

INVESTIGATION OF A GAMMA-PROTON PROCESS IN BERYLLIUM

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The experiments here described were performed with the 20-Mev betatron at the Los Alamos Scientific Laboratory, New Mexico. The work was done under the direction of William Ogle, with the invaluable assistance of Leon J. Brown.

Many radioactive substances can be produced artificially by bombarding non-radioactive samples with high-energy nuclear particles. In such a reaction, a bombarding particle can be thought of as evicting part of the nucleus of an atom of the sample, and residing there in its place. For example, if a high-energy neutron enters a nucleus of stable nitrogen (atomic weight, 14; atomic number 7), a proton may be emitted, the product being radioactive carbon (atomic weight 14, atomic number 6). Such a reaction is known in the language of nuclear physics as a neutron-proton, or, more simply, an n-p reaction. Reactions are known involving all the elementary particles, both as projectiles and as displaced nucleons. One of the less frequently observed is the process in which a high-energy gamma-ray causes a proton to be evicted from a nucleus. The betatron would seem to be an ideal source of gamma-rays for the observation of such a so-called γ -p process. Its high, easily controlled energies render it very

useful, but there is one serious complication. A great many fast neutrons are associated with the beam from the betatron; these induce radioactivities which may easily be confused with or misinterpreted as the results of γ -p processes.

An effort was made to find a substance in the bombardment of which fast-neutron reactions would cause no confusion. Be⁹ seemed to be such a substance. The γ -p reaction on this isotope should yield Li⁸, which decays with the emission of beta particles with a half-life of 0.88 sec. Except for He⁶, which may be produced in several ways and also emits betas with a half-life of 0.8 sec., all other possible reactions yield products which either break up at once or have extremely long half-lives.

A rough experiment indicated that when beryllium is exposed to 20-Mev gamma-rays from the betatron, an activity is induced, and that it has a half-life of the order of one second.

In order to measure the half-life, the beryllium sample was placed against a glass Geiger counter directly in the betatron beam. With this arrangement, counting could begin a few tenths of a second after irradiation, and a high counting rate was achieved. Since the decay was too fast for visual recording of the

data, a timer and the interpolation lights of a scaling circuit were photographed with a moving picture camera. The film could then be projected at a much-reduced rate, and the number of counts per second determined. (The background due to the activity induced in the counter itself of course had to be subtracted.) The half-life thus measured was 0.88 ± 0.03 sec.

Since it is almost certain that some He^6 will be produced, and since it has a half-life almost equal to that measured, it was necessary to be certain that this was not the activity being observed. He^6 is known to decay with the emission of beta particles with a maximum energy of 3.7 Mev, while Li^8 decays with the emission of betas with maximum energy 12 Mev. Thus, a simple absorption measurement should serve to distinguish the two.

Activities induced in an aluminum absorber would have been very troublesome if the sample, absorber,⁸ and counter had been held in the beam, as before. Hence, during irradiation the sample ($3 \times 3 \times \frac{1}{2}$ inches in size) was placed at the top of a vertical track in such a way that as soon as the betatron was turned off the sample dropped about 9 inches into position in front of the absorber and counter. As it dropped into place it activated the scaling circuit and a time delay which turned the scaler off at the desired time. In this way the number of counts in the interval between 0.3 and 1.3 seconds after irradiation was measured. This was repeated with many different thicknesses of aluminum absorber. An absorption curve plotted from the data indicated the

presence of beta particles of energies up to 13 Mev, showing that Li^8 was present. The presence of He^6 was also indicated by the presence of a low-energy component.

To determine the threshold of the reaction, it was necessary to vary the energy of the radiation from the betatron. In our experiment this was done by changing the time of expansion of the orbit, so that the electrons were made to hit the target at some selected time before reaching their full energy. Sensitive timing circuits were available; so the energy could be varied with considerable accuracy over a large range. The intensity of the beam dropped off sharply as the energy was decreased; so the practical lower limit was about 6 Mev.

Using the dropping technique described previously, a curve of beta activity versus maximum bremsstrahlung energy from the betatron was run with $\frac{5}{16}$ inch of aluminum (enough to absorb all He^6 betas) between the beryllium and the Geiger tube. At the end of each series of runs at a given energy the betatron yield was measured. A curve of counts per unit of irradiation versus maximum gamma-ray energy indicated a threshold of 18 ± 1 Mev, as compared with a theoretical value of about 17 Mev. With no absorber between the beryllium and the counter, an effect was still observed as low as 6 Mev. This was to be expected, as the threshold for the formation of He^6 is about 3 Mev.

Li^8 decays into Be^8 , which immediately splits up into two alpha particles. Since there are no alphas associated with the decay of He^6 , the observation of the alpha-particles

themselves should be another method of verifying the presence of Li^8 .

Since the alphas expected should have energies of only about 1.6 Mev, their penetrating power is very small. Thus the problem in observing them is to irradiate a large amount of beryllium distributed thinly so that a detectable number of the alphas produced may reach a counter. To get measurable intensities, the sample must be as close to the betatron target as possible. The problem was finally solved with some success by constructing a large wheel of micarta and gluing on one face beryllium flakes in a band of 3 inches average width and 12 inches average radius. This wheel was arranged vertically, immediately in front of the betatron, and connected to a small motor in such a way that it could be rotated at four speeds. The radiations were observed with an alpha-sensitive counter placed at the bottom of the wheel. The counter was at such a distance from the beryllium that only alphas with energies greater than 1.6 Mev could reach it. Numerous tests were made to be sure that the counter was not

affected by betas, or by electrical pickup from the betatron, motor, and other apparatus. Shielding was a major problem.

Actual measurements were made by observing visually on an oscillograph the pulses made by alphas. Five-minute runs with betatron yield were alternated with five-minute runs with the betatron off but the wheel still rotating. All runs were made at 20 Mev. A definite, though small, effect was observed (less than 10 counts per minute). To make a rough estimate as to the half-life of the observed activity, the wheel was run at different speeds, thus varying the time elapsed in turning a given sample of beryllium from the beam to the counter. No accurate value of half-life could be determined because of the effect of growth of activity as the beryllium crossed the beam, decay as it passed the counter, and persistence of activity for a time greater than one revolution of the wheel. Approximate corrections were made for these, and the half-life was shown to be about one second, as it should be.