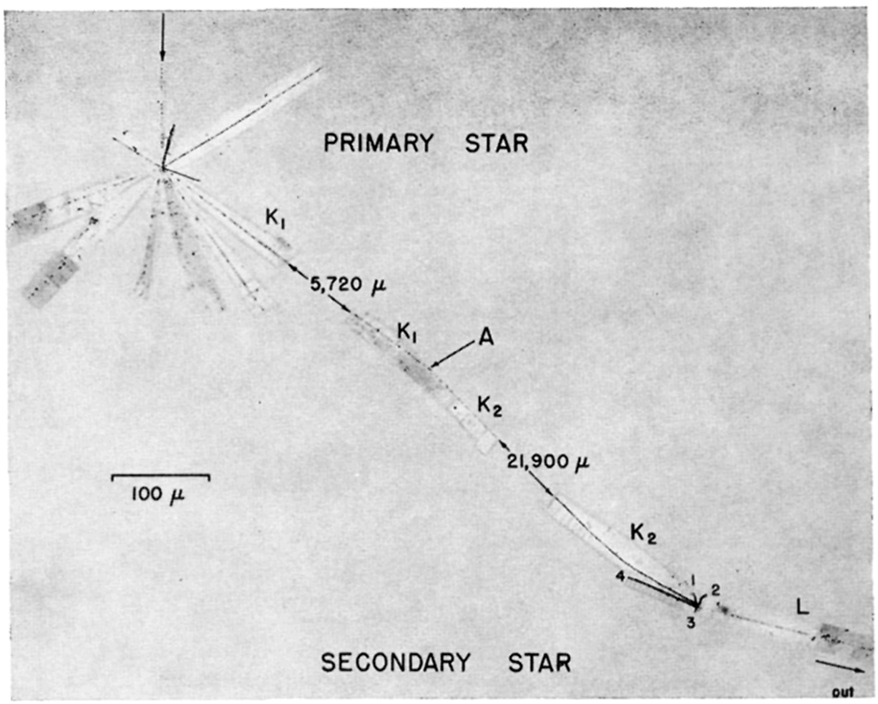

FIG. 1. A microphotograph of the event observed.