The Decay Constant of H^3

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THE decay constant λ of H^3 is too small to be determined conveniently in the usual way from the decay curve.[1] If, however, we can produce a known number N of H^3 nuclei, and observe which number N' of these nuclei decay per unit time, we can obtain λ from the relation $\lambda=N'/N$. We have carried out a determination of λ in this manner. H^3 was produced by exposing lithium to slow neutrons, which leads to the reaction[2] $Li^6+n^1\rightarrow He^4+H^3$.

(1) In a first experiment lithium metal, sealed in a soft glass tube, was exposed inside a large paraffin block in a fixed position A to neutrons from a 100-mg $Ra-\alpha-Be$ source. The total time of irradiation was four months. When the irradiation was completed, water was added to the Li metal until it was all transformed into LiOH whereby hydrogen gas was developed. In this way H^3 can be extracted from the Li metal with an efficiency of about 94 percent (see below). A known fraction of the hydrogen gas, together with some alcohol vapor, was introduced into a large Geiger counter, and an activity of 56 counts/min. in excess of a background of 108 counts/min. was established. This activity varied with the pressure in the Geiger counter in the expected manner. By "scanning" the counter with a well-collimated beam of γ-rays we found that it was sensitive over about 90 percent of its length. If we assume, as is plausible, that every H^3 nucleus decaying in the sensitive portion of the counter is detected, we can calculate from the above measurements N' for the whole piece of Li metal used.

N can be put equal to the total number of C neutrons absorbed in the Li metal, if we neglect two corrections of opposite sign which in this experiment should be of the order of a few percent each: The contribution of neutrons with an energy above the Cd absorption limit, and the loss of some of the H^3 nuclei produced near the surface. (Their range in lithium is about 1/10 mm.) To obtain the total number of C neutrons absorbed in the Li the following experiments were carried out.

(a) The ratio of the number of C neutrons absorbed in the Li to that absorbed in Mn in position A per unit time was measured with an In foil as neutron detector. This foil could be wrapped round the samples.

(b) Mn metal powder was exposed in position A, until the 2.6-hr. period produced by slow neutron capture was saturated. A similar experiment was carried out with the Mn surrounded by Cd. The initial activity of the Mn was measured in each case under identical geometrical conditions by means of a thin-walled Geiger counter.

(c) By mixing a small, known amount of U_3O_8 with Mn powder and measuring its activity in the same way as was used for the activated Mn, the counting arrangement was calibrated. Assuming similar β-ray spectra for Mn^{56} and UX_2, which we found by absorption experiments to be a reasonably good approximation, we obtained the total number of β-rays emitted per minute from the saturated Mn sample. This number is equal to the number of neutrons absorbed by the Mn per minute.

From these measurements we deduce

$$\lambda=7\times10^{-10}\ \text{sec.}^{-1}\pm25\ \text{percent},$$

or the half-lifetime of H^3, $T=31\pm8$ years.

(2) Through the courtesy of Professor Cork, we were able to use for a second set of experiments Li bombarded, intermittently, during three weeks with slow neutrons from the Michigan cyclotron. As a "neutron integrator" which allowed us to estimate the total number of slow neutrons absorbed by the Li we used Sb, which is activated by slow neutrons with a period of 60 days, and which was bombarded close together with the Li. The hydrogen extracted from this Li sample by the procedure described in (1) showed an activity, N', about 100 times larger

[1] L. Alvarez and R. Cornog, Phys. Rev. **58**, 197A (1940).
[2] J. Chadwick and M. Goldhaber, Proc. Camb. Phil. Soc. **31**, 612 (1935).

than in the first experiment. By electrolyzing some of the remaining LiOH solution we found a small activity in the hydrogen developed. From this it followed that the efficiency with which H^3 was extracted from Li by the procedure described in (1) was 94 ± 3 percent.[3]

The activity of Sb^{124} (60-day) was measured 5 weeks after the last irradiation when Sb^{122} (2.6-day) had already decayed. It was compared with the activity of an Sb sample bombarded here (position A). If we assume the percentage contribution of C neutrons to the 60-day activity to be the same under the different conditions of bombardment employed in Michigan and here, we can estimate the number of H^3 nuclei formed in the Li sample. (This assumption, however, may introduce a serious error, as we found by a separate experiment (position A) that the contribution of neutrons above the Cd absorption limit to the 60-day activity of Sb is considerable.) In this way we obtained a value of about 50 years for the half-lifetime of H^3. Though this experiment is less accurate than the first it yielded a valuable check on our method.

We had observed previously[4] that the electrons emitted from H^3 have a range of about 0.5 mg Al/cm^2. This corresponds to an upper limit of the β-ray spectrum $E_0=15\pm3$ kev. As the β-transition may be considered as allowed, we can now check the relation between E_0 and λ, as given by Fermi's theory of β-decay, for this rather extreme case. Using the value for the constant of proportionality as deduced by Grönblom[5] from an analysis of the β-ray data on light elements, we find good agreement between theory and experiment within the present accuracy.

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[3] This high efficiency is not unexpected as a similarly high efficiency has been found for the production of HD in the reaction $LiH+D_2O\rightarrow HD+LiOD$ (Beutler, Brauer and Juenger, Naturwiss. **24**, 347 (1936)).

[4] R. D. O'Neal and M. Goldhaber, Phys. Rev. **57**, 1086A (1940).

[5] B. O. Grönblom, Phys. Rev. **56**, 508 (1939).