Conservation of Energy in the Disintegration of Li^8

Some time ago two of us reported an investigation with isotopic targets of the energy balance in the formation of radio-lithium by the process $Li^7+D^2 \rightarrow Li^8+H^1$, and showed that the emission of a beta-particle must be followed by yet another reaction to absorb an excess of energy which amounts to more than 3 Mev, the predicted processes involving the emission of alpha-particles, gamma-rays, or both.[1] The alpha-particles have been found by Lewis, Burcham, and Chang[2] who report that, though most of the alpha-particles have ranges of less than 1.5 cm of air, about 0.3 percent of the total extend to 5 cm. They suggest that the alpha-particles originate in excited Be^8 formed "either in a number of discrete energy states or in a continuous distribution."

We have continued our investigations of the formation and disintegration of radio-lithium with the following results.

(1) The initial reaction, $Li^7+D^2=Li^8+H^1+Q$, seems the only possible one fitting the experimental facts.

(2) The energy balance, Q_1, for the formation of Li^8 must be greater than -360 kv since radio-lithium was formed by deuterons of energies as low as 360 kv.

(3) Q_1 is not greater than $+260$ kv since, using 860-kv deuterons, no proton group of range exceeding 1.7 cm was observed with even a fraction of the intensity necessary for correlation with the amount of radio-lithium produced.

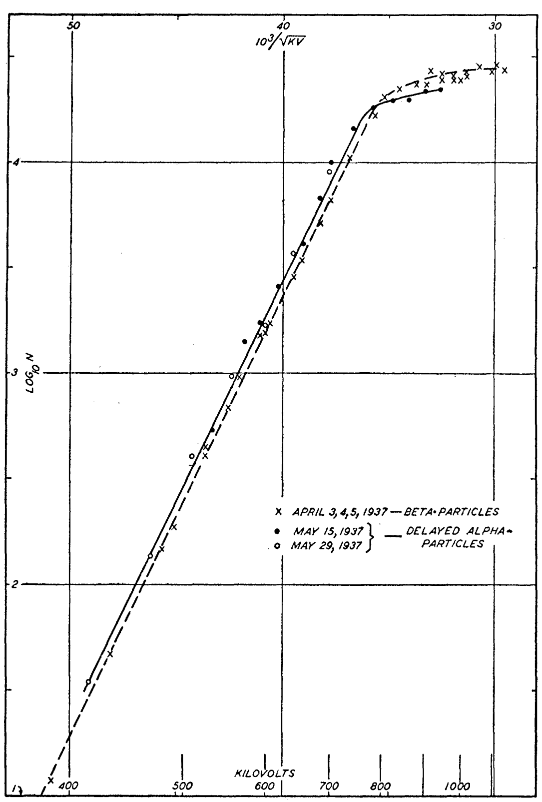

FIG. 1. Yield of delayed particles from Li^7+D^2.

(4) No gamma-radiation was observed in the formation or disintegration of Li^8 although the gamma-radiation from much thinner carbon-targets was readily detected.

(5) The ratio of alpha-particles of ranges exceeding 6 mm to beta-particles counted under the same experimental conditions is very nearly unity. However, corrections for alpha-particles of shorter range and for the geometry of the beta-particle counter would tend to increase this ratio.

(6) The excitation curves for the delayed alpha- and beta-particles as shown in Fig. 1 are identical and markedly different from eight other carefully measured lithium excitation curves.

(7) The disintegration of Li^8 produces alpha-particles with a half-period of 0.85 ± 0.1 sec. and beta-particles with a half-period of 0.90 ± 0.1 sec., indicating that the decay periods are identical.

(8) We have been unable to observe the instantaneous emission of low energy alpha-particles which might be produced by bombardment of Li^6 with deuterons or Li^7 with protons. These might be expected if the delayed alpha-particles arise from excited states of Be^8.

(9) The number range curve for the delayed alpha-particles shows a smooth continuous distribution falling rapidly with increasing range, and decreasing by a factor of 800 between 0.6 and 5.2 cm.

In view of the experimental results (4), (5), (6), (7), and (8) above, it is highly probable that Li^8 always disintegrates into two alpha-particles and a beta-particle. Combining this fact with (9) and the known form of the energy-distribution curve for beta-rays, it follows that, for any given energy interval, both conservation of energy and of electric charge cannot be satisfied simultaneously by considering charged particles alone.

This difficulty is avoided by including an uncharged body (neutrino hypothesis) in the four-body disintegration

$$_3Li^8 \rightarrow {_2He^4}+{_2He^4}+{_{-1}\epsilon}+{_0\nu}+Q_2.$$

The disintegration energy Q_2 is divided between Q_L, the energy of the light particles, and Q_H, the energy of the heavy particles. From conservation of momentum Q_H is very nearly equal to $2Q_\alpha$, twice the energy of a single alpha-particle. Using the Bainbridge-Jordan[3] mass scale and

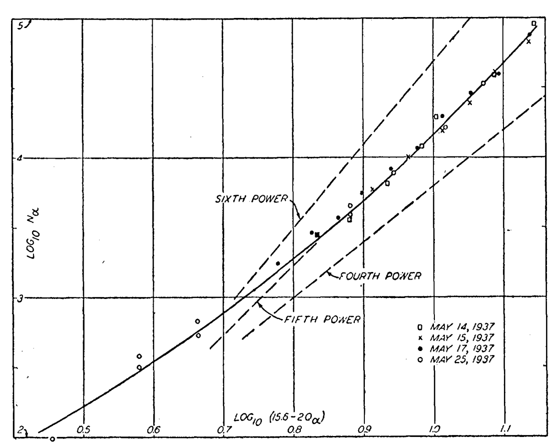

FIG. 2. Energy diagram for Li^8 disintegration.

$Q_1 \sim 0.2$ Mev, according to (2) and (3) above, $Q_2 \sim 15.6$ Mev, whence

$$Q_L = (15.6 - 2Q_\alpha).$$

Since, by conservation of charge, the transition probability for a beta-neutrino energy, Q_L, will be proportional to the number of alpha-particles, N_α, observed with energies Q_α, the relation between this transition probability and Q_L may be obtained by plotting N_α against Q_L as in Fig. 2.

It is interesting to note that *the application of the neutrino hypothesis, conservation of energy, and charge to our alpha-particle data results in a Sargent diagram.* In fact, this diagram is essentially an idealized Sargent diagram because it represents a *continuum* in Q_L for which initial and final nuclei are identical.

We are greatly indebted to Professors Gamow and Teller for discussion of the theory of this disintegration. They have pointed out that considerations based on the Fermi theory predict a number of alpha-particles proportional to $(Q-2E_\alpha)^5(E_\alpha)^n$ where n is $\frac{1}{2}$ or $\frac{3}{2}$ depending on the angular momentum of the alpha-particles. Our observations agree satisfactorily with the fifth power (Fig. 2), although further study of the low energy alpha-particles will be necessary to decide whether n should be $\frac{1}{2}$ or $\frac{3}{2}$. The Konopinsky-Uhlenbeck theory predicts a seventh power dependence which clearly is not in agreement with our observations.

The above interpretation at once suggests additional experiments to establish whether or not the conservation of momentum is also satisfied by the neutrino hypothesis in the disintegration of Li^8. Preparations for such observations have been undertaken.

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June 3, 1937.

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The Radioactivity of K^{38}

Rocksalt bombarded with 0.05 microamperes of 7 Mev alpha-particles accelerated in a cyclotron displays a strong activity of 7.5 ± 0.1 minutes half-life (Fig. 1). $NiCl_2$ bombarded with alpha-particles gives rise to activity of the same period, while Na_2CO_3 does not, so that the 7.5 minute radioelement must be produced from chlorine. Magnetic deflection of the particles emitted shows them to be positrons. The activity has been shown chemically to be due to an isotope of potassium, by precipitating it with sodium cobaltinitrite. These data make it seem extremely likely that the radioelement is the potassium isotope of mass number 38, formed in the reaction Cl^{35} (α, n) K^{38}.

The absorption of the positrons in aluminium has been measured (Fig. 2); the half-value thickness is about 0.23 g/cm², indicating that the maximum energy of the continuous spectrum is of the order of 3 Mev.

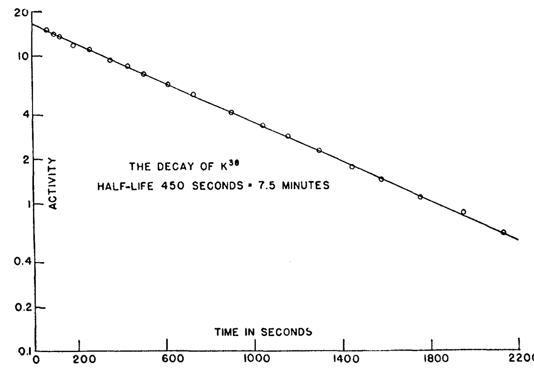

Fig. 1.

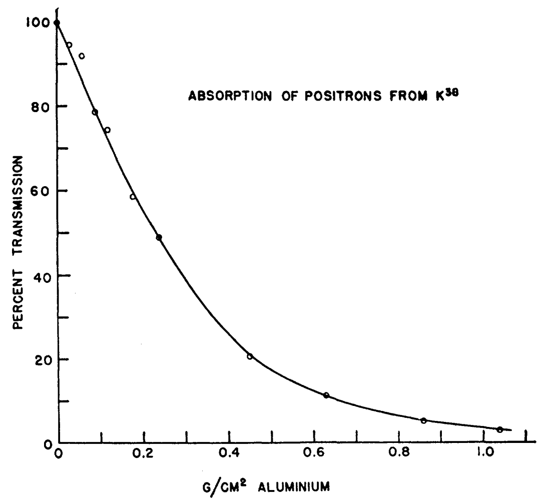

Fig. 2.

Walke[1] has attributed to K^{38} a weak activity of 10.5 hours half-life found by him in the potassium precipitate of a sample of Ca bombarded by deuterons. The present result suggests that this may be a wrong assignment; possibly the observed activity was due to K^{42}, formed by the reaction Ca^{44} (D, α) K^{42}. The half-life of K^{42} is 12.2 hours.

Pollard, Schultz, and Brubaker[2] have observed the emission of neutrons from Cl bombarded with alpha-particles, and have attributed them to the reaction Cl^{37} (α, n) K^{40}. The strength of the activity here reported makes it seem likely that many of the neutrons arise from the reaction Cl^{35} (α, n) K^{38}. The abundance ratio of the chlorine isotopes $(Cl^{35}/Cl^{37} = 76/24)$ slightly favors the second reaction.

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May 17, 1937.

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[2] E. Pollard, H. L. Schultz and G. Brubaker, Am. Phys. Soc. Meeting, Washington, April 30, 1937.