Irradiated nuclei and the energy of γ-photons in kev.

F_9^{19}	Na_{11}^{23}	V_{23}^{51}	Mn_{25}^{55}	Ge_{32}^{73}	Se_{34}^{77}	Mo_{42}	Rh_{45}^{103}	Ag_{47}	Cd_{48}	In_{49}^{115}	J_{53}^{127}	Ta_{73}^{181}	W_{74}	Au_{79}^{197}	Pb_{82}^{207}
125	435	320	126	72	238	206	295	310	297	562	60	138	112	286	580
205			590		452	540	358	409	325		205	301		580	
									543						

Figure 2 shows the amplitude spectrum obtained in the irradiation of manganese by nitrogen ions. We have plotted in Fig. 2*b* the spectrum in the energy region from 300 to 1200 kev. As is evident from the drawing, only one line is observed in this region, with energy ~ 590 kev. In Ref. 3, in which protons are used for the Coulomb excitation of Mn, a number of lines are observed in the given energy region. From comparision of the data of Ref. 3 with ours, it follows that these lines are connected with nuclear reactions, and not with Coulomb excitation. The spectra of Coulomb excitation of molybdenum are plotted in Fig. 3.

In bombardment of K, Ni, Cu, Sn, Bi Coulomb excitations was not observed.

Data are given in the Table of the energy of the excited levels of the nuclei under investigation.

At present, calculations are being carried out on the value of $B_e(2)$ and on treatment of the data on the bremmstrahlung of nitrogen ions.

* The amplitude analyzer was constructed by L. N. Gal'perin.

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Translated by R. T. Beyer
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One-Meson and Zero-Meson Annihilation of Antinucleons

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(Submitted to JETP editor February 25, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) **30**, 947-948
(May, 1956)

IN connection with the extremely interesting communication that appeared recently[1] on the creation of antinucleons in the collisions of protons of high energy with nuclei, certain processes of "extraordinary" annihilation of antinucleons are considered in the present note.

In the collision of antinucleons with free nucleons, the annihilation is evidently connected with the release of not less than two π-mesons (or *K*-mesons). This process ("extraordinary" annihilation), in which, in all probability, several mesons are emitted, also takes place in the collision of antinucleons with nuclei. However, in the collisions of antinucleons with nucleons bound to the nucleus, there is the possibliity of other processes ("extraordinary" annihilation) in which the number of π-mesons emitted is less than or equal to one.

Annihilation with the emission of a single π-meson can take place in the collisions of an antinucleon with a nucleus of atomic mass $A \geq 2$. Annihilation which is not accompanied by emission of even a single meson is possible only in the collisions of an antinucleon with a nucleus of atomic mass $A \geq 3$. It is not difficult to see that the processes of one-meson and zero-meson annihilation of antinucleons occur in processes inverse to those in which antinucleons are created in the collisions of π-mesons and nucleons with nucleons.

Keeping in mind the possibility of setting up experiments, we have considered below several processes of "extraordinary" annihilation of antinucleons which are characterized by the fact that the number of particles in the final state is equal to 2.

In the case of collisions with deuterons, the following reactions are possible:

$$\text{a)}\ \tilde{p}+d \rightleftarrows \pi^0+n;\quad \text{a}')\ \tilde{n}+d \rightleftarrows \pi^0+p;$$
$$\text{b)}\ \tilde{p}+d \rightleftarrows \pi^-+p;\quad \text{b}')\ \tilde{n}+d \rightleftarrows \pi^++n.$$

According to the principle of charge symmetry, the cross sections of reactions of type a) are equal; the cross sections of reactions of type b) are also equal.

It is not difficult to show that charge independence requires that the cross sections of type b) be twice those of reactions of type a). From the experimental point of view, the reactions b) are especially interesting. Here four charged particles take part. The ratio of the cross sections of the direct and inverse reactions of b), for the conditions of identical energy in the center-of-mass system, is equal to

$$\frac{\sigma(\tilde{p}+d \to \pi^-+p)}{\sigma(\pi^-+p \to \tilde{p}+d)} = \frac{(2S_\pi+1)(2S_p+1)}{(2S_{\tilde{p}}+1)(2S_d+1)}\frac{k^2}{q^2} = \frac{k^2}{3q^2},$$

where $S_{\tilde{p}}$, S_d are the magnitudes of the spins of the antiproton, the deuteron, etc.; k and q are the momenta of the π-mesons and the antiprotons in the center-of-mass system. Investigation of the direct and reverse reactions of b) give the possibility of verifying the correctness of the assumption that the spin of a negative particle with proton mass is equal to one-half. For example, the cross section of the reaction b) of the annihilation into a deuteron of an antiproton with kinetic energy 500 mev ought to be 1.6 times greater than the cross section of the reaction of the creation of a deuteron and an antiproton in the collision with a proton of a π-meson with energy 4.6 bev.

Let us consider processes of single meson annihilation of an antinucleon in a nucleus with $A = 3$:

$$\text{c)}\ \tilde{p}+\text{He}^3 \rightleftarrows d+\pi^0;\quad \text{c}')\ \tilde{n}+\text{H}^3 \rightleftarrows d+\pi^0;$$
$$\text{d)}\ \tilde{p}+\text{H}^3 \rightleftarrows d+\pi^-;\quad \text{d}')\ \tilde{n}+\text{He}^3 \rightleftarrows d+\pi^+.$$

The ratio of the cross section of reactions of types c) and d), according to charge independence, is equal to 2. From the experimental viewpoint, the reverse reactions c′) and d′) present interest.

Zero-meson annihilation of an antinucleon is illustrated by the following reactions:

$$\text{e)}\ \tilde{p}+\text{H}^3 \rightleftarrows n+n;\quad \text{e}')\ \tilde{n}+\text{He}^3 \rightleftarrows p+p;$$
$$\text{f)}\ \tilde{p}+\text{He}^3 \rightleftarrows n+p;\quad \text{f}')\ \tilde{n}+\text{H}^3 \rightleftarrows p+n.$$

Here the reverse reaction to e′)--the formation of He^3 in the collision of two protons--is of experimental interest.

Experimental investigation of the above-mentioned processes is of fundamental significance. It is reasonable to expect that the processes of single-meson and zero-meson annihilation are significantly less probable than the process of multiple meson annihilation. This follows, for example, from Fermi's statistical theory of multiple production of mesons.

It should be emphasized that the probability of processes of "extraordinary" annihilation of antinucleons could be increased if one could have especially strong nucleon-antinucleon interactions of the type assumed in the Fermi-Yang model.

The author thanks L. I. Lapidus for his discussions on the subject.

[1] Chamberlain, Segre, Wiegand and Ypsilantis, Phys. Rev. 100, 947 (1955).

Translated by R. T. Beyer.
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Solution of the Schwinger Equation in the Bloch-Nordsieck Model

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(Submitted to JETP editor July 12, 1955)
J. Exptl. Theoret. Phys. (U.S.S.R.) 30, 949-951 (May, 1956)

IN the consideration of the scattering of an electron in an external field, Bloch and Nordsieck[1] assumed a method of approximate solution of the