On the Hypothesis of the Instability of the Deuton

Our attention has been called by Dr. C. C. Lauritsen to a possible alternative explanation of the experiments recently reported by us.[1] In these experiments pairs of targets containing respectively light and heavy hydrogen were bombarded by hydrogen molecule ions. Protons having ranges up to 20 cm were observed from both targets but in greater numbers from the targets containing heavy hydrogen and this difference was attributed to the disintegration of the deutons of the targets by the protons of the beam. The fact that both targets yielded these particles was attributed to a small contamination (about 1 part in 30,000) of H^{2+} in the H^{1+}_2 beam.

The point raised by Dr. Lauritsen is that the contamination of H^2 in the apparatus must be largely increased when the beam is playing on the target containing heavy hydrogen and this added contamination might produce just the effect observed by us, since all of the hydrogen in the chamber contributed to the beam.

It had been our intention to employ in this experiment not the H^{1+}_2 beam but the simple H^{1+} beam which could contain no such contamination; however, this experiment was delayed owing to the rather extensive readjustments of the apparatus that would be required. Now owing to the obvious ambiguity of the experiments which we reported, we recognize that for a final settlement of this question experiments with a pure H^{1+} beam are essential.

We now think it altogether possible however that the results of such an experiment will be negative. For recently alternative and reasonable explanations have been found for those phenomena which originally led us to the hypothesis of the instability of the deuton. There is evidence[2, 3] in the important case of carbon under deuton bombardment that two nuclear reactions occur:

$$C^{12}+H^2\rightarrow C^{13}+H^1+\gamma,$$
$$C^{12}+H^2\rightarrow N^{13}+n.$$

At least at low voltages, these reactions appear to account for the long range protons and neutrons observed. It appears not unlikely that similar reactions with other nuclei and the possibility of carbon and oxygen contamination[4] of targets will ultimately account completely for our observations.

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[1] G. N. Lewis, M. S. Livingston, M. C. Henderson and E. O. Lawrence, Phys. Rev. **45**, 242–244 (1934).

[2] C. C. Lauritsen and H. R. Crane, Phys. Rev. **45**, 345–346 (1934). C. C. Lauritsen, H. R. Crane and W. W. Harper, Science **79**, 234 (1934).

[3] M. C. Henderson, M. S. Livingston and E. O. Lawrence, Phys. Rev. **45**, 428 (1934).

[4] We are indebted to Dr. J. D. Cockcroft for communicating to us evidence that the long range protons observed when tungsten is bombarded by deutons are in fact due to a contamination.

Further Experiments with Artificially Produced Radioactive Substances

C and B_2O_3 bombarded with protons

After having observed induced radioactivity in a number of substances bombarded with deutons,[1] it seemed desirable to bombard the same targets with protons. This led to the striking observation that two of the targets, namely carbon and boron oxide, showed an appreciable activity which decayed at the same rate as did the activity produced by deutons. The intensity of the activity produced by protons, as compared to that produced by deutons under similar conditions was, in the case of carbon, about 10 percent, and in the case of the boron oxide, about 20 percent. That the ion beam could contain 10 to 20 percent deutons due to contamination of the tube with H^2 (adsorbed on the walls, etc.) seems highly improbable, since on other occasions we have changed from deutons to protons and have observed no more of the deuton effect than could be accounted for by the normal amount of H^2 in ordinary hydrogen—about one part in 6000. The fact that the decay periods of the active substances produced by protons and by deutons are quite exactly the same suggests strongly that the same radioactive products are formed. In the case of deuton bombardment the radioactive substances are supposedly N^{13} and C^{11}, respectively, and hence for the case of proton bombardment we may suggest the following alternative reactions which would involve the same radioactive products:

$$\begin{aligned} &C^{12}+H^1\rightarrow N^{13}\rightarrow C^{13}+\epsilon^+ \quad (+6\times10^6 \text{ e.v.}),\\ &B^{10}+H^1\rightarrow C^{11}\rightarrow B^{11}+\epsilon^+ \quad (+9\times10^6 \text{ e.v.}),\end{aligned} \tag{1}$$

where the excess energy calculated from the change in mass in the overall reaction is given, and

$$\begin{aligned} &C^{13}+H^1\rightarrow N^{13}+n^1\rightarrow C^{13}+n^1+\epsilon^+,\\ &B^{11}+H^1\rightarrow C^{11}+n^1\rightarrow B^{11}+n^1+\epsilon^+,\end{aligned} \tag{2}$$

where in accordance with the presumable mass of the neutron the excess energy from the change in mass is nearly negligible and might be either positive or negative.

One hesitates to accept the first type of proposed reaction, mainly because the probability of a particle being

[1] Lauritsen, Crane and Harper, Science **79**, 234 (1934); Crane and Lauritsen, Phys. Rev. **45**, 430 (1934).