Corrected

May 15, 1946

IN PLACE OF A SUMMARY

L. Szilard

Remarks added May, 1946.

It became first apparent to the author in July, 1939 that there is a serious possibility of maintaining a chain reaction in a system composed of uranium and graphite. At that time we had only very imperfect knowledge of the values of the nuclear constants involved but this did not stand in the way of making a comparison between a heterogenious uranium-carbon system and homogenious uranium-water system. The comparison showed that if a homogenious water-uranium system can be constructed which comes very close to be chain reacting, then it should be possible to make a heterogenious carbon-uranium system chain reacting, provided that the absorption of carbon is lower than $.01 \times 10^{-24}$, which happened to be the experimental upper level for carbon absorption, at that time. An experiment previously completed in June 12, 1939, indicated that a uranium-water system could come reasonably close to be chain reacting and the Government was advised of this situation in October, 1939.

In January, 1940, experiments, made by Halban, Joliot, Kowarski, and Perrin, on uranium-water systems, became known. One of the uranium-water systems investigated by them came very close to be capable of maintaining a chain reaction, and one could see that such systems could accordingly get close to be chain reacting for the optimum concentrations. In the opinion of the author, this made it almost certain that a chain reaction can be set up in a uranium-carbon system under practically attainable conditions, if the capture cross-section of carbon had a value of, say, about one half of the experimental upper limit quoted above, i.e., .005.

In order to get somewhat oriented as to what the useable ratios of carbon

to uranium and what the geometrical dimensions might be, some rough formulae to which such a simple theory leads, the author had to decide what values to use for those physical quantities of uranium which were very poorly known at that time. Values were so adjusted to each other as to just about permit a chain reaction in the limiting case of the carbon absorption corresponding to a cross section of $0.01 \times 10^{-24} cm^2$. This adjustment was achieved by proper choice of a value for the resonance absorption.

This paper was therefore written in an attempt to obtain a rough idea as to the optimal composition, geometrical dimensions, and other characteristics of such a chain reacting system. The publication of this paper was delayed in 1940 at the request of the author. Over six years have now elapsed since it was written and naturally, the paper is outdated in many respects. In these circumstances, an attempt was made to cut down somewhat its length without adding to its original contents. A few footnotes were added to draw attention to some of the shortcomings which have in the meantime become evident.

May 11, 1946

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The United States Government was advised of this situation in October 1939. No direct experimental evidence on a uranium-carbon system was available at that time, but experiments completed in collaboration with H.L. Anderson and E. Fermi, earlier in June 1939, had reliably indicated that a water-uranium system can indeed come reasonably close to be chain reacting. No further experiments on such systems were undertaken at Columbia University, or for that matter anywhere in the United States, between June 1939 and March 1940. But in January 1940, an experiment performed by Halban, Joliot, Kowarski, and Perrin, on uranium-water systems became known in this country. One of the uranium-water systems investigated by them came close to be capable of maintaining a chain reaction and one could also see that such systems could get exceedingly close to be chain reacting for the optimum concentrations. In the opinion of the author, this ~~made it certain that a~~ meant that we can expect a chain reaction ~~can be set up~~ in a uranium-carbon system under practically attainable conditions, if the capture cross-section of carbon had a value of, say, about one half of the experimental upper limit quoted above, i.e., .005.

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fraction of the thermal neutrons be captured by the element which is used for the purpose of slowing down, we would have a chain reaction which may diverge for a sufficiently large massof uranium.

This does not necessarily mean that a chain reaction can be maintained in a mixture of water and uranium oxide. Fermi has investigated (June 1939) the question whether more favorable conditions can be obtained in mixtures of uranium oxide and water by keeping the uranium oxide and water in separate layers and found that a slight improvement can thus be obtained. But this improvement was not sufficient to determine whether a chain reaction can be obtained in a system composed of water and uranium oxide.

A recent experiment published by Halban, Joliot, Kowarski, and Perrin, on homogenious uranium-water systems(13) will be discussed below and it will be seen that such systems, while they may or may not be actually capable of sustaining a chain reaction, can in any case come very close to it.

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