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SHORT REPORT ON THE PROGRESS MADE IN WORK ON URANIUM DURING THE LAST THREE MONTHS

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The main purpose of the experimental and theoretical work which I carried out in the last three months in collaboration with Feld, Marshall and Zinn was to determine the contribution of the fast fission neutrons to chain reactions. If we know how efficient fast fission neutrons are in producing further fission neutrons, and if we know how rapidly these fission neutrons are slowed down by uranium, we can answer two important questions:

a) What is the contribution of the fast fission neutrons to the chain reaction in a lattice of uranium spheres which are imbedded in graphite and how much improvement can we expect on account of this effect when we go over from uranium oxide to uranium metal?

b) If we wish to construct a bomb using a certain quantity of element 94 (or uranium 235) in the form of ~~this~~ sphere, by what factor can we reduce the amount required of these precious elements by surrounding this sphere with a shell of ordinary uranium metal due to the fission caused by fission neutrons in the uranium shell?

In experiments which I carried out in collaboration with Dr. J. Marshall, Jr., we succeeded in observing the fission caused by fission neutrons and the preliminary determination of the efficiency of this process gives for the product of the number of neutrons emitted by fission <u>times</u> the fission cross-section for fission neutrons the value of about 1.3×10^{-24} cm^2. The experiments

are continued in order to obtain a more accurate value for this quantity.

Experiments which I carried out in collaboration with Dr. W. H. Zinn and J. Marshall, Jr., concern the slowing down of fast neutrons in uranium and also in lead and bismuth. We find that the cross-section for slowing down of neutrons below the fission threshold of uranium 238 has for uranium a value of about 2.7×10^{-24} cm^2 and that this value does not depend very much on the energy of the neutron.

A rough estimate based on these experiments indicates, that due to the fission caused by fission neutrons, there may be an increase in the efficiency of the uranium lattice in graphite, amounting perhaps to 10 percent if we change over from uranium oxide to uranium metal without changing the uranium graphite ratio. Experiments carried out by Professor Fermi in collaboration with Anderson, Feld and Weil gave for uranium oxide spheres in graphite for the particular ration of uranium to carbon which was used in those experiments a multiplication factor of .87. If we allow for the effect of the absorption due to the tinned iron cans used in this experiment and to the known impurities of the uranium oxide used, we may estimate that for pure uranium oxide the multiplication factor might be perhaps .95 under the conditions of Fermi's experiment. If we now go over to the metal without changing the ratio of uranium carbon, and if the multiplication factor indeed increases by ten percent due to the fission by fission neutrons, we would then arrive at a multiplication factor of about 1.05, and accordingly

should expect a divergent chain reaction.

A more detailed calculation of this contribution which is due to fission by fission neutrons in the uranium carbon system is now being carried out by me in collaboration with Feld. It should be noted, however, that the advantage due to changing over from oxide to metal is greater than would appear from considerations of this type, since the most favorable ratio of uranium to carbon will change if we go over to metal, and may be very different from the ratio actually used in the measurements performed by Fermi and his collaborators.

Based on the above mentioned experiments other calculations are now in progress to determine the effect of fission by fission neutrons in a uranium shell on the amount of element 94 or 235 which is required for the bomb.

It should perhaps be mentioned that measurements were recently made by Fermi and Anderson on the fission cross-section of radon-beryllium neutrons and gave a value of $.45 \times 10^{-24}$ cm^2. This value is consistent with the efficiency as given above for fission production by fission neutrons, if we assume that a very considerable fraction of the fission neutrons is fast enough to produce fission in uranium 238.

Another line of experiments which I pursued in collaboration with Marshall aims at determining the cross-section for the formation of uranium 239 from uranium 238 for neutrons of about 100,000 volt energy. Preliminary results which were obtained with photoneutrons seem to indicate that this cross-section is

surprisingly high, about 5×10^{-25} cm^2. The measurements are being repeated in order to determine this value more accurately.

Fermi and Anderson have recently determined this cross-section for radon-beryllium neutrons and find a value which is about ten times lower. The two results are not inconsistent since they refer to neutrons which have different energies.

The purpose of this second line of investigation is twofold: c) The knowledge of the cross-section of the formation of 239 for neutrons of 100,000 volt energy is very important if one wants to find the best possible arrangement in the uranium graphite system, and particularly if one wants to know the most favorable ratio of uranium to carbon in such a system. d) The accurate knowledge of this cross-section for energies of about 100,000 volts, together with an accurate determination of the first mentioned quantities, will throw light on the question whether a fast neutron chain reaction in natural uranium is possible. No opinion should be expressed on this important issue until the above mentioned quantities have been measured more accurately. It may be stated, however, that the high cross-section for the formation of uranium 239 for photoneutrons from radon-beryllium will, if confirmed, make the chances of such a fast neutron chain reaction appear to be smaller than it may have been estimated previously.