3 bis-3

December 12, 1941

RECEIVED
DEC 27 1941
DEPT. OF PHYSICS
COLUMBIA UNIVERSITY

Preliminary Report on Inelastic Collision of Neutrons in Uranium and other Heavy Elements.

by Leo Szilard and W. H. Zinn.
Columbia University, New York, New York.

In view of the potential possibility of a chain reaction based partly or wholly on fission caused by fast neutrons, it appeared of interest to investigate the inelastic collision of fast neutrons in uranium and certain other elements. In uranium fast neutrons would be slowed down at a certain rate by inelastic collision below the fission threshhold of uranium 238 and the main purpose of our experiments was to determine the cross-section of this process. This cross-section will naturally depend on the velocity of the primary neutrons, and it would be best, although at present not practicable, to use fission neutrons as primary neutrons for the purpose of our experiment.

Experiments were started in February 1941, using as a neutron source a neutron generator previously described by Zinn and Seeley[1] in which neutrons are emitted from a heavy ice target between 2.2 and 2.8 MEV from the D+D reaction.

---

[1] W. H. Zinn and S. Seeley, Phys. Rev. 52, 9 (1937).

In order to determine the cross-section for inelastic collisions, as defined above, for lead, bismuth, and uranium, we proceeded in the following way: An ionisation chamber coated with a thick layer of uranium oxide was placed at about 26 centimeters from the target. The neutrons emitted from the target cause the emission of fission particles from the uranium oxide coating, and the pulses due to these fission particles were counted serving as a measure of the number of fissions produced by these neutrons. The decrees in the number of these fissions which is brought about when the target is surrounded with a lead, bismuth, or uranium sphere gives ~~xxkx~~ a direct measure of the fraction of the neutrons emitted from the target which have been slowed down below the fission threshhold of uranium 238 while passing through a certain thickness of lead, bismuth or uranium, respectively. Since the intensity and the energy of the neutrons which are emitted from the target vary with the angle which the neutron velocity forms with the deuteron beam, this angle, which is defined by the prosition of the fission chamber, was varied from 0 to 120 degrees. The value of the integral of the fission count over the whole sphere was extrepolated assuming cylinderical symmetry around the deuteron beam. The lead, bismuth and uranium spheres which were used had a hole in their centers to allow the introduction of the target and had a radial wall thickness of bismuth, lead and uranium of 6.7 centimeters. The densities of lead, bismuth and uranium in these spheres were as follows:

Pb: 11:15 gm/cm^2 Bi: 9.8 gm/cm^2 U: 7.62 gm/cm^2

For the cross section for inelastic scattering, we obtained by the method indicated above:

Pb: 0.55; Bi:0.64; U:1.9 in units of 10^{-24} cm^2.

Similar experiments were subsequently performed by Marshall and Szilard, using the same lead, bismuth and uranium spheres, but using as primary neutrons neutrons from a radon-beryllium source which have a different spectral distribution. The values obtained for the cross-section for inelastic scattering of radon-beryllium neutrons are the following:

Pb: 1.34; Bi: 1.85; U: 2.21

We see that by changing over from D+D neutrons to radon-beryllium neutrons, there is a conspicuous increase in the cross-section of lead and bismuth which increase to two to three times, whereas there is at the most a slight increase in the value for uranium. Experiments performed by Marshall and Szilard with radon-beryllium neutrons on another, purer, sample of uranium, give a slightly lower value so that it might be that the value for pure uranium and D+D neutrons should be taken as low as 1.5.

The above stated values for uranium was obtained by attributing the observed decrease of the fission count which was caused by the uranium sphere to inelastic scattering in uranium without taking into account the fact that the primary neutrons may produce fission in the uranium sphere, and that additional neutrons may be created hereby which contribute to the fission count observed in our experiment. In the absence of this secondary process, the decrease in the fission count caused by the uranium sphere would be greater than the decrease which was actually observed in our experiment. The inelastic cross-section of uranium is therefore greater than the value given above, and we have to add a correction term. In order to determine the value of this correction term, we shall assume that about 2.6 neutrons are emitted per fission (both for fast neutron fission and thermal neutron fission), ~~xxx~~ We shall also assume that the fission neutrons which are generated by D + D and radon-beryllium neutrons have the same cross-section for causing fission in uranium as fission neutrons which are generated by thermal neutrons, ~~Nexxhaxkxxfxxkhex xxxxxx~~ and that also D + D neutrons and radon-beryllium neutrons have the same cross-section. With these assumptions we can calculate the value of the correction term directly from experimental results obtained by Marshall and Szilard, who observed fission caused by fission neutrons which were generated by thermal neutrons and determined the efficiency of this process. They reported (see Report dated November 14, 1941) for the product of the fission cross-section of fission neutrons and the number of neutrons emitted per fission the value[1] of 1.3×10^{-24} cm^2. From this we find the value of $.8 \times 10^{-24}$ cm^2 for the correction term which has to be added to the above quoted cross-section of 1.9×10^{-24} cm^2 in order to obtain the value for the cross-section for the cross-section of uranium for inelastic scattering, and obtain for this cross-section the value of 2.7×10^{-24} cm^2.

---

1 Result of the first preliminary experiment.