## Radioactive Recoils from Uranium Activated by Neutrons

It has been shown by Hahn and Strassmann[1] and immediately afterward by others[2] in this laboratory and elsewhere that the uranium nucleus under neutrom bombardment sometimes splits into parts with about half the atomic number of uranium, and thus produces radioactive isotopes in the middle of the periodic table. The range of the ejected radioactive particles can be measured by observing the distribution of the activity with depth in a layer of matter placed next to the uranium during bombardment.[3]

An experiment of this kind was done by placing a stack of thin (0.57 mg/cm$^2$) Al foils in contact with a thin layer of $UO_3$ mounted on paper, and exposing to neutrons from the cyclotron. Then the activities of the separate foils were measured. The results are shown in Fig. 1 which gives

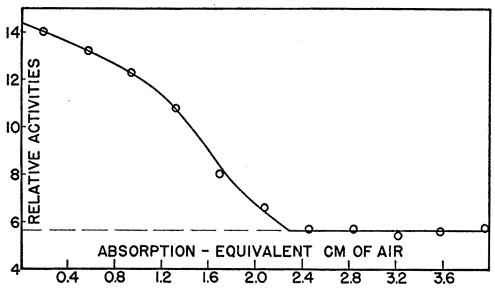


FIG. 1. Relative activities of aluminum foils plotted against the stopping power from the surface of the uranium sample in cm of air equivalent. The points are put at positions corresponding to the centers of the foils. The horizontal line represents the activity induced in the aluminum by the neutrons, and the curve shows the activity deposited by recoil from the uranium. The form of the curve near the end-point is not well determined by the data. The range may be estimated as 2.2±0.2 cm.

the relative activities at about two hours after the end of the bombardment. The horizontal line represents the "background" due to the activity induced in the Al itself. The last foil was omitted from the plot, since its activity is reduced about 30 percent by the recoil of the activated nuclei under the fast neutron impact, which drives some of them into the preceding foil. (The neutron source was to the right in the figure.) If the particles from the uranium had a homogeneous range, the distribution of activity would be rectangular. The observed shape can be explained either by supposing that there is a distribution of ranges, or by taking account of the finite size of the grains of $UO_3$. These grains have sizes ranging from about 40 microns down to 1/10 this or less. Since the mean diameter represents a stopping power of the order of the observed range, we can say that the results are not incompatible with an initially homogeneous range.

Another experiment was done to find out if there is any correlation between range and decay periods of the products. Cigarette papers of about one cm air equivalent stopping power were used instead of the Al foils. These were extracted with hydrochloric acid before use, and the $UO_3$ was mounted on filter paper, to avoid all mineral matter that would give extraneous activities. After bombardment, activity was found on the first three sheets of paper. The decay curve of the second sheet was followed for about 24 hours, and of the third for about 12 hours, and they were found to run parallel to that of the first sheet within the accuracy of the measurements. But the decay curve of the uranium sample (including the paper backing) showed quite striking differences from these. The uranium curve has a strong additional component of about 25 minutes half-life, which may be the substance identified by Hahn, Meitner and Strassmann[4] as a uranium isotope produced by resonance neutron capture, and also a long period (~2 day) which is strong compared with any activity of corresponding period in the recoil samples. (The intensity of activation is so great that the natural uranium activity can be neglected.) The ratio of the total activity on the paper sheets to the activity of the uranium sample is about $\frac{1}{6}$ at three hours after bombardment, when this ratio reaches its largest value. This means that at this time the total recoil activity from both sides of the $UO_3$ sample is about $\frac{2}{5}$ as great as the activity remaining in the uranium. Since a considerable part of the latter consists of the nonrecoiling activities mentioned above, it should be easy to make a complete separation of the recoils from the others by using a more finely divided uranium preparation. This work is being continued. By using thin inactive foils of organic material and a very thin layer of uranium, it should be possible to obtain a very accurate range curve of this method. The financial support of the Research Corporation is very much appreciated.

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[1] O. Hahn and F. Strassmann, Naturwiss. **27**, 11 (1939).
[2] These are too numerous to give individual references here.
[3] The same idea occurred to F. Joliot, who performed a similar experiment, and communicated the results in a letter to Professor E. O. Lawrence, received during the course of the above work. Joliot's result was reported at the January 30 meeting of the French Academy of Sciences. He found a recoil range of about 3 cm.
[4] L. Meitner, O. Hahn and F. Strassmann, Zeits. f. Physik **106**, 249 (1937).

## Further Observations on the Splitting of Uranium and Thorium

Continuing a survey of the effects produced by bombarding uranium and thorium with neutrons we have measured the range of the energetic particles emitted. This was done by coating a movable plate with the substance to be investigated and observing the distance at which the particles could no longer be detected by an ionization chamber with a gauze front, connected to a pulse amplifier. The ranges found were 10.5±1 mm and 12.0±2 mm for the particles from uranium and thorium, respectively.

To test the possibility of the delayed emission of neutrons a boron-lined ionization chamber was placed a few centimeters from a lithium target used as a source of neutrons, both the chamber and the target being surrounded with paraffin. With this arrangement no pulses were observed after the deuteron bombardment was stopped. However, when a bottle containing about 100 grams of uranium nitrate was placed between the source