geometry and in the degree of moderation of the neutrons, precise agreement is not to be expected.

The ratio of 5×10^{-5} should, however, be considered as an upper limit to the ratio of the cross section for photo-disintegration of the proton to that for Be, since the same two γ-rays (1.81 and 2.13 Mev) are involved in both cases. The cross section for the Be (γ,n) reaction appears to vary with photon energy in an unknown manner. Russell *et al.*[6] give $>10\times10^{-28}$ and 3.3×10^{-28} cm^2 as the cross sections at 1.67 and 2.5 Mev, respectively. Assuming a value of the order of 8×10^{-28} cm^2 near 1.81 and 2.13 Mev, an upper limit of 4×10^{-32} cm^2 can be set for the cross section for photo-disintegration of the proton by photons of energy in the neighborhood of 2 Mev.

The authors wish to express their indebtedness to A. A. Schulke for his assistance in providing the radioactive source used.

* The research described in this paper was supported, in part, by the Research Corporation and by the Navy Department under Contract N6ori-117, T.O. 1.
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On γ-Induced β-Disintegration: Theoretical*

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May 13, 1948

IN conjunction with the experiment performed by Dr. Kurie and Dr. Burling, and described in the present issue of the Physical Review,[1] a calculation has been made of the cross section for neutron (and positron) production due to irradiation of hydrogenous materials by γ-rays. The reaction treated is

$$\gamma+P\rightarrow N+e^{+}+\nu, \tag{1}$$

where γ, P, N, e^{+}, and ν refer to the γ-ray, proton, neutron, positron, and neutrino, respectively; the cross section obtained on the basis of the Fermi theory of β-decay is $\sim10^{-46}$ cm^2 at the γ-ray energies used. Thus, Burling and Kurie's failure to detect any γ-induced neutrons in their experiment and their estimate of an upper limit to the cross section as $\sim10^{-32}$ cm^2 is in agreement with the β-decay theory.

The numerical value for the cross section quoted above is obtained with the use of time dependent perturbation theory to calculate the corresponding transition probability, the scalar interaction between the electron-neutrino and proton-neutron fields being assumed. In this perturbation theory, the reaction in Eq. (1) is treated as a two-step process: $P\rightarrow N+(e^{+})'+\nu$ followed by $(e^{+})'+\gamma\rightarrow e^{+}$ and $\gamma\rightarrow e^{+}+e^{-}$ followed by $P+e^{-}\rightarrow N+\nu$, the matrix elements, the energy denominators, the density of final states, the summations over intermediate states and over the spins and polarization of the P, N, e^{+}, ν, and γ being all evaluated in the usual way. The resultant expression for the cross section of (1), σ_γ may be written as

$$\begin{aligned}\sigma_\gamma &\sim(2\pi^3\cdot30)^{-1}(2\pi e^2/\hbar c)G^2(\hbar/m_ec)^2\\ &\quad\times\{[[E_\gamma-(M_Nc^2-M_Pc^2)]/m_ec^2]^5(m_ec^2/E_\gamma)\}\\ &\sim(2\pi e^2/\hbar c)(\hbar(T)^{-1}/m_ec^2)(\hbar/m_ec)^2(m_ec^2/E_\gamma)\end{aligned} \tag{2}$$

for $M_Nc^2-M_Pc^2\ll E_\gamma\ll M_Pc^2$. (For $E_\gamma\gg M_Pc^2$ the γ-energy dependent quantity in the curly brackets is replaced by $\sim[M_Pc^2/m_ec^2]^2$.) In Eq. (2), e, $\hbar$, c have their usual significance; M_P, m_e, M_N are the proton, electron, and neutron rest masses, respectively; E_γ is the γ-ray energy; G is the (dimensionless) interaction constant between the electron-neutrino and proton-neutron fields; T is the mean life of a completely allowed β-decay process with an energy release equal to $E_\gamma-(M_Nc^2-M_Pc^2)$; one has $\sigma_\gamma\sim10^{-46}$ cm^2 for $E_\gamma\leqq2$ Mev. Other types of interaction between the light and heavy particle fields, e.g., polar vector, should yield comparable values for σ_γ.

In conclusion it might be of interest to give the results of a calculation for the cross section of the electron capture reaction:

$$e^{-}+P\rightarrow N+\nu, \tag{3}$$

i.e., the creation of neutrons and neutrinos as a result of electron-proton collisions. The corresponding cross section, σ_e (calculated in a manner analogous to that of σ_γ, though, of course, the reaction now involves a single step process), is

$$\sigma_e\sim(2\pi)^{-1}G^2(\hbar/m_ec)^2\{E_e-[(M_Nc^2-M_Pc^2)/m_ec^2]\}^2, \tag{4}$$

for an electron energy $E_e\ll M_Pc^2$. (For $E_e\gg M_Pc^2$, the electron-energy dependent quantity in the curly brackets is replaced by $\sim[M_Pc^2/m_ec^2]^2$.) Thus $\sigma_e\sim2\times10^{-43}$ cm^2, for $E_e\leqq2$ Mev. A cross section of essentially the same value also applies to the neutrino capture reaction, $\nu+P\rightarrow N+e^{+}$,[2] in which the roles of the neutrino and electron are interchanged (relative to Eq. (3)).

* The research described in this paper was supported in part by Contract N6ori-117, U. S. Navy Department.
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Attempt to Detect Neutral Particles Produced by Exchange of Charge with Cosmic-Ray Mesons

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May 17, 1948

RECENT experiments at Berkeley[1] indicate the existence of exchange of charge between protons and neutrons. In such an exchange the particle may suffer little loss of energy or deviation in angle. The same type of exchange might be expected to occur between charge and neutral mesons if the latter exist. During the course of some experiments on absorption and scattering an attempt was made to detect the production of high speed neutral particles in heavy elements by cosmic-ray mesons which have penetrated a considerable layer of absorbing material in the laboratory. If such particles were produced by an exchange process, their detection would depend on the life of the neutral particle and the frequency of occurrence of the exchange.

Recently de Vos and du Toit[2] reported an effect which they ascribed to neutral particles in incident cosmic rays detected by means of paraffin placed either above or below the first tube of a coincidence counter. In the present experiment measurements were made to see if the ionizing rays which have already passed through the first tube of a coincidence-anticoincidence arrangement would produce an effect in iron or lead which would then be sensitive to the presence of a light substance such as paraffin. Measurements with iron were of interest because of the observations that negative mesons absorbed in iron do not give evidence of ionizing decay products.

Four Geiger-Mueller tubes $18\times 2\frac{1}{4}$ inches were used in a vertical array. The second tube from the top was connected in anticoincidence. Layers of iron, lead, and paraffin were used in thicknesses of 10, 7, and 3.7 centimeters, respectively. Above the lowest tube 7 centimeters of lead served to insure that the rays which were counted after passing through the absorbing material were penetrating rays, presumably mesons. With lead or iron above the anticoincidence tube and paraffin below it, as many as 20 percent more counts was registered than when the position of the heavy absorber and paraffin were reversed.

Comparison measurements with layers of one material in different positions, however, indicated that these large differences were mostly due to scattering and absorption depending on the position and nature of the material. The differences in counts which were obtained were always in the direction to be expected if a neutral ray from iron or lead passed through the anticoincidence tube and produced an ionizing ray in the paraffin, but it is obvious that the probability of such a twofold occurrence would be small unless the separate probabilities were fairly large.

Because of low counting rate, in spite of large tubes, the measurements were made over a period of several months and the total counts for each of a considerable number of combinations was of the order of 600. Upon subtracting the corrections for scattering and absorption a small effect remained which was of the order of magnitude of the statistical error. However, in repetitions of the measurement this difference was always in the same direction and could be explained by the presence of neutral mesons. Since the heavier meson is now thought more probably to interact with nuclei, the effect may not be measurable with the lighter meson. It may be concluded from the measurements that exchange, if present, is small but not completely ruled out. On account of the size of the tubes and their arrangement, shielding from side showers and accidental counts was impractical. A more exact check of the possibility of the above exchange phenomena might be made if adequate shielding could be provided.

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The Polarization of Neutrons by Magnetized Iron

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May 13, 1948

RECENT measurements of the amorphous[1] and disorder[2] scattering cross sections of iron for slow neutrons permit a redetermination of the mean scattering length of the iron nuclei.

The new value is

$$\langle a_r\rangle_{\text{Av}} = (1/2\pi^{\frac{1}{2}})(11\cdot 0-0\cdot 8)^{\frac{1}{2}}\times 10^{-12} = 9\cdot 01\times 10^{-13}\text{ cm.}$$

The significance of this result in the present context lies in the fact that p, the magnetic scattering cross section which determines the magnitude of neutron polarization effects,[3] is proportional to $\langle a_r\rangle_{\text{Av}}$.

Since Halpern, Hamermesh, and Johnson[3] used a value $\langle a_r\rangle_{\text{Av}} = 7\cdot 33\times 10^{-13}$ cm, their theoretical values of p should be raised by a factor $1\cdot 23$; the theoretical "single transmission effects" are correspondingly increased by a factor $(1\cdot 23)^2 = 1\cdot 51$.

This modification removes about half of the discrepancy between the observations of Fryer[4] and the theoretical values, as recalculated by Hamermesh.[5] Little further increase can be expected in $\langle a_r\rangle_{\text{Av}}$, since the disorder scattering adopted here has already a very small effect, and the amorphous scattering cross section is not likely to be much in error.

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Cloud-Chamber Study of Electrons from Meson Decay*

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May 24, 1948

AN experiment is under way to determine the energy spectrum of electrons arising from decay of mesons at sea level. Three cloud-chamber tracks have been obtained. Range and scattering observations are consistent with energies of 13, 18, and 50 Mev.

The experimental arrangement is shown in Fig. 1. The telescope accepts mesons through angles of 30° and 95° parallel and perpendicular to the plane of the figure, respectively. The cloud chamber, C.C., is rectangular, $10\times 16\times 4\frac{1}{2}$ in., and contains nine $\frac{1}{8}$- and $\frac{1}{4}$-in. aluminum plates. It is set off by a fourfold coincidence event $(ABCD-X)$ within a resolving time of 30 μsec. Mesons are absorbed in a carbon plate, D, 2 cm thick by $4\frac{1}{2}\times 10$ in. Counters, E, have $\frac{1}{32}$-in. copper walls.

The telescope recorded 485 incident mesons per hour Calculations, neglecting scattering, lead to a conservative estimate of $\frac{1}{2}$ percent for the fraction of mesons stopped. The solid angle subtended by the set of side counters is 2.3