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REPORT ON THE RATIO OF THE FISSION CROSS SECTION OF URANIUM-238 TO THAT OF URANIUM-235

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REPORT ON THE RATIO OF THE FISSION CROSS SECTION OF URANIUM-238 TO THAT OF URANIUM-235

R. R. Carlson

The ratio of the fission cross section of U^{238} to that of U^{235} has been measured at various neutron energies. The values found indicate a threshold at about 1 Mev and a plateau running from about 2 Mev to the highest neutron energy used. There is no evidence of any structure in the dependence of the ratio on energy. Such evidence has been reported in the case of the ratios of the fission cross sections of U^{234} and U^{236} to that of U^{235}.

Relative fission cross sections were determined with equipment that has been previously described.[1] Briefly, it consisted of two parallel-plate ionization chambers with one plate in common. The common plate held foils of U^{238} and U^{235} back to back and was biased -300 volts. Ionization caused by fission particles was detected by electron collection on the two outer plates. The signals were amplified by special low-noise preamplifiers and then by A-1 amplifiers. Argon gas with 3% carbon dioxide admixture flowed through the chamber at a pressure of 1 1/2 atmospheres. In order to check the gain setting and pulse-height selector (PHS) setting on the A-1 amplifier, provision was made to insert a pulse generator with well-known pulse voltages in place of the ionization chambers. No appreciable changes in gain were ever detected during a run.

These settings were selected on the basis of a measurement of the counting rate of the ionization chamber, containing U^{235}, as a function of PHS setting. A thermalized polonium-beryllium neutron source was used. At low values of the PHS setting, alpha particles are counted; at high values, only fission particles should be counted. If there is no self-absorption of fission particles, the bias curve should exhibit a plateau with no slope. This was found to be essentially the case when U^{235} foils were used in the form of 1 mg plated in a 1-in.-dia circle on platinum. A value of the PHS setting near the middle of the plateau was chosen, and the pulse height corresponding to this PHS setting and gain value was determined with the calibrated pulse generator.

Neutrons were produced by the $H^3(p,n)He^3$ reaction through the use of the 5.5-Mev Van de Graaff machine. A tritium gas target was used and the proton beam passed through

[1] R. W. Lamphere, Fission Cross Sections of Uranium-234 and Uranium-236 for Incident Neutron Energies up to 4 Mev, ORNL-1312, p. 1 (July 15, 1952).

a 0.275-mil aluminum window. Since the uranium subtended an angle of 15 deg at the gas target, and the gas target itself introduced an energy spread, the procedure resulted in a neutron beam with a resolution ranging linearly from 70 kev at 1 Mev to 120 kev at 4 Mev. The neutron energy was determined from the proton energy, which was, in turn, measured by bending in a magnetic field. Because of the window thickness, the threshold for neutron production could only be checked close enough to guarantee the neutron energy to ±50 kev.

The ratio of the fission cross sections was measured in two ways. First, medium-thick foils of uranium were used. By medium thick, a self-absorption of about 15% is meant. These foils had about 4 mg of uranium deposited in a circle 1 in. in diameter on a platinum backing. They were obtained from C. S. Fultz at Y-12 and have weights accurate to 0.8%, according to his calculations. These weights were checked by placing the foils in an alpha-counting ionization chamber, and the agreement was as good as could be expected. With foils having as high a self-absorption as these, there is some question as to whether the correction for self-absorption can be made accurately enough. Actually, the necessity of such a correction can be avoided by using the medium-thick foils to obtain data with the neutrons from the Van de Graaff machine and by comparing a medium-thick foil with a thin foil of the same isotope by using a polonium-beryllium source of neutrons.

The thin foils were also obtained from C. S. Fultz and were made in the same manner and from the same stock as the medium-thick ones. The U^{238} and U^{235} foils were isotopically pure. The formula for the ratio of the fission cross sections is as follows:

$$\frac{\sigma_f(28)}{\sigma_f(25)} = \frac{N(28)}{N(25)} \frac{238}{235} \frac{W(25)}{W(28)} \frac{R(25)}{R(28)} \left(1 - 0.01\sqrt{E_n}\right)$$

where N is the number of fission counts observed by using the medium-thick foils, W is the weight of the thin foils, and R is the ratio of thick-to-thin fission counts observed when using a polonium-beryllium neutron source and the same pulse amplification and PHS setting as those used when observing the value of N. The final factor is necessary because the beam momentum aids fission fragments leaving the foil in the same direction as the beam and hinders those going in the opposite direction. Fission particles from U^{238} were aided in the arrangement used. E_n, which was derived in a previous report,[2] is the neutron energy

[2] Ibid., p. 9.

expressed in million electron volts. The results are listed in Table 1; statistics are standard deviation values. The error in the absolute value of the ratio resulting from statistics, errors in weights, and errors in *R* is estimated to 7% on the plateau.

One of the greatest difficulties with the measurement of the ratio of fission cross sections is the low counting rates encountered. In the second method of measurement, the difficulty was overcome by using infinitely thick foils of U^{238} and U^{235}. These foils were obtained from J. H. Erwin of J. E. Cunningham's metallurgy group at ORNL. The U^{238} foil was in the form of a 1-in.-dia, 4-mil-thick piece of isotopically pure material. The U^{235} foil was in the form of a 1-in.-dia, 6-mil-thick piece that was 93% U^{235} and 7% U^{238}.

These foils were placed in the fission chamber back to back in the same manner as that used with the medium-thick foil. The same pulse amplification and PHS setting were used. Gains were checked at various times during a run but no appreciable changes were ever found. The ratio of the observed fission counts, when corrected for the 7% U^{238} in the U^{235} foil, does not give the absolute value of the ratio because self-absorption may be different for different foils. The difference is taken care of by normalizing the curve to a point taken with thin foils where self-absorption does not occur. As a consequence of this method, the shape of the curve of ratio vs. neutron energy is determined to the statistical accuracy of 2% standard deviation, but the absolute value of the ratio has the larger error of the point taken with the thin foils. The normalizing point was taken on the plateau. An error of 7% is estimated for the absolute value of the ratio. The results are listed in Table 2.

The latter method suffered because the thick foils were not flat and therefore intercepted slightly different amounts of the neutron beam. When the foils were interchanged, different values were obtained for the ratio, and this covered up the effect of beam momentum. Consequently, there has been no attempt to correct the ratio in this case for the effect of beam momentum. The correction can be no more than a few per cent at the highest energy.

The error owing to scattering was determined by measuring the ratio at one energy at two distances from the gas target in such a manner that the foils subtended angles of 15 and 7 1/2 degrees. A difference of less than 1% was observed; consequently, no correction for scattering was made.

Values given in the tables are plotted in Fig. 1. The curve drawn through these points is estimated to give the ratio of the fission cross section of U^{238} to that of U^{235} to an accuracy of 7%.

TABLE 1

Ratio of Fission Cross Section of Uranium-238 to Uranium-235 (Medium-thick Foils)

Neutron Energy (Mev)	Ratio of Cross Sections	Statistics (%)
0.86	0.01	
0.98	0.01	
1.09	0.02	
1.19	0.02	
1.31	0.04	
1.39	0.07	
1.47	0.16	
1.55	0.24	
1.62	0.31	
1.70	0.32	4
1.78	0.36	4
1.84	0.36	4
1.94	0.39	4
2.01	0.39	4
2.10	0.41	4
2.18	0.40	4
2.26	0.42	4
2.34	0.41	4
2.43	0.40	4
2.51	0.41	4
2.60	0.41	3
2.69	0.40	3
2.78	0.42	3
2.86	0.41	3
2.94	0.43	3
3.03	0.41	3
3.12	0.44	3
3.20	0.42	3
3.30	0.42	3
3.39	0.44	3
3.48	0.44	3
3.56	0.44	3

TABLE 2

Ratio of Fission Cross Section of Uranium-238 to Uranium-235 (Infinitely Thick Foils)

Neutron Energy (Mev)	Ratio of Cross Sections for Thick Foils	Ratio of Cross Sections for Thin Foils	Statistics (%)
0.86	0.01		
0.94	0.01		
1.02	0.01		
1.09	0.01		
1.16	0.02		
1.24	0.03		
1.31	0.04		
1.39	0.07		
1.47	0.14		
1.55	0.23		3
1.62	0.29		3
1.70	0.32	0.35	3
1.78	0.33		2
1.86	0.36		2
1.94	0.39	0.41	2
2.01	0.40		2
2.10	0.40		2
2.18	0.41		2
2.26	0.42		2
2.34	0.43		2
2.43	0.43		2
2.51	0.43		2
2.60	0.43*	0.43	2
2.69	0.43		2
2.78	0.43		2
2.86	0.44		2
2.94	0.42		2
3.03	0.43		2
3.12	0.45		2
3.20	0.44		2
3.30	0.44		2
3.39	0.44		2
3.48	0.44		2
3.56	0.46		2
3.65	0.48		2
3.75	0.46		2
3.85	0.46		2
3.94	0.47		2
4.02	0.48		2
4.12	0.46		2
4.22	0.48		2

*Normalizing point.

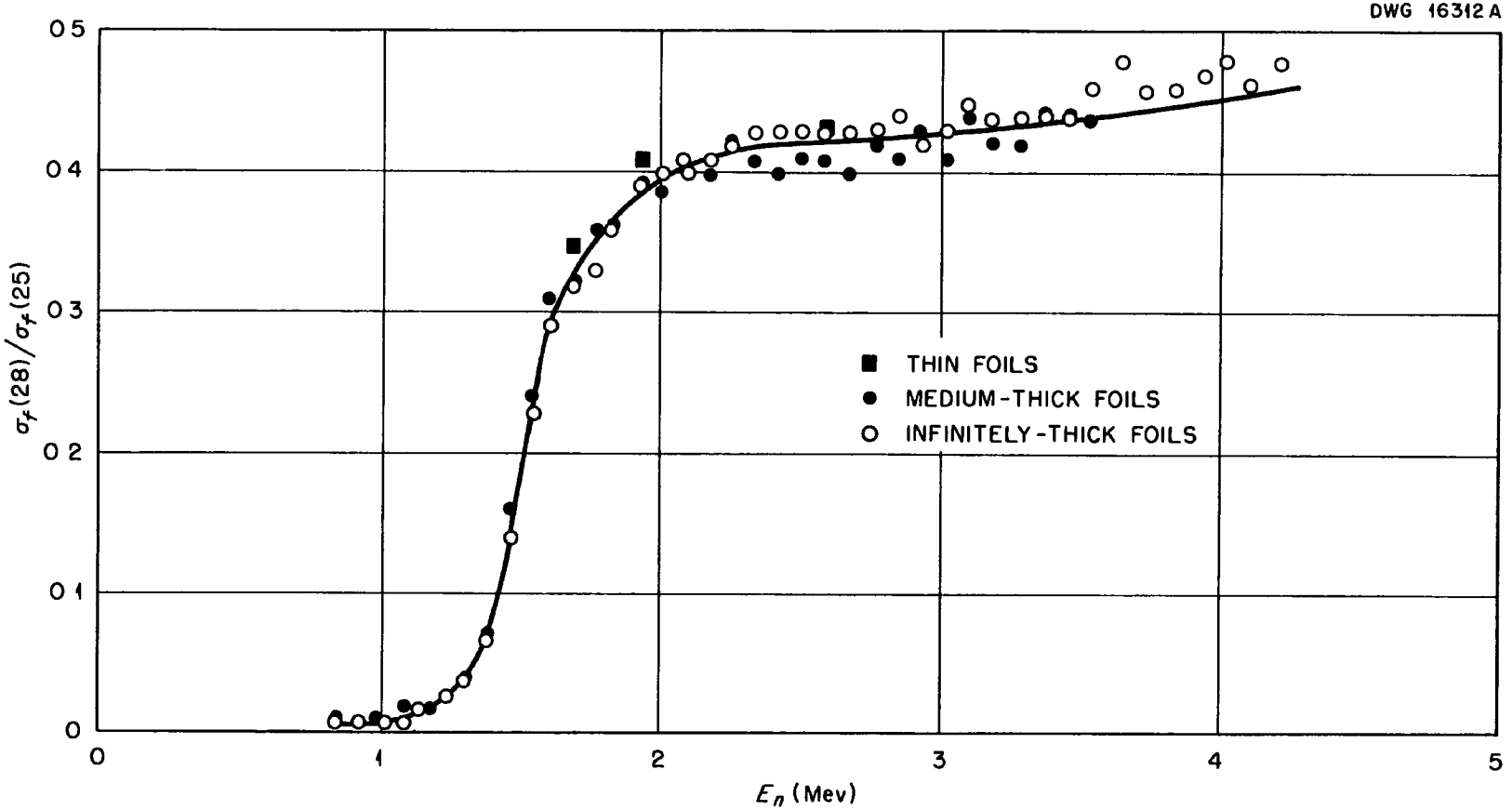

Fig 1 Ratio of the Fission Cross Section of Uranium-238 to Uranium-235