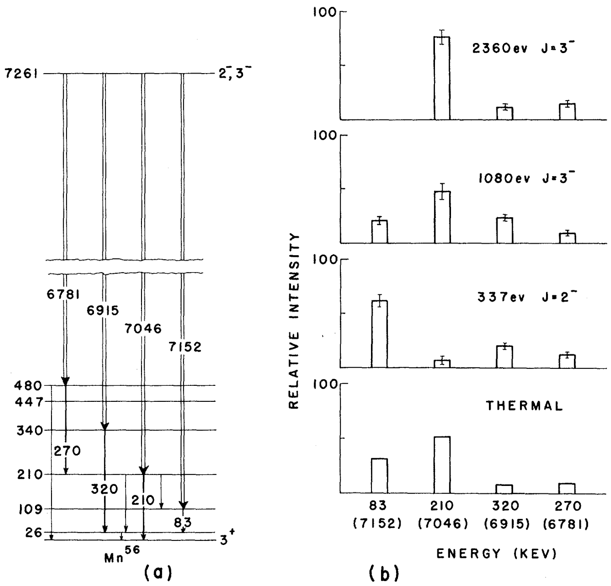

FIG. 2(a). The low-lying states of Mn^{55} and the transitions observed following neutron capture in Mn^{55}. (b) The relative intensities of the transitions observed following neutron capture in manganese resonances. Corrections have been made for γ-ray branching and the sum of the intensities for each resonance is normalized to 100.

about $\frac{1}{2}\%$. The reality of this high resolution is demonstrated by the relative ease with which the 320- (6915-) kev line is observed. Although its intensity is about 1%, Bartholomew and Kinsey[7] did not observe it, possibly because of masking by the strong (6.5%) 7046-kev line. The intensities shown in Fig. 2(b) have been corrected for branching. The wide fluctuations in intensity are apparent and clearly are much greater than the statistical uncertainty of the experiment.

Although the measurements are of a preliminary nature, some rather significant conclusions can be drawn from them. The marked difference between the γ-ray spectra resulting from the capture of thermal and 337-ev neutrons is of considerable interest and had not been anticipated. This difference suggests that the thermal cross section is strongly influenced by a resonance at negative energy and not only by the 337-ev resonance, as had previously seemed probable. Quantitative calculations show that this suggestion is not inconsistent with the total cross section measurements.[5] Of more fundamental importance, the spectra for the resonances at 1080 and 2360 ev differ from each other in a marked way even though the compound nucleus has the same spin state in both cases. Thus the data may be an indication that $\Gamma_{\gamma i}$ is not constant but varies in a statistical manner, possibly as proposed by Porter and Thomas.[8]

An extensive program is underway to study several nuclides. It is hoped that spins and lifetimes can be assigned to the low-lying levels and that additional information can be obtained regarding the actual distribution of $\Gamma_{\gamma i}$.

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1 Harvey, Hughes, Carter, and Pilcher, Phys. Rev. 99, 10 (1955).
2 H. H. Landon and E. R. Rae, Phys. Rev. 107, 1333 (1957).
3 Fenstermacher, Bennett, Walters, Bockelman, and Schultz, Phys. Rev. 107, 1650 (1957).
4 Fenstermacher, Draper, and Bockelman (to be published).
5 Bollinger, Dahlberg, Palmer, and Thomas, Phys. Rev. 100, 126 (1955).
6 Green, Smith, Buechner, and Mazari, Phys. Rev. 108, 841 (1957).
7 G. A. Bartholomew and B. B. Kinsey, Phys. Rev. 89, 386 (1953).
8 C. E. Porter and R. G. Thomas, Phys. Rev. 104, 483 (1956).

HIGHER-ORDER EFFECTS IN THE ALLOWED BETA DECAY OF F^{20}†

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It has been proposed by Gell-Mann[1] that the usual vector interaction in beta decay should be modified by addition of a small correction term due to the effect of virtual meson currents around the nucleons. This term is proportional to the difference of the anomalous magnetic moments of protons and neutrons and is of the order of 0.1% per Mev beta energy. This correction term, if it exists, gives rise to a slight deviation from the well known allowed shape of the beta spectrum. An experiment to study this effect has been suggested.[1]

We consider here another way of studying this effect, namely the beta-gamma angular correlation. Normally the beta-gamma angular correlation of an allowed transition is isotropic. The addition of the new term, however, gives rise to a small anisotropy which can be detected experimentally.

Since the resulting correction to both the beta spectrum and the beta-gamma angular correlation is very small, similar corrections due to the finite wavelength of the electron and relativistic nucleon motion have to be considered in both types of experiments. All these corrections are approximately of the same order of magnitude. Nevertheless, for a rough discussion we shall neglect these terms. Such an approximation is entirely equivalent to a description of a magnetic dipole transition by the anomalous magnetic moments of the nucleons alone, neglecting the orbital parts. Under this assumption one obtains for the angular distribution in the case of an allowed Gamow-Teller transition

$$W(\theta) = 1 - \tfrac{4}{3}\,\frac{\mu_p - \mu_n}{2Mc^2}\left\{E_0 - E\left(1 + \frac{v^2}{c^2}\right)\right\} + \frac{\Sigma_{\lambda\lambda'} F_2(\lambda, \lambda', I_{ff} I_f)\,\delta_\lambda \delta_{\lambda'}}{\Sigma_\lambda |\delta_\lambda|^2} \times F_2(1, 1, I_i I_f)\, 2\,\frac{\mu_p - \mu_n}{2Mc^2}\,\frac{v^2}{c^2}\,E(\cos^2\theta - \tfrac{1}{3}). \qquad (1)$$

In this expression θ is the angle between electron and gamma quantum, $\mu_p - \mu_n = 3.7$, and all other quantities have conventional meaning such as defined in by Alder *et al.*[2]

An experimental study of the coefficient of $\cos^2\theta$ has been done for the beta decay of F^{20}. F^{20} has an electron spectrum with an end point of 5.4 Mev and a subsequent gamma ray of 1.63 Mev. With a spin pattern $I_i = 2^+$,[3] $I_f = 2^+$, $I_{ff} = 0^+$,[4] Eq. (1) gives an angular distribution

$$W(\theta) = 1 + a \cos^2\theta, \qquad (2)$$

with

$$a \approx 1.0 \times 10^{-3} E[1 - (m_e/E)^2] \quad (E, m_e \text{ in Mev}).$$

F^{20} was produced by bombarding a CaF target with deuterons of 1.7 Mev from the 2-Mev Van de Graaf. The CaF target, which was prepared by vacuum evaporation onto a thin nickel foil, had a total thickness of a few hundred kilovolt for the incoming deuterons. Its thickness for electrons consequently was neglegible. The target chamber consisted of a hollow Lucite cylinder of 3 inches inner diameter and $\frac{1}{8}$ inch wall thickness. The deuteron beam entered the target chamber after passing through an electrostatic analyzer and impinged on a well-defined spot on the target.

The counter arrangement consisted of a $1\frac{1}{2} \times 1\frac{1}{2}$-inch NaI crystal for the detection of the gamma rays and a $1\frac{1}{2} \times 1$-inch plastic scintillator for the detection of the electrons. The gamma counter was stationary and the beta counter was movable and could assume angles of 90° and 180° with respect to the gamma counter. Both counters were connected to a fast coincidence circuit. The single pulses of the gamma counter were biased at 1.2 Mev and those of the beta counter at 4.5 Mev. These pulses together with the fast coincidence pulses were fed to a slow triple coincidence circuit. The ratio of accidental to real coincidences over one run was 5%. Data was taken in the following way. With the counters turned off the target was irradiated until a certain activity level of F^{20} was reached as indicated by the monitor. The deuteron beam then was turned off and after a few seconds, when the source strength had assumed a certain preset value, the counters were turned on by the monitor system for a counting period of 16 seconds. About 300 coincidences were obtained in each run. Sets of 5 runs were taken at 90° and 180° alternatively. In the analysis, the number of triple coincidences was divided by the number of single counts in the beta counter, thus eliminating a possible small difference in the solid angle of the beta counter at 90° and 180°.

The result of this experiment, accepting all electrons above 4.5 Mev, is

$$a = (+0.94 \pm 0.28)\%.$$

This result has to be compared with the value of $a \approx +0.45\%$ derived from Eq. (2).

As a check of the experimental arrangement the beta-gamma angular correlation in the decay of Na^{24} has been measured for an electron energy of 0.8 Mev. The value of $a = (+0.01 \pm 0.1)\%$ has been found. The theoretically predicted value from Eq. (1) is $a \approx +0.05\%$.

The observed effect in F^{20} is the first indication of the presence of higher-order corrections in an allowed beta-gamma correlation experiment. The sign and the magnitude agree with the rough estimate of the Gell-Mann term.

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[1] M. Gell-Mann, Phys. Rev. (to be published).

[2] Alder, Stech, and Winther, Phys. Rev. 107, 728 (1957).

[3] The spin 2^+ for the ground state of F^{20} seems more likely than the spin 1^+ reported by F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. 27, 77 (1955). A spin assignment 1^+ would reverse the sign of a.

[4] In the case of a 2-2 transition we also would expect a contribution from the usual vector part. But this contribution must be small by virtue of the isotopic spin conservation. The "orbital parts" are consistently neglected [see Eq. (1) and above].

ERRATUM

CIRCULAR POLARIZATION OF A^{37} INTERNAL BREMSSTRAHLUNG. Lloyd G. Mann, John A. Miskel, and Stewart D. Bloom [Phys. Rev. Lett. 1, 34 (1958)].

In the line following the first equation, the expression $P_{1S}(k)$ should be replaced by $p_{1S}(k)$.