PHYSICAL REVIEW VOLUME 71, NUMBER 3 FEBRUARY 1, 1947

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is, for the issue of the 1st of the month, the 8th of the preceding month and for the issue of the 15th, the 23rd of the preceding month. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

On the Disintegration of Negative Mesons

M. Conversi, E. Pancini, and O. Piccioni*
Centro di Fisica Nucleare del C. N. R. Istituto di Fisica dell'Università di Roma, Italia

December 21, 1946

IN a previous Letter to the Editor,[1] we gave a first account of an investigation of the difference in behavior between positive and negative mesons stopped in dense materials. Tomonaga and Araki[2] showed that, becuase of the Coulomb field of the nucleus, the capture probability for negative mesons at rest would be much greater than their decay probability, while for positive mesons the opposite should be the case. If this is true, then practically all the decay processes which one observes should be owing to positive mesons.

Several workers[3] have measured the ratio η between the number of the disintegration electrons and the number of mesons stopped in dense materials. Using aluminum, brass, and iron, these workers found values of η close to 0.5 which, if one assumes that the primary radiation consists of approximately equal numbers of positive and negative mesons, support the above theoretical prediction. Auger, Maze, and Chaminade,[4] on the contrary, found η to be close to 1.0, using aluminum as absorber.

Last year we succeeded in obtaining evidence of different behavior of positive and negative mesons stopped in 3 cm of iron as an absorber by using magnetized iron plates to concentrate mesons of the same sign while keeping away mesons of the opposite sign (at least for mesons of such energy that would be stopped in 3 cm of iron). We obtained results in agreement with the prediction of Tomonaga and Araki. After some improvements intended to increase the counting rate and improve our discrimination against the "mesons of the opposite sign," we continued the measurements using, successively, iron and carbon as absorbers. The recording equipment was one which two of us had previously used in a measurement of the meson's mean life.[5] It gave threefold (III) and fourfold (IV) delayed coincidences. The difference (III)−(IV) (after applying a slight correction for the lack of efficiency of the fourfold coincidences) was owing to mesons stopped in the absorber and ejecting a disintegration electron which produced a delayed coincidence. The minimum detected delay was about 1 μsec. and the maximum about 4.5 μsec. Our calculations of the focusing properties of the magnetized plates (20 cm high; $\beta=15{,}000$ gauss) and including roughly the effects of scattering, showed that we should expect almost complete cut-off for the "mesons of the opposite sign." This is confirmed by our results, since otherwise it would be very hard to explain the almost complete dependence on the sign of the meson observed in the case of iron.

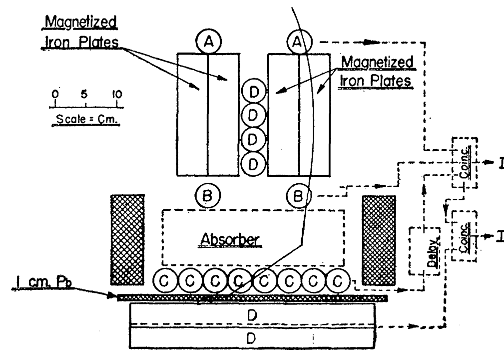

Fig. 1. Disposition of counters, absorber, and magnetized iron plates. All counters "D" are connected in parallel.

The results of our last measurements with two different absorbers are given in Table I. In this table "Sign" refers to the sign of the meson concentrated by the magnetic field. $M=(\text{III})-(\text{IV})-P(\text{IV})$, the number of decay electrons, is corrected for the lack of efficiency (p) in our fourfold coincidences ($\sim$0.046).

Table I. Results of measurements on β-decay rates for positive and negative mesons.

Sign	Absorber	III	IV	Hours	M/100 hours
(a) +	5 cm Fe	213	106	155.00′	67±6.5
(b) −	5 cm Fe	172	158	206.00′	3
(c) −	none	71	69	107.45′	−1
(d) +	4 cm C	170	101	179.20′	36±4.5
(e) −	4 cm C+5 cm Fe	218	146	243.00′	27±3.5
(f) −	6.2 cm Fe	128	120	240.00′	0

The value M_- (5 cm Fe) is but slightly greater than the correction for the lack of efficiency in our counting, so that we can say that perhaps no negative mesons and, at most, only a few ($\sim$5) percent undergo β-decay with the accepted half-life.

The results with carbon as absorber turn out to be quite inconsistent with Tomonaga and Araki's prediction. We used cylindrical graphite rods having a mean effective thickness of 4 cm because we were unable to procure a graphite plate. In addition, when concentrating negative mesons, we placed above the graphite a 5-cm thick plate of iron to guard against the scattering of very low energy mesons which might destroy the concentrating effect of our magnets. We alternated the following three measurements:

A. Negative mesons with 4 cm C and 5 cm Fe,
B. Negative mesons with 6.2 cm Fe (6.2 cm Fe is approximately equivalent to 4 cm C+5 cm Fe as far as energy loss is concerned.
C. Positive mesons with 4 cm C.

The comparison between A and B gave the difference in behavior between Fe and C, once we had established the fact that practically no disintegration electrons came from negative mesons in the 5-cm iron plate. The comparison between A and C gives the difference in behavior between negative and positive mesons in carbon. This must be considered as a qualitative comparison because of the slightly different action of the magnetic field in concentrating mesons of different ranges (4 cm C+5 cm Fe in one case and 4 cm of C in the other). We could not, of course, add 5 cm of Fe for the positive mesons too, since positive mesons do decay in Fe.

The great yield of negative decay electrons from carbon shows a marked difference between it and iron as absorbers. Tomonaga and Araki's calculation also give for carbon a much higher ratio of capture to decay probability for negative mesons, so we are forced to doubt their estimation. It is possible that a suitable dependence of the capture cross section, σ_c, on the nuclear charge, Z, might explain these results; however, if the ratio of the capture to decay probability also depends on the density as Tomonaga and Araki pointed out, then it would require a very irregular dependence on Z to also explain the cloud-chamber pictures of some authors[6] showing negative mesons stopped in the chamber without any decay electrons coming out.

Concerning the difference between M_+ and M_- in carbon, we should like to point out that it is not necessary to assume that σ_c for carbon has an appreciable value for negative mesons. A positive excess, $(H_+-H_-)/(H_++H_-)$ of 20 percent in the hard component, as it seems to be[7] is sufficient to explain our results since this gives $H_+/H_-=1.5$ which is greater than M_+/M_- for carbon. Impurities in the graphite could also explain some preference for M_+, with a suitable dependence of σ_c on Z.

Further experiments on this subject are now in progress, in an attempt to calculate the capture cross section, and to know how it depends on Z.

* Now Visiting Research Associate at Massachusetts Institute of Technology, Cambridge, Massachusetts.

[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. **68**, 232 (1945).

[2] S. Tomonaga and G. Araki, Phys. Rev. **58**, 90 (1940).

[3] F. Rasetti, Phys. Rev. **60**, 198 (1941); B. Rossi and N. Nereson, Phys. Rev. **62**, 417 (1942); M. Conversi and O. Piccioni, Nuovo Cimento **2**, 71 (1944); Phys. Rev. **70**, 874 (1946).

[4] P. Auger, R. Maze, and Chaminade, Comptes rendus **213**, 381 (1941).

[5] M. Conversi and O. Piccioni, Nuovo Cimento **2**, 40 (1944); Phys. Rev. **70**, 859 (1946).

[6] Y. Nishina, M. Takeuchi, and T. Ichimiya, Phys. Rev. **55**, 585 (1939); H. Maier-Leibnitz, Zeits f. Physik **112**, 569 (1939); T. H. Johnson and R. P. Shutt, Phys. Rev. **61**, 380 (1942).

[7] H. Jones, Rev. Mod. Phys. **11**, 235 (1939); D. J. Hughes, Phys. Rev. **57**, 592 (1940); G. Bernardini, M. Conversi, E. Pancini, E. Scrocco, and G. C. Wick, Phys. Rev. **68**, 109 (1945).

Further Remarks on the Redundant Zeros in Heisenberg's Theory of Characteristic Matrix

S. T. MA
Institute for Advanced Study, Princeton, New Jersey
December 27, 1946

RECENTLY Dr. Opechowski[1] made a remark on my previous communication concerning the redundant zeros.[2] Reasoning in accordance with the current scheme of quantum theory, he came to the conclusion that all the eigenvalues of the closed states in the problem discussed in my note were given by the first condition, and there were no eigenvalues given by the second condition. That is of course quite correct. In fact it is a result already well known, and that is why the term "redundant zeros" was introduced for the eigenvalues given by the second condition.

Dr. Opechowski has, however, apparently overlooked the fact that I was studying the eigenvalue problem from the point of view of the theory of characteristic matrix, a new scheme of quantum theory recently proposed by Heisenberg.[3] In applying this theory to the spherically symmetrical states of a particle in a central field of force, one determines first $S(k)$, the eigenvalue of the characteristic matric for the spherically symmetrical states and *real* values of k. The quantity $S(k)$ is equal to the ratio of the amplitude of the outgoing wave to that of the incoming wave. One then performs an analytic continuation into the complex plane of k and determines the zeros of $S(k)$ in the lower half of the complex plane. Proceeding in this way, I obtained both sets of eigenvalues mentioned in my note. It is clear that my conclusion based on the new scheme of quantum theory cannot be invalidated by Dr. Opechowski's considerations based on the current scheme of quantum theory.

The question of the part played by the characteristic matrix as a fundamental concept in the future development of quantum theory need not be considered here, as that is irrelevant to the point at issue.

[1] W. Opechowski, Phys. Rev. **70**, 772 (1946).

[2] S. T. Ma, Phys. Rev. **69**, 668 (1946).

[3] W. Heisenberg, Zeits. f. Physik **120**, 513, 673 (1943). Heisenberg's third and fourth papers on the same subject are now in press. A summary of the four papers has recently been given by Heisenberg in a paper entitled "On the Theory of Elementary Particles," now also in press. Cf. also C. Møller, Det. Kgl. Danske Vid. Sels. Fys.-Math. Medd. **23**, No. 1 (1945); **24**, No. 19 (1946); ter Haar, Physica (1946) in press; S. T. Ma, Phys. Rev. (1947), in press.

Production and Isotopic Assignment of a 90-Day Activity in Element 43*

E. E. MOTTA, G. E. BOYD, AND A. R. BROSI
Clinton Engineer Works, Monsanto Chemical Company, Clinton Laboratories, Oak Ridge, Tennessee
July 31, 1946

PREVIOUS deuteron bombardments of Mo using the cyclotron have led to the production of a variety of periods associated with the chemistry to be expected from element 43.[1,2] However, the mass assignment of many of these isotopes has not been reported. Neutron bombardments of purified samples of $Ru(OH)_3$ in the Clinton self-sustaining chain reacting pile have been found to produce a number of these same activities, and, in one case at least, an isotopic assignment seems possible.

Experiments have been carried out wherein growth was observed of a daughter activity formed by K-capture decay of a previously-discovered three-day Ru^{97} isotope.[3] Extensive chemical tests in which the known six-hour 43^{99} activity was employed as a monitor have shown this daughter activity to be an isotope of element 43, thus permitting its assignment to 43^{97}. The activity has been observed to decay with a half-life of 93 ± 5 days over three months time. The radiations have been found to consist