Radioactive Alpha-Particles from Li^7+H^2

From their disintegration experiments with the separated isotopes of lithium, Rumbaugh and Hafstad[1] concluded that the energy difference of the normal states of Li^8 and Be^8 had a minimum value 3 to 4 Mev greater than the maximum energy of the beta-rays which are produced when Li^7 is bombarded by deuterons and which Crane, Delsasso, Fowler and Lauritsen[2] had attributed to Li^8. This discrepancy could be accounted for by assuming the nucleus resulting from the beta-disintegration to be an excited configuration[3] of Be^8 and the possibility was presented of observing the disintegration of this nucleus into two alpha-particles. We have looked for and found alpha-particle radioactivity when lithium is bombarded by deuterons. This radioactivity has in the meantime been reported by Lewis, Burcham and Chang.[4]

A target of lithium metal placed within a well inside a cloud chamber was bombarded by 850 kv peak deuterons. A grid allowing the observation of particles making an angle of $90°\pm5°$ with the incident deuterons was covered by a thin Al foil of 4 mm air equivalent stopping power. The target was bombarded for 1.8 seconds during each cycle and the cloud chamber expanded 0.2 seconds after the end of the bombardment. Gas-vapor mixtures of stopping powers 0.05, 0.10, 0.13, 0.16, 0.25, 0.50 and 1.00 were employed to secure the numbers distribution of the particles over various portions of the range. The lowest stopping powers were secured by using He as the chamber gas and water as the vapor, and were checked by measurement of the known ranges of He^4 and He^3 from Li^6+H^1.

The complete distribution in range curve secured in this manner is shown in Fig. 1. The large spread in range of the radioactive alpha-particle distribution is evident. No certain evidence was found for any line-structure in the curve. The distribution in energy of the alpha-particles has a maximum at 1.3 Mev and falls sharply to less than half the maximum at 1.0 Mev. The width at half-maximum of this distribution corrected for straggling and target spreading is very close to 0.5 Mev. The high energy portion of the distribution decreases rapidly with increasing energy but extends to at least 6.0 Mev. The average energy of the alpha-particles is 2.0 Mev.

The reactions proposed to account for the observed beta- and alpha-activity and the energy relation governing the experimentally determinable quantities are as follows:

$$Li^7+H^2\rightarrow Li^8+H^1+Q$$
$$Li^8\rightarrow Be^{8*}+e^-+E_0$$
$$Be^{8*}\rightarrow 2He^4+T$$
$$Q+E_0+T=15.6\pm0.2 \text{ Mev.}$$

Rumbaugh and Hafstad[1] have shown that the range of protons accompanying the formation of Li^8 is probably less than 8 cm so that $Q<1.8$ Mev and the observation that the beta-activity requires a bombarding energy of 500 kv establishes that $Q>-0.5$ Mev. We have shown[2] that E_0 extends up to at least 10 Mev and that the average kinetic energy of the beta-rays is 3.9 Mev. If the reactions proposed above are correct, then several points are of especial interest in connection with the observed alpha-particle distribution.

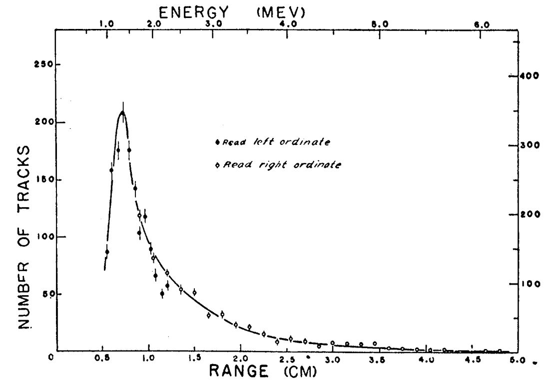

FIG. 1. Distribution in range of the radioactive alpha-particles from Li^7+H^2. The solid points were secured with stopping powers of 0.05 to 0.16 and when the left ordinate is read indicate the number of tracks counted in 0.06 cm intervals of normal range. The circles were secured with stopping powers of 0.25 to 1.0 and when the right ordinate is read indicate the number of tracks counted in 0.15 cm intervals. The two sets of data have been fitted together at 1 cm normal range.

(1) As has been previously pointed out[1, 3] a rigid selection rule must forbid the beta-neutrino transition from Li^8 to the normal state of Be^8 which suggests that the angular momentum of normal Li^8 and normal Be^8 must differ by at least two units.

(2) A straightforward application of Fermi's theory of beta-decay would require that the probability of disintegration of Li^8 contain a factor $(W_m-T)^\gamma$ where W_m is the excess energy of the Li^8 nucleus over two alpha-particles and where $\gamma\sim5$ on Fermi's interaction ansatz and $\gamma\sim7$ on on the Konopinski-Uhlenbeck ansatz. This factor in conjunction with the Gamow penetration factor governing the behavior of low energy alpha-particles will essentially account for the observed shape of the curve below 3 Mev provided that Be^8 has no stationary state of appropriate angular momentum below 2 Mev excitation. Because of the factor $(W_m-T)^\gamma$ we would expect from this fewer long range particles than are observed. Feenberg and Phillips[5] have suggested that triplet states of Be^8 may account for these high energy particles; the relatively large contribution of these states may be understood in terms of their long lifetimes.

(3) The observed beta-spectrum must no longer be looked upon as a transition with a single maximum energy end point. An additional asymmetry will be introduced into the spectrum but definite conclusions cannot be drawn until the possibility of gamma-ray emission has been investigated.

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[1] Rumbaugh and Hafstad, Phys. Rev. **50**, 681 (1936).
[2] Crane, Delsasso, Fowler and Lauritsen, Phys. Rev. **47**, 971 (1935).
[3] Wigner and Breit, Phys. Rev. **50**, 1191 (1936).
[4] Lewis, Burcham and Chang, Nature **139**, 24 (1937).
[5] Feenberg and Phillips, Phys. Rev. **51**, 597 (1937).