

On the Hypothesis of the Instability of the Deuteron

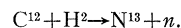
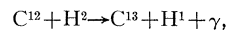
Our attention has been called by Dr. C. C. Lauritsen to a possible alternative explanation of the experiments recently reported by us.¹ In these experiments pairs of targets containing respectively light and heavy hydrogen were bombarded by hydrogen molecule ions. Protons having ranges up to 20 cm were observed from both targets but in greater numbers from the targets containing heavy hydrogen and this difference was attributed to the disintegration of the deuterons 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 H²⁺ in the H¹⁺² beam.

The point raised by Dr. Lauritsen is that the contamination of H² 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 H¹⁺² beam but the simple H¹⁺ 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 H¹⁺ 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 deuteron. There is evidence^{2, 3} in the important case of carbon under deuteron

bombardment that two nuclear reactions occur:



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 contamination⁴ 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).

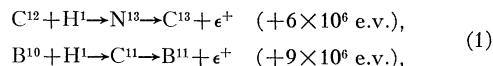
⁴ We are indebted to Dr. J. D. Cockcroft for communicating to us evidence that the long range protons observed when tungsten is bombarded by deuterons are in fact due to a contamination.

Further Experiments with Artificially Produced Radioactive Substances

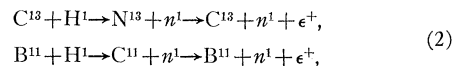
C and B₂O₃ bombarded with protons

After having observed induced radioactivity in a number of substances bombarded with deuterons,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 deuterons. The intensity of the activity produced by protons, as compared to that produced by deuterons 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 deuterons due to contamination of the tube with H² (adsorbed on the walls, etc.) seems highly improbable, since on other occasions we have changed from deuterons to protons and have observed no more of the deuteron effect than could be accounted for by the normal amount of H² in ordinary hydrogen—about one part in 6000. The fact that the decay periods of the active substances produced by protons and by deuterons are quite exactly the same suggests strongly that the same radioactive products are formed. In the case of deuteron bombardment the radio-

active substances are supposedly N¹³ and C¹¹, respectively, and hence for the case of proton bombardment we may suggest the following alternative reactions which would involve the same radioactive products:



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



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).