with the stopcock in either position. We should have been able to detect very unambiguously a difference of 3 electron counts/min. due to the changed position of the stopcock, and similarly a difference of 20 counts per min. in the γ-ray case. No such differences were observed. We calculate that with the stopcock closed there would be 2×10^7 He^{3*} caught in the side chamber after a ten-minute bombardment. From the geometry used and from the counter sensitivities we find that if there exists an excited He^3, its lifetime for positron emission is greater than 10 days and its lifetime for γ-ray emission is greater than 45 min. The high voltage apparatus used was built with the aid of a grant to Professor Ladenburg from the Rockefeller foundation.

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Pair Emission from Fluorine Bombarded with Protons

When fluorine is bombarded by protons of suitable energies gamma-rays with 6.3 ± 0.1 Mev quantum energy are emitted. Measurements of the gamma-ray yield as function of proton energy were first made by Hafstad and Tube[1] and later with higher resolution and over a greater range by Bernet, Herb and Parkinson.[2]

These measurements were made with ionization chambers and the radiation was filtered through $\frac{1}{8}$ in. or more of lead. They show that the penetrating gamma-radiation is produced at several sharply defined energies. Dee, Curran and Strothers[3] have shown that the resonance levels at 330, 670 and 860 kev all give rise to the same gamma-radiation. We[4] have confirmed this and in addition have found that the same is true for the prominent resonances at 0.920 and 1.36 Mev. It has also been shown in this laboratory[5] that at the 330-kev resonance the gamma-rays are accompanied by alpha-particles, with a range of 8 mm in air. It seemed safe, therefore, to conclude that the 6.3-Mev gamma-radiation originates from the reaction

$$F^{19}+H^1\rightarrow(Ne^{20})\rightarrow{}^*O^{16}+He^4$$

and represents a transition in oxygen from an excited state to the ground state. The alpha-particle group at 330 kev has also been found by Burcham and Smith[6] and we have recently been informed that Burcham and his collaborators have found the corresponding alpha-particles at the 860- and 920-kev resonances.[7]

In order to investigate the possible existence of radiation of low penetrating power from fluorine bombarded by protons we have made yield measurements by simultaneous observations with two ionization chambers, to which we shall refer as No. I and No. II. The two chambers were as similar as practicable but No. II was arranged so that suitable filters could be interposed between target and chamber. To reach the chambers the radiation passed through the 0.13-mm German silver wall of the target tube and the 0.40-mm aluminum ionization chamber wall. This filtration was desirable in order to exclude the x-rays produced by protons in the target, which consisted of a copper disk on which a thin layer of CaF_2 was deposited.

The filter chosen for the yield measurements with chamber No. II was 3.3 mm of lead. This is sufficient to absorb gamma-radiation up to several hundred kv or electrons up to 10 Mev.

Curves 1 and 2 (Fig. 1) represent the readings obtained with chambers I and II, respectively, as function of bombarding voltage, and curve 3 represents the difference between 1 and 2.

On the assumption that curve 2 is a measure of 6.3-Mev radiation only, and that chamber No. I is equally affected by this radiation, we can conclude that curve 3 represents a kind of radiation which is completely absorbed in 3 mm of lead. These assumptions are not entirely correct and for this reason we cannot exclude the existence of a few percent of absorbable radiation, even where curves 1 and 2 coincide, but this does not in any way invalidate the conclusions to be drawn from the difference between them.

Measurements of the absorption in lead and in aluminum made at 820 and 1130 kv proved that the radiation represented by curve 3 did not consist of soft gamma-radiation and that it probably consisted of fast electrons with a maximum range of approximately 1.5 mm in lead and 7.5 mm in aluminum. From 500 cloud-chamber photographs, taken at 820 kv, we obtained 166 positive and 173 negative electrons and 29 pairs could be identified with some certainty.

We conclude from this that curve 3 represents the ionization produced by pairs. The observed energy is 5.9 ± 0.5

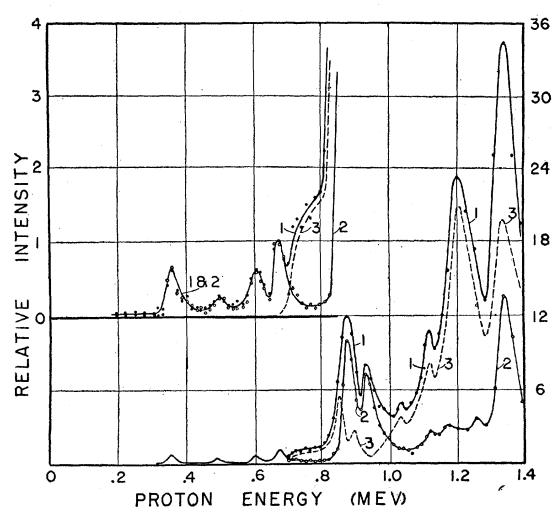

FIG. 1. Relative intensity of ionization *vs.* bombarding proton energy. Curve 1—radiation filtered by 0.5 mm aluminum. Curve 2—radiation filtered by an additional 3.3 mm lead. Curve 3—difference between 1 and 2.

Mev. In comparing the relative transition probabilities it must be remembered that the pairs are approximately twenty times as effective in producing ionization as are the gamma-rays, hence the latter are in all cases much more numerous.

It is interesting that although these pairs occur at definite resonance energies they do not coincide with the gamma-ray resonances. For example, at 920 kv the ionization due to gamma-radiation is nearly ten times as intense as that produced by pairs, while at 840 and 1190 kv the reverse is true. Clearly, therefore, the pairs are not produced by internal conversion of gamma-rays in the usual sense, but are emitted directly from a nucleus in an excited state. Presumably this is a state in O^{16} with $j=0$ and the transition is to the ground state which is known to have $j=0$. It is, however, possible that some or all of the pairs observed originate from a transition in Ne^{20}. If so, gamma-rays of approximately 7.5 Mev energy should accompany the pairs and we cannot exclude this possibility from our experiments so far. If the transition is in O^{16} alpha-particles should be observable at the pair resonances. Since no single quantum transition is allowed from such a state, the lifetime must be very long. Professor Oppenheimer has made a tentative estimate of 10^{-4} second for the half-life.

It seems probable that the pairs observed by Crane and Halpern[8] at 600 kv—11 pairs per thousand quanta—are to be attributed to this process rather than to internal conversion.

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Low Energy Gamma-Radiation from Lithium Bombarded with Protons

By means of the method described in the preceding letter we have investigated the radiation from Li^7+H^1 as function of proton energy. The target used consisted of separated Li^7 with a stopping power of approximately 30 kev.[1]

The filter used in front of ionization chamber No. II was 1.33 cm of lead. The readings of chambers Nos. I and II are shown in curves 1 and 2, respectively, and curve 3 is the difference between 1 and 2 (Fig. 1).

The resonance at 440 kev appears to be due entirely to the well-known 17.5 Mev gamma-radiation, while the radiation above 800 kev is strongly absorbed in lead.

We have measured the attenuation of the radiation at 1080 and 1290 kev and find an apparent absorption coefficient $\mu=1.50\pm0.10$ cm^{-1} in lead and $\mu=0.12\pm0.01$ cm^{-1} in aluminum. For annihilation radiation from N^{13} we find,

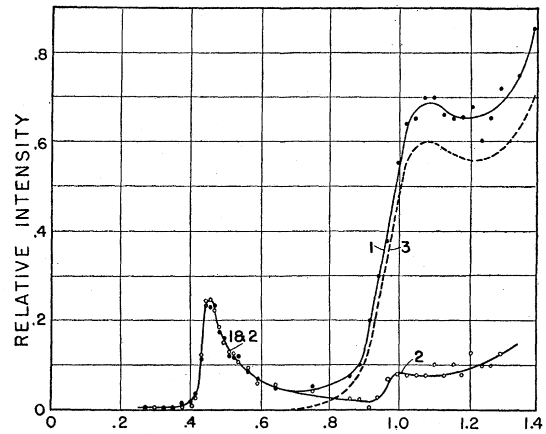

FIG. 1. Relative intensity of ionization *vs.* bombarding energy. Curve 1—radiation filtered by 0.15 mm lead. Curve 2—radiation filtered by an additional 1.33 cm lead. Curve 3—difference between 1 and 2.

with the same arrangement, $\mu=1.43\pm0.05$ cm^{-1} in lead. This gives the value 495 ± 25 kev for the gamma-rays at 1080 and 1290 kev bombarding energy.

From this and from the character of the yield curve above 800 kev it seems reasonable to assume that this radiation originates from excitation of Li^7 without capture of the proton in analogy with the well-known excitation of Li^7 by He^4. Rumbaugh, Roberts and Hafstad[2] have observed the same state in the following reactions:

$$\begin{aligned} Li^6+H^2 \rightarrow (Be^8) &\rightarrow Li^7+H^1 \\ &\rightarrow {}^*Li^7+H^1 \\ &\rightarrow Be^7+n^1 \\ Be^7 &\rightarrow {}^*Li^7-e^-. \end{aligned}$$

From the difference in proton ranges they find the separation of the states in Li^7 to be 455 ± 15 kev, and from the attenuation of the radiation following the decay of Be^7, 425 ± 25 kev.

Although our value 495 ± 25 kev is somewhat higher there can be little doubt that the same state in Li^7 is involved.

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[1] We are indebted to Professor Rumbaugh and the Bartol Foundation for their kindness in supplying us with this target.
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On the Equality of the Proton-Proton and Proton-Neutron Interactions

A comparison of the ^1S proton-proton interaction and the ^1S proton-neutron interaction has been made recently by Breit, Hoisington, Share and Thaxton.[1] It is the purpose of this letter to add a remark to this subject. With the meson type of potential, $Ce^{-\lambda r}/r\lambda$, a variational calculation has been made of the binding energy of H^3 of high accuracy (error <0.1 percent).[2] This calculation together with the value of the binding energy of H^2 and the scattering of