Further Experiments on Fission of Separated Uranium Isotopes*

Recently[1] we bombarded with slow neutrons small quantities of uranium isotopes which had been separated by means of a mass spectrometer. Measurement of the fission rates from the samples gave strong support to the view that it is U^{235} (or possibly U^{234}) rather than U^{238} which undergoes fission under slow neutron bombardment.

This conclusion has now been verified with considerably larger samples of separated uranium isotopes. In addition, it has been possible to obtain tests of several samples of partially separated U^{235} and U^{234}. In the new work the uranium ion currents were increased by a factor of about ten times by increasing the electron current bombarding the UBr_4 vapor by a factor of ten. The U^{238} ions were collected on an insulated platinum plate (1×15 mm) and the current to this plate measured with an electrometer tube amplifier. The U^{235} and U^{234} ions were collected in the first set of samples on a single grounded platinum plate and in the second set on a pair of grounded plates. The dispersion of the apparatus is such that for infinitely great resolving power, ions differing in mass by one unit would fall along sharp parallel lines on the collector separated by 0.75 mm. From a measure of the variation of the current to the insulated collector with energy of ions, it was possible to determine the actual spread of the ion beam and hence the overlap of adjacent isotopes. It was concluded that for a region 0.75 mm wide, centered about the U^{234} position, one would collect approximately 25 percent as many U^{235} ions as in an equally wide strip centered about the U^{235} position. As the ion peaks are nearly symmetrical the converse also holds. That the resolution was good enough to separate U^{234} and U^{235} was not apparent in the earlier work as the insulated collection plate was considerably wider (2.0 mm).

Slow neutron tests.—The separated isotopes were first tested by placing in an ionization chamber connected to a linear amplifier, and bombarding with neutrons from the Columbia cyclotron which had been slowed in paraffin.

TABLE I. *Slow neutron tests of separated* U^{238}, U^{235} *and* U^{234}.

	U^{238}	U^{235}	U^{234}
Sample set No. 1: Mass $U^{238}=3.1\mu g$			
alphas/min. expected	1.1	0.05	1.1
alphas/min. observed	1.0 ± 0.1	0.25 ± 0.05	0.75 ± 0.1
fissions/min.	0.1 ± 0.1	4.4 ± 0.2	1.5 ± 0.1
fission/alpha ratio	0.1	18.	2.
Sample Set No. 2: Mass $U^{238}=4.4\mu g$*			
alphas/min. expected	1.6	0.07	1.6
alphas/min. observed	2.3 ± 0.1	0.63 ± 0.1	2.2 ± 0.2
fissions/min.	0.5 ± 0.2	10.3 ± 0.5	7.8 ± 0.5
fission/alpha ratio	0.22	16.	3.5

* Considerable difficulty in obtaining large ion currents was encountered in this run. As a result, a great deal of testing and adjustment was necessary. Unfortunately, no record of the time or currents was kept while adjustments were being made. The mass of the U^{238} target was thus larger than $4.4\mu g$. This would account for a good share of the discrepancy between the expected and observed alpha-counts. The resolution of the apparatus was definitely poorer in this run than the number one run.

TABLE II. *Fast neutron tests of separated* U^{238}.

	U^{238} No. 2	U^{238} No. 3
alphas/min.	2.3 ± 0.1	5.5 ± 0.2
fissions/min. without Cd	0.5 ± 0.1	1.4 ± 0.2
fissions/min. with Cd	0.5 ± 0.1	1.4 ± 0.2

For the first set of samples, where the U^{234} and U^{235} were deposited on the same plate with some overlapping, the alpha-particle and fission counts were made by covering each of the sample regions in turn with aluminum foil 0.008 cm thick.

Table I shows (*a*) the number of alpha-particles/min. to be expected on the basis of the masses of the uranium isotopes deposited as calculated from the mass spectrometer ion currents assuming complete separation, (*b*) the observed number of alpha-particles/min., (*c*) the number of fissions/min., and (*d*) the fission/alpha-ratio, for the various isotope samples. The background has been subtracted.

The number of alpha-particles/min. observed is in agreement with the expected number within the limits of error. The amount of overlapping of U^{234} and U^{235} is likewise close to that calculated from the resolution of the mass spectrometer.

The number of fissions/min. observed and the fission/alpha ratios show conclusively that U^{235} is responsible for at least seventy-five percent of the slow neutron fission observed in unseparated U. Since U^{234} is present only to 1 part in 17,000, it cannot be excluded that U^{234} does undergo some slow neutron fission, but the total contribution of U^{234}, if any, is small.

Fast neutron tests.—Further tests were made of U^{238} to see if the small numbers of fissions observed from it in the slow neutron tests, were due to fast neutrons. Measurements were made without paraffin, and with and without Cd surrounding the fission chamber, on the U^{238} sample from set No. 2 and also on a much larger sample, No. 3 (18.9 micrograms), subsequently collected under improved conditions. The data are recorded in Table II.

These results indicate that U^{238} undergoes fast neutron fission only. Furthermore, the number of fissions/microgram of U^{238} observed under these neutron intensity conditions, is sufficient to account for practically all the fast neutron fission observed from unseparated U.

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[1] Nier, Booth, Dunning and Grosse, Phys. Rev. **57**, 546 (1940).