LETTERS TO THE EDITOR

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Communications should not in general exceed 600 words in length.

β-Ray Selection Rules and the Meson Theory

The selection rules for β-decay have been discussed on the basis of Fermi's theory,[1] with the result that the only allowed transition is the one in which the angular momentum of the nucleus does not change. According to the modification of Fermi's formalism, proposed by Gamow and Teller,[2] the inversion of the spin of the heavy particle may take place in the β-emission, thus transitions in which the angular momentum of the nucleus changes by 1, are also allowed. It was shown by these authors that the new selection rule is in better agreement with the experimental evidence than the original one.

We want to discuss here the significance of these two selection rules from the point of view of the Yukawa theory of β-emission.[3] We shall consider here the two possibilities of a meson with spin 0 and 1. In this theory, the β-decay is a second-order process, consisting in the emission of a meson and its consequent disintegration into an electron and a neutrino. In order to deal with the changes of the angular momentum of the emitting nucleus, we need to consider only the first step of the β-disintegration i.e., the emission of the meson.

According to Kemmer[4] there are four possible forms of the meson theory, two of which correspond to mesons with spin 0 and the other two to mesons with spin 1. The non-relativistic part of the interaction leading to the meson emission are:

$$H_0^{\mathrm{I}} = H_1^a = ck\int dV\{\Phi_N^*[g_a\psi^* - f_a\pi]\Phi_P + \text{conjugate complex}\}$$

$$H_0^{\mathrm{II}} = H_1^d = -c\int dV\{\Phi_N^* g_d(\boldsymbol{\sigma}\ \mathrm{grad}\ \psi^*)\Phi_P + \text{conj. comp.}\}$$

$$H_1^{\mathrm{I}} = H_1^b = c\int dV\{\Phi_N^*[(\boldsymbol{\sigma}\ \mathrm{curl}\ \psi^*) - g_b\ \mathrm{div}\ \Psi^*]\Phi_P + \text{conj. comp.}\}$$

$$H_1^{\mathrm{II}} = H_1^c = -ck\int dV\{\Phi_N^*[f_c(\boldsymbol{\sigma}\boldsymbol{\psi}^*) + f_c(\boldsymbol{\sigma}\boldsymbol{\Pi}) - g_c(\boldsymbol{\sigma}\boldsymbol{\pi}) + g_c(\boldsymbol{\sigma}\boldsymbol{\Psi}^*)]\Phi_P + \text{conj. comp.}\}$$

$$\mathrm{div}\ \boldsymbol{\psi} = \mathrm{div}\ \boldsymbol{\pi} = 0 \qquad \mathrm{curl}\ \boldsymbol{\Psi} = \mathrm{curl}\ \boldsymbol{\Pi} = 0.$$

The notations are the same as Kemmer's paper. We can observe that these interactions behave under space symmetry as a scalar or an axial vector and so they cannot lead to odd changes of the orbital part of the angular momentum of the nucleus. Thus we may consider only transitions without changes in this momentum.

The transitions due to H_0^{I} do not affect the spin of the heavy particle, as far as H_0^{I} does not contain $\boldsymbol{\sigma}$. On the other hand H_0^{II} leads to the emission of mesons with the angular momentum $l=1$ and $m=0$ or 1, with a change of 0 or 1 in the spin of the heavy particle. H_1^{I} induces emissions of transversal mesons with $l=1$ and $m=0$ or 1 and to the emission of longitudinal mesons (terms wigh g). The first correspond to a spin change of 0 or 1, whereas the second leave the spin unchanged. The analysis of the emissions due to H_1^{II} is much more complicated and will be discussed elsewhere.

Thus we come to the conclusion that *the meson theory of disintegration leads to the Gamow-Teller selection rule*, not only for the theory with spin 1 that gives correct neutron-proton forces, but even for one of the forms of the theory with 0 spin.

I thank Professors Gamow and Wataghin for the discussions and the interest they took in this paper.

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[1] E. Fermi, Zeits. f. Physik **88**, 161 (1934).
[2] G. Gamow and E. Teller, Phys. Rev. **49**, 895 (1936).
[3] H. Yukawa, Proc. Phys. Math. Soc. Japan **17**, 48 (1935).
[4] N. Kemmer, Proc. Roy. Soc. **166**, 127 (1938).

The Elastic Scattering of Fast Electrons by Heavy Elements

Mott[1] has derived an exact expression for the scattering of a Dirac electron in a Coulomb field, as a series in Legendre polynomials. We have summed this series numerically for mercury, and the results should be approximately true for the nearby elements (gold, lead, thallium and bismuth).

Let θ be the angle of scattering, and $q=Zc/137v$, where v is the velocity of the incident electrons, and $Z=80$ for Hg. If we multiply our calculated scattering intensity by $(4/q^2)\sin^4\frac{1}{2}\theta$, we obtain the ratio r of our intensity to that of ordinary Rutherford scattering (with relativistic electron mass). In Table I are given the values of the ratio r, together with those of δ (polarization quantity defined by Mott), as a function of q or of $\epsilon(=E/mc^2)$.

TABLE I. *Values of r and δ.*

q	ϵ	15°	30°	45°	60°	90°	120°	150°	180°	δ
0.6	3.35	1.12	1.34	1.62	1.85	1.89	1.30	0.51	0.15	0.012
0.65	1.28	1.09	1.29	1.55	1.78	1.89	1.44	0.82	0.54	0.036
0.73	0.666	1.06	1.22	1.45	1.67	1.86	1.59	1.19	1.00	0.057
0.8	0.463	1.04	1.17	1.37	1.58	1.82	1.68	1.43	1.31	0.064
0.9	0.314	1.03	1.11	1.28	1.48	1.77	1.75	1.65	1.59	0.068
1.0	0.232	1.02	1.07	1.21	1.39	1.71	1.78	1.80	1.78	0.066
1.2	0.145	1.01	1.02	1.10	1.25	1.58	1.79	1.97	1.98	0.057
1.5	0.086					1.39	1.73	2.05	2.31	
2.0	0.046					1.19	1.58	2.04	2.35	0.027

The angular variation of r at high energies will be about the same as at $q=0.6$, and the intensity at 180° approaches zero with increasing energy. The previous approximate formula due to Mott[2] gives only the correct order of magnitude of scattering intensity for a heavy element such as mercury.

Our angular distribution agrees well with that observed by Barber and Champion,[3] the numbers in the angular ranges 20°–30°, 30°–60°, and 60°–180° being in the ratio 37 : 27 : 9 (theoretical) as against the experimental ratio 37 : 30 : 8. However, the disagreement between theory and experiment concerning absolute intensities still remains.

Our polarization values are about 10 percent less than those of Mott at the maximum, so that the theory still predicts an effect which has not yet been observed.

The angular distributions at small energies will probably be modified when shielding is taken into account.

Full details will be published later.

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[1] N. F. Mott, Proc. Roy. Soc. **A135**, 429 (1932).
[2] N. F. Mott, Proc. Roy. Soc. **A124**, 438 (1929).
[3] A. Barber and F. C. Champion, Proc. Roy. Soc. **A168**, 159 (1938).

Helium and Hydrogen of Mass 3

We have now adjusted the shims of the 60-inch cyclotron so that it is possible to obtain a steady beam of 24-Mev He^{3++} ions.[1] We have compared the isotopic ratio He^3/He^4 of tank (gas-well) helium to that of spectroscopically pure (atmospheric) helium, and find that it is about twelve times as great for atmospheric helium as for the gas-well variety. The absolute values have been approximately determined with the aid of a thin-walled Victoreen R-meter. These ratios are 10^{-8} and 10^{-7} for the two types of helium. When the cyclotron chamber is filled with atmospheric helium, the He^3 beam has sufficient intensity to induce appreciable radioactivity in silicon. We have observed a 2.5-minute period with an initial intensity of 200 counts/minute, on a background of 30 counts per minute. The activity could be followed for four half-lives; it is probably P^{30} formed in the reaction.

$$_{14}Si^{28}+{}_2He^3 \rightarrow {}_{15}P^{30}+{}_1H^1$$
$$_{15}P^{30} \rightarrow {}_{14}Si^{30}+e^+.$$

When the silicon was bombarded under identical conditions except for the substitution of tank helium for spectroscopic helium, the activity was reduced to a small value consistent with the abundance ratios given above.

Since we have shown that He^3 is stable, it seemed worth while to search for the radioactivity of H^3. We have therefore bombarded deuterium gas with deuterons, and passed the gas into an ionization chamber connected to an FP-54 amplifier. The gas showed a definite activity of long half-life. We have now shown that this gas has the properties of hydrogen by circulating it through active charcoal cooled in liquid nitrogen and allowing it to diffuse through hot palladium. The radiation emitted by this hydrogen is of very short range as was shown by the almost linear form of the intensity *vs.* pressure curve when the gas was pumped out of the chamber. When sufficient time has elapsed for us to make some statement regarding the half-life of this activity, we will submit the details of the work to this journal for publication.

We are indebted to Dr. S. Ruben for the use of his thin-walled counter and to Dr. A. Langsdorf for the loan of a d.c. amplifier. It is a pleasure to acknowledge the friendly interest of Professor E. O. Lawrence in these experiments, and to thank the Research Corporation for financial assistance.

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[1] L. W. Alvarez and R. Cornog, Phys. Rev. **56**, 379 (1939).

Intensity and Rate of Production of Mesotrons as a Function of Altitude

With the view of obtaining information on the intensity and on the rate of production of mesotrons as a function of altitude, we have performed the following free balloon experiment.

Four G-M counters were arranged with lead absorbers, as shown in Fig. 1. Counters 1, 2 and 3 constituted one threefold coincidence set and counters 2, 3 and 4 constituted the other. Since a particle which passes through either set of counters must penetrate at least 8 cm of lead, we are dealing here only with the penetrating component, i.e., mesotrons. The top set of counters can be actuated only by mesotrons which have originated outside of the equipment, whereas the lower set can be set off by either a mesotron entering from the outside or by one which is produced in the lead block L. If there is such a production of mesotrons in the lead block L, by a non-ionizing radiation, one should observe a greater number of counts in the lower set of counters than in the upper set.[1]

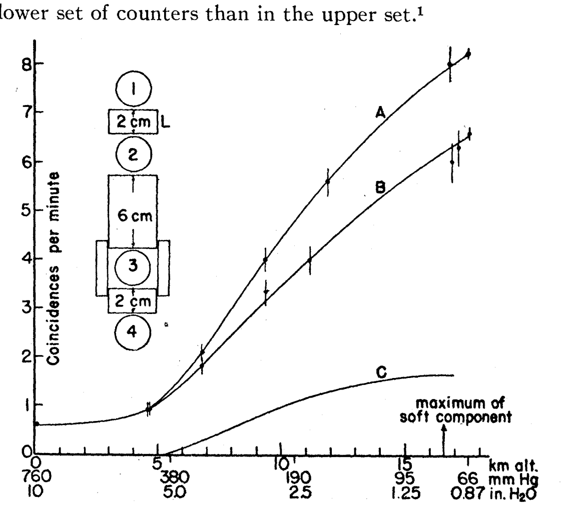

Fig. 1. Arrangement of counters and number of coincidences per minute in the lower (A) and upper (B) counters.