Radioactivity of Be^7

As reported at the Washington meeting of the American Physical Society[1] we have obtained evidence for the formation of Be^7 in the reaction $Li^6+H^2 \rightarrow Be^7+n$. At that time we had found that there was no radioactive emission of charged particles. We have since discovered a gamma-ray radioactivity with a 43-day half-life in lithium targets which have been bombarded by deuterons. Further experiments indicate that the gamma-ray activity originates in K electron capture by Be^7 which leaves the residual Li^7 nucleus in the 450-kv excited level.

The activity was first observed in a LiF target which had been bombarded a month previously with 35 microampere hours of 1000-kv deuterons. Similar activity was subsequently produced by bombarding a lithium metal target with 20 microampere hours of 1000-kv deuterons. The activity was followed for a month and showed a half-life of 43 ± 6 days. The absorption-coefficient in lead was 0.169 g cm^{-1}. No charged particles could be detected either by thin-walled counters, by ionization chambers, or by placing the sample in a cloud chamber, although the gamma-ray counting rate indicated the emission of more than 100 quanta per second.

The surface of the target (in which the activity was concentrated) was scraped off and subjected to a chemical separation, carried out by Dr. M. H. Van Horn of George Washington University. The activity was concentrated in the final precipitation of 100 micrograms of beryllium carbonate which had been added as a carrier. The separation would not, however, remove iron or aluminum. As iron also shows a 40-day period, we bombarded an iron target and looked for a similar gamma-ray. The iron impurity necessary to produce the observed gamma-rays from the lithium targets is greater than 100 percent.

Although we were not able to detect the alpha-particle group produced in the reaction[1] $B^{10}+H^1 \rightarrow Be^7+He^4$, we have since observed a long period gamma-ray activity from a B_4C target which had been bombarded with 11 microampere hours of 950-kv protons. The intensity of the radiation was 25 percent less than that produced in the lithium metal target. Its absorption-coefficient was also 0.169 g cm^{-1}. We therefore ascribe both this activity and that produced in the lithium targets to Be^7.

This unusual type of radioactivity could originate in two nuclear reactions. Either a positron is emitted with so little energy that it does not ionize appreciably and is detected only by the annihilation radiation, or a K electron is captured and the residual nucleus is left in an excited state. In the latter case the average number of quanta per disintegration is less than one because there exists the alternative process of capture in which the nucleus is left in the ground state. Assuming as usual that a neutrino is emitted, these reactions may be written:

$Be^7 \rightarrow Li^7+e^+ +\eta$	
$e^+ + e^- \rightarrow h\nu + h\nu$	$h\nu = 0.5$ Mev
$Be^7 + e_k^- \rightarrow Li^7 + \eta$	neutrino energy $=E$ Mev
$Be^7 + e_k^- \rightarrow Li^{7*} + \eta$	neutrino energy $=E-0.45$ Mev
$Li^{7*} \rightarrow Li^7 + h\nu$	$h\nu = 0.45$ Mev

The absorption-coefficient in lead of the gamma-rays from the lithium targets and of the annihilation radiation of the positrons from N^{13} were measured under idential conditions and were observed to be 0.169 ± 0.008 and 0.130 ± 0.002 g cm^{-1}, respectively. This indicates that the energy of the radiation is 425 ± 25 kv, which agrees well with the energy expected from K electron capture but differs from the energy of annihilation radiation.

A comparison of the numbers of quanta observed per neutron emitted from the carbon and lithium targets gives additional information about the process. Li^6 and Li^7 are (per atom) equally effective in producing neutrons at 800 kv and the yield curves for the two reactions are known.[2] The energy distribution of the neutrons from Li^6 shows that approximately one atom of Be^7 is formed for every two neutrons emitted. In carbon one neutron is emitted for each N^{13} atom formed. The comparison of the number of neutrons emitted by lithium and carbon has been made by Amaldi, Hafstad, and Tuve.[3] Thus the relative numbers of Be^7 and N^{13} atoms can be calculated. Assuming two quanta per N^{13} we find that, on the average, one quantum is emitted for each 10 Be^7 atoms produced. Positron-emission should lead to a gamma-ray intensity 20 times greater than that observed. On the other hand the data are consistent with the hypothesis of K electron capture, because in this case transitions to the ground state should be more probable than transitions to excited levels.

As a final check we have looked for double coincidence counts. No appreciable change in the background rate of 0.8 per minute was observed although the simultaneous emission of two quanta at 180°, which would be expected if positron annihilation occurred, should increase the rate by at least a factor of three.

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1 R. B. Roberts and N. P. Heydenburg, Abstract No. 78, 1938 Washington Meeting American Physical Society.
2 L. H. Rumbaugh, R. B. Roberts, and L. R. Hafstad, to be published shortly in Phys. Rev.
3 E. Amaldi, L. R. Hafstad, and M. A. Tuve, Phys. Rev. 51, 896–912 (1937).

The Transmutations of the Cosmic-Ray Electrons and the Nuclear Forces

The "transmutations of mass" (i.e., the changes of the rest mass) of the electrons probably play an important role in the passage of cosmic rays through the atmosphere. Thus according to Blackett[1] the cosmic-ray particles at sea level are heavy when energetic, but change their mass suddenly when slowed down below a critical energy of about $2–3\cdot10^8$ ev and become ordinary electrons. According to Bowen, Millikan and Neher[2] the penetrating heavies are mainly secondaries produced in the atmosphere by incoming electrons and photons. However this conclusion, does not necessarily follow from the data of the authors mentioned;